Patent ductus arteriosus is usually found as an isolated lesion in the patient with noncyanotic congenital heart disease. Infrequent reports of the co-existence of patent ductus arteriosus and aortic or sub-aortic stenosis have appeared in the literature. \(^1\)\(^2\) We have encountered this combination of lesions in 7 of the first 50 patients operated on for patent ductus arteriosus. The purpose of this report is to indicate the criteria for clinical diagnosis in this group of patients.

Campbell and Kauntze,\(^5\) Taussig and Schessel,\(^6\) Grishman and associates,\(^7\)\(^8\) Downing,\(^9\) Young,\(^10\) and others\(^11\)\(^12\) have presented the clinical picture associated with isolated congenital lesions of the aortic valve. The criteria now appear to be well founded and generally accepted, despite a relative paucity of autopsy material. In the group of patients under consideration, because of the dynamic effects of the patent ductus arteriosus, these criteria require certain modifications.

Case Reports

**Case 1.** A 14-year-old girl was admitted to the hospital in October 1950, with a diagnosis of congenital heart disease and healed bacterial endocarditis.

Examination revealed a systolic thrill and a loud harsh systolic murmur in the second right interscostal space that was transmitted to the neck vessels. In the second and third left interscostal spaces there was a loud, moderately long systolic murmur immediately followed by a short diastolic murmur. The aortic second sound was not heard.

The blood pressure was 110/60 in the right arm and 160/88 in the right leg. There was no evidence of congestive failure.

The electrocardiogram showed a vertical heart and enlargement of the left ventricle with myocardial involvement. Angiocardiogram revealed marked hypertrophy of the left ventricle and the infundibulum of a ductus arteriosus.

Cardiac catheterization showed evidence of a patent ductus arteriosus. A direct brachial artery tracing was that of aortic or subaortic stenosis (fig. 1C).

At operation a patent ductus measuring 6 mm. long by 6 mm. wide was found. The aorta was extremely friable and tore at the site of the ductus insertion, and the patient died.

On postmortem examination the heart weighed 500 Gm. The left ventricle was markedly hypertrophied; the left atrium was slightly dilated and hypotrophied. The aortic valve ring measured 5.5 cm. in circumference. There was irregular diffuse thickening of all 3 aortic cusps on which were superimposed tiny white-yellow flecks. A thick rod of connective tissue ran along the bases of the cusps and fused with the cusps and endocardium resulting in stenosis of the outflow tract of the left ventricle (fig. 2). Microscopic examination showed thickening of the aortic cusps by moderately cellular connective tissue with a few scattered lymphocytes. The ductus showed no evidence of old or recent inflammation.

**Comment.** The patent ductus arteriosus was recognized by its characteristic murmurs, the aortic lesion by a different systolic murmur. Disproportionate left ventricular enlargement relative to the left-to-right shunt was believed to be due to the aortic valve lesion.

**Case 2.** A 5-year-old girl was admitted to Montefiore Hospital in April 1953. A heart murmur had been discovered at 1 month of age. Growth and development were normal.

On examination the heart was not enlarged. A continuous murmur and thrill were present in the
second left intercostal space. In the second right intercostal space, however, the systolic murmur became rougher with transmission into the right carotid, and the diastolic murmur was of shorter duration and assumed a high pitched blowing character. The blood pressure was 80/40 in the left arm and 130/50 in the left leg. There was no congestive failure.

The electrocardiogram was normal. Cardiac fluoroscopy showed slight enlargement of the outflow tract of the left ventricle and slight enlargement of the left atrium. The pulmonary artery and hilar branches were slightly prominent. The supracardiac aorta and arch were mildly widened. The infundibulum of the ductus was readily visualized.

At operation a patent ductus arteriosus 4 mm. long by 5 mm. wide was found and ligated. Postoperatively the ductus murmurs disappeared and the blood pressure rose to 110/70. The harsh rough systolic murmur in the aortic area and short diastolic blow along the left sternal border persisted.

At present, 4 years later, the same murmurs are heard. The carotid artery pulse tracing is that of atrial or subaortic stenosis (fig. 1B). The patient continues well without cardiac symptoms. The electrocardiogram is normal and cardiac fluoroscopy shows no enlargement.

Comment. The patent ductus arteriosus was recognized by its characteristic murmurs, the aortic lesion by additional systolic and diastolic murmurs that were different in pitch, duration, and location. The aortic lesion apparently has no effect on cardiac dynamics.

Case 3. An 8-year-old girl was admitted to Montefiore Hospital in February 1955. A heart murmur had first been noted 6 months previously. Exertional dyspnea was the only complaint.

The heart showed no clinical enlargement. The pulmonic second sound was accentuated. In the second left intercostal space there was a long, loud systolic murmur and a softer, high-pitched diastolic with transmission below the left clavicle. A systolic thrill was present in the same area. In the second right intercostal space there was a fairly loud systolic murmur transmitted into the neck. The blood pressure was 105/75 in the left arm and 150/105 in the left leg. There was no congestive failure.

Cardiac fluoroscopy revealed slight lengthening of the outflow tract of the left ventricle, and slight enlargement of the left atrium. The electrocardiogram was normal.

Cardiac catheterization showed evidence of a left-to-right shunt. An aortogram demonstrated a patent ductus arteriosus and additional anomalies of the great vessels of the aortic arch.

The ductus was closed in March 1955, following which the murmurs in the second left intercostal space disappeared, but the moderately loud harsh systolic murmur transmitted to the neck vessels has persisted. The blood pressure is 90/50. The carotid artery pulse tracing is consistent with aortic or subaortic stenosis. The child is asymptomatic and has grown and gained weight.

Comment. The murmurs caused by the patent ductus arteriosus were somewhat atypical but still distinct from an additional systolic murmur originating in the aortic area. Corroboration was obtained by laboratory means prior to surgery. The aortic lesion apparently has no dynamic effect.

Case 4. A 6-year-old boy was admitted to Montefiore Hospital in September 1953. A heart murmur had been discovered at the age of 3 months.

On examination there was a systolic thrill in the second left intercostal space and over both carotid arteries. The pulmonic second sound was split and accentuated. A "machinery type" murmur was heard in the second left intercostal space. In the aortic area there was a harsh systolic murmur and an early diastolic blow that was different in character from that heard in the second left intercostal space. At the apex there was a systolic blow and short diastolic roll. The blood pressure was 100/25-0. There was no congestive failure.

The electrocardiogram indicated enlargement of both left and right ventricles, with a delay in right ventricular conduction. Cardiac fluoroscopy showed moderate enlargement of the left ventricle and the left atrium, slight enlargement of the right atrium and inflow tract of the right ventricle, and marked enlargement of the outflow tract of the right ventricle. The aorta was slightly dilated and showed expansile pulsations. The hilar vessels were moderately prominent.

At operation a patent ductus measuring 2 mm. long by 8 mm. wide was obliterated. A direct aortic pressure curve taken at the time of operation was consistent with aortic or subaortic stenosis.

On subsequent follow-up there has been a significant increase in size and weight. The aortic systolic murmur radiating into the neck persists. The blood pressure is 100/65. Roentgenographic study shows a decrease in size of the left atrium but the other chambers, aorta and hilar vessels are unchanged. The electrocardiogram still shows left and right ventricular enlargement and also deep inversion of the T waves in all the precordial leads.

Comment. The patent ductus arteriosus was readily recognized by its characteristic murmurs and the aortic lesion by the different systolic and diastolic murmurs. Despite elimination of the
ductus, the heart remains considerably enlarged with progressive myocardial involvement as manifested by the inversion of the T waves in all precordial leads. It is assumed that the aortic valvular disease is sufficiently obstructing to have increased the cardiac burden.

Case 5. A 12-year-old boy was admitted to Montefiore Hospital in August 1955. A heart murmur was first noted at 3 years of age. He had no cardiovascular symptoms.

Examination revealed the heart enlarged to the left. The pulmonic second sound was accentuated. A systolic thrill was felt in the second left intercostal space and in the suprasternal notch, and a continuous murmur was heard in the second left intercostal space. In the second right intercostal space the systolic and diastolic murmurs were separate and not continuous, the former being rough and the latter a high-pitched blow. The systolic component was also heard in the neck vessels. A systolic blow and a short diastolic roll were heard at the apex. The blood pressure was 130/26. There was no congestive failure.

The electrocardiogram showed a large left ventricle with inversion of the T wave in lead V6. Roentgenographic study showed moderate enlargement of the left ventricle and slight enlargement of the left atrium and right ventricle. Both the aorta and the hilar vessels were moderately dilated and showed intrinsic expansive pulsations.

On cardiac catheterization a left-to-right shunt due to a patent ductus was demonstrated. At operation a patent ductus measuring 4 mm. long by 9 mm. wide was ligated. Following surgery the continuous murmurs disappeared but the moderately long and loud aortic systolic murmur transmitted to the neck vessels persists.

Over a 2-year follow-up period he has grown and gained weight at a greater rate than prior to operation. The blood pressure is 120/76. By x-ray the heart size has diminished, there being now only mild left ventricular and slight left atrial enlargement, decrease in the pulmonary vasculature, and disappearance of the hilar dance and expansive aortic pulsations. The electrocardiogram shows a lowering of the QRS voltage in the left-sided chest leads and the T wave in lead V6 is upright. The carotid artery pulse tracing is that of aortic or subaortic stenosis.

Comment. The patent ductus arteriosus murmurs were characteristic. The additional aortic lesion was apparent from the obviously different murmurs in regard to location, pitch, and lack of continuity throughout the cardiac cycle. The major dynamic effect was due to the patent ductus, for since its obliteration the heart size has decreased considerably and the inverted T wave in lead V6 has returned to normal.

Case 6. A 22-year-old girl was admitted to Montefiore Hospital in December 1951, in congestive heart failure. A heart murmur had been discovered at the age of 5 years. In September 1948, at another hospital, she was found to have a loud continuous murmur in the second left intercostal space, blood pressure 110/50 and a phonocardiogram typical of a patent ductus arteriosus. In October 1948 a large patent ductus was ligated.

In November 1948, she developed subacute bacterial endocarditis, which was successfully treated with penicillin. Following this she developed aortic systolic and diastolic murmurs and a corroborative phonocardiogram distinctly different from the earlier record. Cardiac catheterization showed no evidence of a patent ductus. It was believed that she had developed bacterial endocarditis on a congenital aortic valve anomaly.

On examination a systolic thrill was felt in the third left intercostal space and in the right carotid artery. The pulmonic second sound was accentuated, the aortic absent. A loud, long rough systolic murmur and a long, loud early diastolic blow were heard maximally in the third left intercostal space next to the sternum. The blood pressure was 160 to 300 systolic and zero diastolic. The liver was enlarged 3 fingerbreadths below the right costal margin.

The electrocardiogram showed a large left ventricle with myocardial involvement. Marked enlargement of the left ventricle and a dilated expansile aorta were seen on fluoroscopy. The hilar branches of the pulmonary artery were moderately dilated but showed no hilar dance.

She was discharged following treatment for the congestive failure but was rehospitalized 5 times in the subsequent 4 years because of this and anginal pain. The clinical findings were essentially the same. In 1954 cardiac catheterization was again performed and no shunt was demonstrable. In April 1956 she suddenly died at another institution.

Comment. This patient had a patent ductus arteriosus that was successfully obliterated but she developed bacterial endocarditis on an aortic valve anomaly, which resulted in severe deformity and possible rupture of a cusp. Dynamically, aortic insufficiency was the most important component.

Case 7. A 32-year-old woman was first admitted to Montefiore Hospital in May 1955, for treatment of subacute bacterial endocarditis.

On examination the heart was clinically enlarged. The fingers were clubbed. Congestive failure was present. The pulmonic second sound was accentuated. A systolic thrill was present in the pulmonic area, where a loud continuous "machinery-like" murmur was audible. In addition, a loud, harsh moderately long systolic murmur was
present in the aortic area and right carotid artery, and an early diastolic blowing murmur was heard in the third and fourth left intercostal spaces, adjacent to the sternum. The blood pressure was 120/70.

The electrocardiogram showed enlargement of the left ventricle. On cardiac fluoroscopy there was marked enlargement of the outflow tract of the left ventricle and slight enlargement of the left atrium and right ventricle; the lungs showed pulmonary congestion; the hilar branches were widened and showed intrinsic pulsations.

Following successful treatment of the bacterial endocarditis, operation was performed in July 1955, under induced hypotension. A patent ductus arteriosus measuring 4 mm. long by 8 mm. wide was ligated. Although the machinery murmur disappeared on the operating table, later that same day it was again heard. It was assumed that recanalization had occurred.

She was re-admitted in November 1955. Cardiac findings were the same as on the first admission, with no evidence of congestive failure. Cardiac catheterization was compatible with a patent ductus arteriosus. A carotid artery pulse tracing (fig. 1D) was that of aortic or subaortic stenosis.

At re-operation the patent ductus was divided. The aorta split at the upper margin of the insertion of the ductus and was repaired, but further bleeding later occurred and the patient died.

Comment. The patent ductus arteriosus was apparent by virtue of the typical murmurs. The murmurs representing an aortic lesion differed in their location and pitch from those associated with the patent ductus. The left-to-right shunt through the ductus, as estimated by the pulse pressure and data obtained on cardiac catheterization, was small. The disproportionately enlarged left ventricle, therefore, was believed to be secondary to a significant degree of aortic obstruction.

Discussion

Clinical recognition of the combined lesions is not difficult. The presence of a patent ductus arteriosus was readily determined by the classical continuous machinery murmur in the second left intercostal space with radiation to the left below the clavicle. This was confirmed at operation in each case. The diagnosis of an associated aortic valvular lesion was suggested prior to surgery in 5 patients. In a sixth, this was not recognized until after recovery from operation, and, in
The seventh, after operation performed at another hospital.

The aortic or subaortic valvular lesion was suspected when a separate systolic murmur, differing in quality and pitch from the systolic component of the continuous murmur, was heard in the second right intercostal space. This radiated into the neck and was sometimes associated with a thrill over the aortic area or the cervical vessels. In 4 patients additional early aortic diastolic blowing murmurs differing from the lower pitched diastolic murmur due to the patent ductus were heard. Transmission of the murmur to the neck preoperatively was not of diagnostic importance because this may also be noted in cases of uncomplicated patent ductus arteriosus. The aortic second sound was absent in only 1 patient of the 6 observed prior to surgery. Following obliteration of the patent ductus arteriosus, the continuous murmur disappeared. The loud, harsh, high-pitched aortic systolic murmur with radiation to the neck persisted in all, and a short early diastolic blow in one. In case 6 the aortic diastolic blow was not present preoperatively, but developed owing to the bacterial endocarditis.

Phonocardiography revealed a typical diamond-shaped murmur in some patients. The carotid artery pulse tracings7,8,13 were studied in 4 patients, a direct aortic curve in 1, and in another a direct brachial artery curve was obtained (fig. 1). In our normal control group the peak came within 0.12 second of the onset of ejection, while it was delayed beyond 0.15 second in the presence of aortic stenosis. The clinical impression of aortic valvular disease was thus confirmed. We have not attempted to differentiate between aortic and subaortic stenosis on the basis of these studies.12

Four patients presented an electrocardiographic pattern of left ventricular enlargement. In another there was evidence of combined ventricular hypertrophy. The other 2 showed no abnormality.

All patients showed dilatation of the supravalvular segment of the aorta, a finding that has been considered significant in the diagnosis of isolated congenital aortic stenosis. It was of no diagnostic value in the present group of cases because of its frequent occurrence with patent ductus arteriosus. Roentgenographic evidence of cardiac chamber enlargement was in agreement with the electrocardiographic findings.

The width of the ductus at the time of operation was not unusually large in any of these patients (table 1). In addition, the calculated size of the shunt through the patent ductus, as determined by cardiac catheterization, was small in most.

Two patients, (cases 1 and 7) with small shunts and only moderate sized ductuses showed a large degree of left ventricular enlargement roentgenographically. Although these were two of the older patients, the left ventricular enlargement was still greater than expected with a simple patent ductus arteriosus of the indicated size. It is suggested, therefore, that disproportionate enlargement

<p>| Table 1.—Correlation of Heart Size and Approximate Shunt |
|---|---|---|---|---|---|---|</p>
<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>BP</th>
<th>PA-RV</th>
<th>ECG</th>
<th>X-ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>F</td>
<td>110/60</td>
<td>2.1</td>
<td>LV</td>
<td>LV 3+</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>F</td>
<td>80/40</td>
<td>1.7</td>
<td>N</td>
<td>LV sl.</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>F</td>
<td>105/75</td>
<td>1.7</td>
<td>N</td>
<td>LV sl.</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>M</td>
<td>100/25-0</td>
<td>—</td>
<td>LV &amp; RV</td>
<td>LV 2+ RV</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>M</td>
<td>130/36</td>
<td>3.6</td>
<td>LV</td>
<td>LV 2+</td>
</tr>
<tr>
<td>6</td>
<td>22</td>
<td>F</td>
<td>110/50</td>
<td>—</td>
<td>LV</td>
<td>LV 2+</td>
</tr>
<tr>
<td>7</td>
<td>32</td>
<td>F</td>
<td>120/70</td>
<td>1.4</td>
<td>LV</td>
<td>LV 3+</td>
</tr>
</tbody>
</table>

* Av. 7 mm.—10 mm. X 5 mm.—7 mm. (Taussig).14
PA, Pulmonary artery; RV, Right ventricle; LV, Left ventricle.
of the left ventricle in a patient with a patent ductus arteriosus and a relatively small shunt may point to the co-existence of a dynamically significant aortic valvular lesion.

Right heart catheterization ruled out intracardiac shunts in 6 patients subjected to these studies. In none was a history of rheumatic fever obtained nor were findings of additional valvular lesions present. Because the occurrence of isolated aortic stenosis on a rheumatic basis in children and young women is extremely rare, the aortic lesions in every case were assumed to be congenital in origin.

Three of these patients also demonstrated significant noncardiac congenital anomalies (table 2). This frequent association of anomalies has been noted by Bonham-Carter\(^\text{2}\) in patients with patent ductus arteriosus and aortic valvular lesions. On the other hand, they are relatively infrequent in cases of uncomplicated patent ductus arteriosus.

Subacute bacterial endocarditis and sudden death are well known complications in patients with congenital lesions of the aortic valve. Three of these patients (cases 1, 6, 7) developed subacute bacterial endocarditis. Autopsy study of 1 patient revealed healed bacterial endocarditis of the congenital stenosed aortic valve and not of the ductus. In another patient, as well as could be determined at surgery, the ductus had not been the site of the previous bacterial endocarditis, and the third patient ultimately died with severe congestive heart failure following rupture of an aortic valve cusp.

The surviving 4 patients have now been followed 4, 2, 3½ and 2½ years since obliteration of the ductus. Two patients (cases 2, 3) show normal heart size and, therefore, the aortic lesion would seem to be of no dynamic significance. The other 2, however, (cases 4, 5) continue to show roentgenographically disproportionate left ventricular enlargement and case 4 shows additional electrocardiographic evidence of increasing ventricular "strain." It is assumed that in these 2 patients the aortic stenosis is of sufficient severity to overburden the heart even after elimination of the left-to-right shunt.

In such patients the possibility of an additional procedure, aortic commissurotomy, should be considered. In this regard, it might be advisable to obtain direct measurement of the pressure gradient across the aortic valve at the time of division of the ductus to estimate more accurately the degree of valvular obstruction.

**Summary**

The co-existence of patent ductus arteriosus and congenital aortic or subaortic valvular disease is probably greater than has been previously noted. This combination has been found in 7 of 50 patients with proved patent ductus arteriosus. Relatively simple clinical criteria are presented for recognition of the combined lesions. In the uncomplicated patent ductus arteriosus one can be reasonably sure of cure following surgical obliteration. The prognosis cannot be as good when there is an associated aortic valve lesion with its attendant hazards of subacute bacterial endocarditis, increasing burden on the left ventricle, and sudden death.

**Addendum**

Since submission of this paper, out of the next 40 patients with patent ductus arteriosus, we have seen 2 more with associated aortic valvular disease. This would make the incidence 10 per cent.

The first patient was a 5-year-old boy with clinical and laboratory evidence of a combined lesion. Six months after obliteration of the patent ductus arteriosus, his heart size has returned to normal. It is assumed, therefore, that the aortic lesion is dynamically unimportant at this time.

The second patient was a 20-year-old girl known to have a patent ductus since the age of 6 months. She had been carefully followed and always known to have no cardiac enlargement; the blood pres-
sure were about 120/80. She was seen by us 2 months after a healed bacterial endocarditis and found to have aortic insufficiency, a blood pressure of 110/0 and left ventricular and left atrial enlargement. Cardiac catheterization showed a relatively small shunt through a patent ductus. An aortogram showed aortic insufficiency and a bicuspid aortic valve as well as the patent ductus. This is most likely now a dynamically significant aortic insufficiency resulting from bacterial endocarditis of a bicuspid valve in the presence of a dynamically insignificant patent ductus arteriosus.

**SUMMARIO IN INTERLINGUA**

Le coexistencia de patente ducto arteriosum con congenite morbo de valvula aortic es probablemente plus frequente que previamente notate. Le combination esseva trovate in 7 ex 50 casos de demonstrare patente ducto arteriosum. Es presentate relativamente simple criterios clinic pro la recognition del combine lesion. In casos de non-complicate patente ducto arteriosum on pote esser relativamente secur de cura post obliteration chirurgie. Le prognosis non pote esser equalmente bon in casos de associate lesions del valvula aortic proque istos adde le hasardos de subacute endocarditis bacterial, de augmentate cargas sinistro-ventricular, a de morte subitanee.

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Coexistence of Patent Ductus Arteriosus and Congenital Aortic Valvular Disease
HERBERT MARK, BELLE JACOBSON and DENNISON YOUNG

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