Isolated Anomalous Connection of a Great Vein to the Left Atrium

The Syndrome of Cyanosis and Clubbing, "Normal" Heart, and Left Ventricular Hypertrophy on Electrocardiogram

By W. R. Meadows, M.D., Ingemar Bergstrand, M.D., and J. T. Sharp, M.D.

The findings of cyanosis and clubbing not explained by diffuse pulmonary disease and in the presence of a normal heart on physical examination suggest pulmonary arteriovenous fistula. Absence of electrocardiographic evidence of right ventricular hypertrophy and a normal right ventricular pressure on catheterization are further evidence for this diagnosis. The present case, the fourth of its kind to appear in the literature, shows that when the electrocardiogram under these conditions exhibits left ventricular hypertrophy without evident cause, the most probable diagnosis is isolated anomalous connection of a great vein to the left atrium.

Case Report

A 37-year-old Negro was referred to the cardiopulmonary laboratory for evaluation of cyanosis, clubbing, and polycythemia. He had been hospitalized since May 1954 for active pulmonary tuberculosis.

Except for frequent headaches, especially as a child, there were no symptoms attributable to the findings. There was no history of dyspnea, exercise intolerance, or other symptoms of cardiac insufficiency. Clubbing of the fingers had been present for as long as he could remember but had not attracted any attention prior to the present hospitalization. He worked at manual labor, and during the war he had no trouble keeping up with the other men during periods of rigorous training.

The patient's father, one of his five brothers, and two of his six sisters were said to have died of heart trouble, the father while the patient was still a child, the brother at age 38, and the sisters at ages 40 and 46. Another sister is living with a heart condition at age 42. His one child is in good health.

The report of the autopsy on his brother revealed a patent foramen ovale 14 mm. in diameter, marked dilatation, hypertrophy, and fibrosis of the right ventricle, and moderate pulmonary arteriosclerosis. A small anteroseptal myocardial infarction was present although there was no coronary sclerosis. Other findings included pulmonary tuberculosis of the right upper lobe and clubbing of the fingers and toes.

The patient was well developed and showed no wasting from his tuberculous disease. Marked clubbing of the fingers and cyanosis and suffusion of the conjunctivae, bucal mucosa, and tongue were present. No murmurs were heard. The first heart sound was normal, but the second was not split. A transient early diastolic "filling sound" was audible at the apex immediately after lying down and upon raising the legs. Except for post-tussive rales in the left apex the remainder of the examination was unremarkable. The blood pressure was 110/75.

Chest x-rays including lateral and both oblique views revealed bilateral far advanced cavitory tuberculosis, but the heart size and configuration were normal. Barium studies showed no evidence of an abdominal situs inversus. Electrocardiograms for years had consistently shown the T-wave changes commonly ascribed to left ventricular hypertrophy, a P-R interval of 0.24 to 0.26 second, notching of P waves in leads II, III, and aVp, and occasional wandering of the pacemaker to the atrioventricular node (fig. 1).

The hemoglobin had varied from 15 to 21.7 Gm., and the hematocrit value had been as high as 74 per cent. In January 1955 the blood volume was found to be 35 per cent above the predicted value; the cell volume was increased by 56 per cent while the plasma volume was normal. The arterial oxygen saturation at this time was 82 per cent, and the oxygen capacity was 25.97 volumes per cent; the arterial pCO₂ was 42 mm. Hg. The arterial oxygen saturation was again

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Table 1

Catheterization Data

<table>
<thead>
<tr>
<th>Catheter site</th>
<th>Right heart catheterization via SVC 9/25/60</th>
<th>Left heart catheterization via IVC 10/25/60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Oxygen saturation</td>
<td>Pressure</td>
</tr>
<tr>
<td></td>
<td>S/D</td>
<td>Mean</td>
</tr>
<tr>
<td>Right atrium</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Right ventricle</td>
<td>61</td>
<td>23/3</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>67</td>
<td>18/8</td>
</tr>
<tr>
<td>Left pulmonary vein</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Right pulmonary vein</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Left atrium</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Inferior vena cava</td>
<td>74-79</td>
<td></td>
</tr>
<tr>
<td>Radial artery</td>
<td>79</td>
<td>106/67</td>
</tr>
<tr>
<td>O₂ consumption*</td>
<td>275 ml./min.</td>
<td></td>
</tr>
<tr>
<td>Blood O₂ capacity†</td>
<td>26.1 vol. %</td>
<td></td>
</tr>
<tr>
<td>Systemic A-V diff.</td>
<td>3.9 vol. %</td>
<td></td>
</tr>
<tr>
<td>Pulmonary A-V diff.</td>
<td>8.6 vol. %</td>
<td></td>
</tr>
<tr>
<td>Ratio of systemic to</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>pulmonary flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systemic flow</td>
<td>4.2 L./min./M.²</td>
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</tr>
<tr>
<td>Pulmonary flow</td>
<td>1.9 L./min./M.²</td>
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<tr>
<td>Systemic vascular</td>
<td>914 dynes sec. cm.²</td>
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</tr>
<tr>
<td>resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary vascular</td>
<td>250 dynes sec. cm.²</td>
<td></td>
</tr>
<tr>
<td>resistance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BSA = 1.65

*Oxygen consumption was determined on 11/8/60.
†Blood O₂ capacity was calculated from the hemoglobin determination of 19.5 Gm. per cent on 9/14/60; six hemoglobin determinations within the previous year had varied from 18.2 to 20.3 Gm. per cent.

The anatomic situation prevented the obtaining of a true mixed venous blood sample for determination of oxygen content and calculation of systemic flow. In lieu of this a pulmonary artery sample was used for the calculation of systemic flow during the first catheterization while a high inferior vena cava sample was used for the calculation of both systemic and pulmonary flows during the second catheterization. Analysis of data on 30 cases without shunts in this laboratory showed no significant difference in the oxygen content between samples taken from the superior vena cava and samples from the pulmonary artery. From this it is inferred that the oxygen content of inferior vena cava blood is not enough different from that of the superior vena cava blood to alter the oxygen content of the mixed venous blood. Otherwise stated, the oxygen contents of superior and inferior vena cava blood are essentially the same.

found to be 82 per cent in April 1960 and rose only to 92 per cent on breathing 100 per cent oxygen for 10 minutes. This submaximal rise in oxygen saturation was considered to be indicative of a sizable anatomic right-to-left shunt.

Pulmonary function studies revealed a vital capacity of 3.85 liters, a minimally depressed one-second timed vital capacity of 77 per cent, and a maximal breathing capacity of 107 L./min. (81 per cent of normal). The nitrogen washout curve was normal, and the alveolar nitrogen after 7 minutes of breathing 100 per cent oxygen was 1.7 per cent, these findings indicating a normal distribution of inspired air in the lungs. The residual volume was 0.88 liters or 70 per cent of normal and made up 19 per cent of the total lung capacity of 4.73 liters. The single-breath carbon monoxide pulmonary diffusing capacity of 8.8 ml. CO/min./mm. Hg/M.² of body surface area was slightly below normal and was thought

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to be compatible with the low pulmonary blood flow found on catheterization and the extent of his pulmonary tuberculosis. It was not considered sufficiently low to produce the degree of arterial oxygen unsaturation that was present.

Right heart catheterization was performed on September 20, 1960, via a branch of the left basilic vein and again on October 28, 1960, from the right saphenous approach (table 1). On the first occasion the catheter approached the right atrium in the usual manner, but some difficulty was experienced at this point before it entered the right ventricle. It then passed superiority and somewhat to the right of the expected course of the right ventricular outflow tract to enter the pulmonary artery. Blood oxygen saturations in the right atrium, right ventricle, and pulmonary artery were 63.4, 61.0, and 67.1 per cent, respectively, whereas pressures measured in the latter two chambers were 23/3 and 18/8. A pulmonary angigram visualized a normal vascular tree on the left, but technical difficulties prevented visualization of the right pulmonary arteries. From the saphenous vein the catheter passed superiority into the cardiac shadow and then almost immediately into a left pulmonary vein from which fully saturated blood was withdrawn. A careful pull back with spot films and repeated blood sampling indicated that the catheter tip passed into a chamber within the heart shadow containing fully oxygenated blood. This was presumed to be the left atrium. It was then withdrawn into the inferior vena cava from which blood with saturations from 74 to 79 per cent was obtained.

Figure 1
Electrocardiogram showing changes consistent with left ventricular hypertrophy.

Dye-dilution curves recorded from the left radial artery on patient J. W. (A, top) and on a normal subject (B, bottom) following femoral and brachial vein injection. The slight deviation from the baseline at 11 seconds in the basilar vein injection of J. W. is within the limits of baseline instability and was not observed on another curve following injection from the same site.

During an unsuccessful attempt to catheterize the left ventricle the catheter passed into the right inferior pulmonary vein. Blood in this vein was fully saturated, a finding that excludes an arteriovenous fistula in the parenchyma drained by that vein.

Dye-Dilution Studies: Indocyanine green in-
An anteroposterior and lateral angiocardiogram from inferior vena cava injection and their schematic interpretations. Left atrial, left ventricular, and aortic filling (left ventricle not clearly outlined here was well visualized on other frames). No right ventricular or pulmonary artery filling occurred.

Injections of dye were made alternately from the right femoral and right cubital veins and were recorded from the left radial artery. The average appearance time from the femoral vein (three recordings) was 9 seconds and that from the cubital vein (two recordings) was 17 seconds. The curves were in addition markedly dissimilar in contour (fig. 2).

Venous angiocardiograms were done at Billings Memorial Hospital on November 30, 1960. Injections of Hypaque from the inferior vena cava showed only the left heart chambers and aorta, whereas a similar injection from the right cephalic vein outlined the superior vena cava, right heart chambers, and pulmonary artery exclusively (fig. 3). The main pulmonary artery was again noted to be displaced medially but was anterior to the aorta.

Because of the additional risk in the presence
Anteroposterior and lateral angiograms from right cephalic vein injection. The right ventricle and pulmonary artery are visualized.

Discussion

The recent literature contains descriptions of two cases of a solitary superior vena cava\(^1,2\) and one of an inferior vena cava\(^3\) in which isolated anomalous drainage into the left atrium was present. It is remarkable that of far-advanced pulmonary tuberculosis and the lack of evidence that the tuberculous disease would be improved by normalizing his pulmonary flow or correcting his cyanosis, a decision for surgical intervention has not been made.

Taussig’s text,\(^4\) the reviews of Abbott\(^5\) and Monckeberg,\(^6\) and to our knowledge all other pertinent medical literature prior to 1955 do not mention these isolated anomalies although instances complicated by associated intracardiac defects are to be found.\(^7\) The latter are usually serious, frequently associated with levocardia, and only rarely compatible with survival to adulthood.

Each of the three previously reported cases was cyanotic, and all had some degree of ef-
fort intolerance, which is in contrast to the case reported here. The electrocardiograms of two showed the T-wave changes of left ventricular hypertrophy while the tracing of the 10-year-old girl with isolated drainage of the superior vena cava into the left atrium was normal except for an S in V of 28 mm. Her diagnosis was proved by angiocardiography, and she was living with only slight disability, not warranting surgical correction, at the time of the report. The 15-year-old boy with the same anomaly died following surgical interference, and the 32-year-old woman with anomalous drainage of the inferior vena cava collapsed and died suddenly while leading a comparatively active life.

Two reports of bilateral superior venae cavae in which the left cava drained into the left atrium as an isolated anomaly are also to be found. In the one with a left-to-right shunt via the left innominate vein the left superior vena cava opened into the left atrium together with the left superior pulmonary vein. The other with a similar anatomic situation had minimal electrocardiographic evidence of left ventricular hypertrophy and cyanosis, which disappeared following ligation of the aberrant vessel. Both had a communication between the right and left superior venae cavae, and there was no readily apparent reason for the difference in shunting. We would like to suggest, however, that a difference in left ventricular distensibility due to the previously corrected aortic coarctation of the first case may have been the determining factor.

Although there were no clinical data to suggest an atrial septal defect, and the first catheterization by way of the superior vena cava had shown no arterialization of the right heart, the possibility of such a defect had to be considered when the catheter passed from the inferior vena cava into the pulmonary veins. In addition the dye-dilution curve from the cubital vein was compatible with a left-to-right shunt (fig. 2A, bottom curve), and although a controversial point, certain authorities believe that rare instances of atrial septal defect uncomplicated by pulmonary hypertension may be cyanotic from infancy.

Since radiopaque dye injected into the right cephalic vein sharply delineated the right heart chambers and pulmonary artery and when injected into the inferior vena cava outlined only the left heart chambers and aorta, we believe that such absolute separation of blood returning from the two vena cavae most probably indicates anatomic partition. Complete selective streaming of inferior vena caval blood through an atrial septal defect without any right atrial mixing with blood returning from the superior vena cava would be virtually impossible.

The salient feature of the dye-dilution curves (fig. 2) is the abnormally short appearance time following femoral vein injection. This feature plus the single primary peak characterizing this curve can only be explained by a direct communication between the inferior vena cava and the left heart. Examination of dye curves recorded following brachial and femoral injection in two normal subjects (fig. 2B) and one patient with an atrial septal defect and a right-to-left shunt revealed a maximum difference of one second between brachial injection and femoral injection appearance times. In our patient brachial injection appearance time was 7 seconds more than femoral appearance time.

Two features less striking but also requiring explanation are the abnormal shape of the curve recorded following brachial vein injection and the absence of clearly defined recir-
culation deflections in either curve. We believe that both these abnormalities are explained by the occurrence of equal but small recirculations (first inferior caval, then superior caval via the pulmonary veins) at 8- or 9-second intervals rather than the larger, more widely spaced (13 to 16 seconds) recirculations that are present normally. An injected bolus of dye would be clearly definable as a distinct concentration peak only the first time around as in the upper curve of figure 2A.

Although flows cannot be estimated with precision, there is at least reasonable agreement between the outputs as calculated from the two catheterizations especially with respect to the systemic-to-pulmonary ratio (table 1). Since systemic flow is equal to the total venous return while pulmonary flow is limited to the return via the superior vena cava and coronary sinus, it becomes possible to estimate the separate caval flows. With coronary flow assumed to be 10 per cent of the total,11 these values were calculated for our patient and the one reported by Tuckman et al.2 (table 2). It will be noted that there is close agreement between the per cent values obtained.

Since the inferior vena caval flow and presumably all the pulmonary venous return enter the left atrium, pulmonary inflow and consequently pulmonary venous outflow is less than it would be normally. These considerations lead one to predict that in the absence of attempts at compensation systemic blood flow would be normal and pulmonary blood flow one-third12 to one-half normal. In the presence of low pulmonary blood flow a normal oxygen uptake is maintained by two mechanisms that increase the oxygen-carrying capacity of the blood flowing to the lungs. One of these, polycythemia, is seen in the presence of arterial hypoxemia and provides for a widening of the arteriovenous oxygen difference in terms of volumes per cent without necessarily an associated widening in terms of oxygen saturation or pO₂. Thus, despite arterial hypoxemia, a normal mixed venous oxygen saturation (pO₂) may often be maintained, indicating adequate tissue-oxygen delivery. The other mechanism, seen in the absence of arterial hypoxemia, necessarily involves a widening of the arteriovenous difference by lowering the mixed venous oxygen saturation (tension) and is accompanied by inadequate tissue-oxygen delivery.

Our patient's moderate polycythemia was obviously one adaptation enabling him to take up oxygen normally and at the same time to maintain a normal mixed venous oxygen saturation. A moderate increase in left ventricular output appeared to be a further compensation. This provided an increase in total venous return including, importantly, superior vena caval return and hence augmented pulmonary blood flow. The mechanisms involved are not known. In the nearly analogous situation of pulmonary arteriovenous fistula, the systemic output is not usually increased nor has the left ventricle usually been hypertrophied as in this and analogous anomalies. A brief review of recent literature on pulmonary arteriovenous fistula further revealed no relationship between the level of arterial hypoxemia and the systemic output. Hypoxemia alone then would not explain the high systemic output.

One may consider partial anomalous systemic venous drainage into the left atrium to be analogous, but in reverse, to partial anomalous pulmonary venous drainage into the right atrium. In the former, pulmonary flow is low and systemic flow high; in the latter, the reverse is true, pulmonary flow exceeding systemic flow. Though facilitating understanding of some features of the former syndrome, realization of this analogy is not helpful in explaining the high systemic flow in anomalous systemic venous drainage into the left atrium. Indeed it brings up the question why in anomalous pulmonary venous drainage the pulmonary flow is not normal and systemic flow low, rather than the well-known pattern of slightly depressed to normal systemic flow accompanied by high pulmonary flow. Anatomic considerations explain adequately why pulmonic and systemic flows are in a given ratio to one another but leave unclear what the absolute flow values will be.
This aspect of the regulation of cardiac output in human disease warrants more investigation.

Summary
A case is reported of isolated anomalous drainage of the inferior vena cava into the left atrium, the second in the literature and the first with catheterization data and dye-dilution curves. The anomaly is reflected by a well-defined clinical syndrome, is compatible with full cardiac competence at least until middle life, and should be relatively simple to correct surgically.

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References

Art and Science
In art and letters, personality dominates everything. There we are concerned with a spontaneous creation of the mind, that has nothing in common with the notion of natural phenomena, in which the mind must create nothing. The past keeps all its worth in the creations of art and letters; each individuality remains changeless in time and cannot be mistaken for another. A contemporary poet has characterized this sense of the personality of art and of the impersonality of science in these words—"Art is myself; science is ourselves."—Claude Bernard. An Introduction to the Study of Experimental Medicine. New York, The MacMillan Company, 1927, p. 42.
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