Differential Diagnosis of the Taussig-Bing Heart from Complete Transposition of the Great Vessels with a Posteriorly Overriding Pulmonary Artery

By Alois Beuren, M.D.

According to a recent review article, there seems to be some disagreement about what constitutes a transposition of the Taussig-Bing variety, what the criteria for its diagnosis are, and with what certainty this diagnosis can be made during life. There is, however, general agreement that in the cyanotic group of congenital heart disease, the various forms of transpositions of the great vessels constitute a well-defined entity as far as their physiology is concerned. The hemodynamics are characterized by the separation of the 2 circulations and the amount of blood-mixing that is allowed between them by the number and size of the additional lesions. In regard to the anatomic arrangement which may be found in transpositions of the great vessels, it is well known that the degree of displacement of the aorta and pulmonary artery and their relation to each other may vary considerably from case to case. This was early recognized by Peacock, Rokitansky, Lochte, Spitzer, and Pernkopf and was clinically analyzed by Taussig. Among these various forms of transpositions, the Taussig-Bing transposition is a well-described clinical and anatomic entity. Physiologically, however, the Taussig-Bing transposition is not so fundamentally different from the other types of transpositions as it is anatomically. This is notably true of the other group of transpositions with an overriding pulmonary artery and also of the complete transpositions with large ventricular septal defects. This physiologic similarity may account for the difficulty in the differential diagnosis.

Although there has been no further case reported from this clinic since Taussig and Bing described their original case in 1949, a number of cases were reported in the literature, indeed there is probably no center in which identical transpositions have not been observed. This led to the opinion that the Taussig-Bing transposition is not rare. It is the purpose of this paper to review the Taussig-Bing transpositions that were diagnosed in this clinic and to describe some characteristics that could be helpful in differential diagnosis from the transposition with posteriorly placed pulmonary artery. Furthermore, comparison will be made to some cases published in the literature.

In their first report, Taussig and Bing described this malformation as “complete transposition of the aorta and a levoposition of the pulmonary artery.” This report described an abnormal physiologic condition associated with a definite pathologic anatomy. There is another transposition of the aorta and an overriding pulmonary artery with a very different anatomic situation. These are the 2 transpositions with which we are concerned. In the Taussig-Bing heart, “the pulmonary artery arose approximately in its normal position, the aorta was transposed; it arose entirely from the right ventricle. There was a ventricular septal defect at the base of the ventricular septum of 1.2 x 0.6 cm. The superior portion of the ventricular septum deviated to the right to such an extent that the pulmonary orifice overrode the septal defect by a few millimeters.” In other words, despite the approximately normal position of the pulmonary artery, this vessel overrode the septal defect because of the deviation of the ventricular septum. This is schematically demonstrated in figure 1, which is taken from the original paper. A muscular ridge sep-
arated the pulmonary artery and the aorta, so that most of the venous blood entering the right ventricle was ejected into the aorta and most of the pulmonary blood from the left ventricle entered the pulmonary artery.

In figure 1 the Taussig-Bing heart and the normal heart are not shown as they are placed in the body. In accordance with the concept of Barry and Patten,\textsuperscript{18} and Walmsley,\textsuperscript{19} figure 2 shows the position of the normal heart in the body; the position of the Taussig-Bing heart in the chest is shown in figure 3. These figures also show the heart as seen in the various projections on x-ray and fluoroscopy. In figure 3 it is evident that in the Taussig-Bing transposition in the anteroposterior position, the 2 vessels are side by side. In comparison with the normal position of the 2 vessels it is evident that they must lie side by side, if “the pulmonary artery occupies its approximately normal place” and the aorta is transposed in such a manner that it comes off the right ventricle.

In the second group of transposition of the great vessels in which there is a transposition of the aorta and an overriding pulmonary artery, the relation of the 2 great vessels to each other is very different (fig. 4). The pulmonary artery does not occupy its “approximate normal place,” but is placed far posteriorly to the aorta. It also overrides a ventricular septal defect. The aorta arises from the right ventricle in this malformation, but directly anterior to the pulmonary artery. Thus, in the Taussig-Bing heart the aorta is transposed and the pulmonary artery overrides the ventricular septal defect in its normal place, whereas in the latter malformation both vessels are completely transposed in their relation to each other. These 2 anatomically different transpositions are frequently confused because of the similarity of the history, and the possible similarity in x-ray appearance and catheterization findings.

Case Material

Since the original publication of the Taussig-Bing case in 1949, there have been 73 cases listed in the clinic file as possible Taussig-Bing transpositions. These cases were reviewed in the present study. The essential clinical features are cyanosis dating from birth, right ventricular hypertrophy in the electrocardiogram, and the characteristic cardiac contour on x-ray, namely, increased pulmonary vascularity and a very prominent pulmonary conus. The diagnosis is established if in addition to these clinical findings one or more of the following criteria are fulfilled: (1) at catheterization highest oxygen content in the pulmonary artery, systemic pressure in the pulmonary artery, and a step-up in oxygen content in the right ventricle combined with good evidence of a typical position of the pulmonary artery; (2) demonstration of the characteristic relation of the 2 great vessels to each other, either by angiocardiography or by observation of the course of the cardiac catheter during catheterization; (3) autopsy proof. If the diagnosis is based upon the catheterization findings, there should in addition be evidence of the typical position of the great vessels.

Of the 73 patients reviewed, 14 were accepted as definite Taussig-Bing transpositions (table 1). Three of these were proved at autopsy (cases 4, 8, 11). One of the autopsied cases (case 11) was clinically diagnosed without further tests. In the other 2 autopsied cases, the diagnosis was made by angiocardiography during life (cases 4 and 8). In 3 cases the diagnosis was based mainly on the catheterization data (cases 2, 12, 13), in 5 on angiocardiography (cases 1, 7, 9, 10, 14), and in 3 on angiocardiography and catheterization data (cases 3, 5, 6). Besides these 14 cases, there were 17 among the 73 cases reviewed in which the clinical diagnosis of a Taussig-Bing transposition was highly probable but in which the diagnosis was not established by autopsy, angiocardiography, or cardiac catheterization. Several of these 17 patients underwent thoracotomy for the creation of an artificial atrial septal defect. Observations of the position of the great vessels, which may be made during surgery, are not considered as diagnostic criteria in this report. In addition there

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was 1 autopsied case in which there was a transpo-
position with an overriding pulmonary artery but
in which no mention was made as to the exact
position of the vessels. Since the specimen has
been destroyed, this case cannot be classified defini-
tively.

From the initial 73 cases, 7 were excluded be-
cause the diagnosis of complete transposition with
ventricular septal defect seemed more likely, and
1 case because of the possible diagnosis of a single
ventricle with a transposition. Twenty-five cases
were excluded because the data were insufficient
to make an absolute diagnosis. There was 1 addi-
tional case with a dextrocardia and a transposition
similar to the Taussig-Bing heart. This case also
has been excluded.

The history, physical, and clinical findings are
similar in all 14 cases. Most of the patients were
seen at yearly intervals over a period of several
years. The age at the first examination ranged
from 12 days to 27 years. When last seen, 6
patients were 10 years or older. There were only
3 patients above 15 and 1 patient was 27 at the
time of his only examination.

All patients showed cyanosis from birth. Above
the age of 1 year all had clubbing. There was only
1 patient with a history of spells of unconscious-
ness associated with deepened cyanosis. Growth
and development were retarded, and exercise tol-
erance was reduced in almost all of these patients.
Thirteen had a systolic murmur at the left sternal
border in the third and fourth left intercostal
spaces. The murmur was usually heard during
the first few weeks of life. One patient had no
murmur. Mid-diastolic murmurs were heard in 2
patients. Only 3 patients had a systolic thrill at
the left sternal border. Ten patients had marked
polycythemia. On x-ray and fluoroscopy the pul-
monary vascularity was markedly increased in all
14 patients. Each had a prominent pulmonary
conus similar to that of the original Taussig-Bing
case (fig. 5). There was moderate to marked car-
diac enlargement in all patients. Right axis devia-
tion and right ventricular hypertrophy were pres-
ent in all electrocardiograms. These findings made
the diagnosis of a Taussig-Bing transposition prob-
able. Cardiac catheterization was performed in 11
patients, but the pulmonary artery was not en-

**Figure 2**

The normal heart as placed in the body. The lines demonstrate how the shadow of the great vessels is projected upon the x-ray screen in the different views.
Figure 3

The Taussig-Bing heart as placed in the body. In the right anterior oblique view, appears on the screen from the right to left: chest wall, lung, pulmonary artery, aorta. In the left anterior oblique view from the left to right: chest wall, lung, aorta, pulmonary artery.

tered in 5 of them. In the remaining 6, the pulmonary artery was entered and the catheterization data provided significant information for the diagnosis of a Taussig-Bing transposition. As in the original case of Taussig and Bing, there was a large step-up in oxygen content in the right ventricle. The oxygen content in the pulmonary artery was markedly higher than in all other samples obtained. As in the original case, there was a small bidirectional shunt, and the pressures in the pulmonary artery were at systemic levels. The course and the position of the catheter were observed and this provided good evidence for the position of the great vessels. In some cases spot films with the catheter in the pulmonary artery were taken.

To obtain further information, intravenous angiocardiography was carried out in 11 of the 14 patients. This examination was unsuccessful in 1 patient. In 10 patients good evidence of the typical position of the great vessels of the Taussig-Bing transposition was obtained. The pictures were usually taken in the anteroposterior and right lateral projection. On filling of the right atrium, there is usually a good demarcation of the atrial septum. A large atrial septal defect was demonstrated in 1 patient (case 10). In each case there was a good, early visualization of the aorta immediately after the filling of the right ventricle. As first described by Taussig, and later shown in angiocardiograms published by Cooley and Sloan, in complete transposition there is usually an absence of the shadow cast of the pulmonary conus of the right ventricle, which shows that the pulmonary artery does not occupy its normal position. This sign was absent in all of these 10 angiocardiograms; in contrast there was a full pulmonary conus in the anteroposterior and lateral views. The right ventricular shadow in the lateral view showed the contour characteristic of a large right ventricle that is pressed against the anterior chest wall. In all of these angiocardiograms the aorta was better opacified than the pulmonary artery. This was so not only because of the origin of the aorta from the right ventricle but also because of the dilution of the contrast medium in the large dilated pulmonary artery, which receives a large amount of blood from the
left ventricle. It is also possible that the muscular ridge that separates the origin of the aorta from the pulmonary artery may not allow a substantial shunt of contrast medium into the pulmonary artery. In the right lateral view the aorta was seen further anterior to its normal position, whereas in the anteroposterior projection the aorta was side by side with the pulmonary artery; (figs. 3, 6, and 7). In case 1, angiocardiograms were taken in the left anterior oblique position that showed the aorta anterior to the pulmonary artery. This is schematically demonstrated in figure 3. In the Taussig-Bing heart, the left anterior oblique view is the only position in which the aorta is projected anteriorly upon the x-ray screen.

The characteristic appearance of the great vessels as seen in all of these angiocardiograms is also demonstrated in the angiocardiogram of the original case of Taussig and Bing. The angiocardiogram was not published in the first report but is shown in figure 6. In the original case, the patient died during angiocardiography and these are the only 2 films that were obtained. There were no deaths during or immediately following angiocardiography in the present series. In 2 of the 10 patients with angiocardiographic studies, the diagnosis was confirmed at autopsy. A summary of the autopsy reports is given at the end of this paper.

From the 73 cases reviewed, it was possible to remove 4 cases in which the diagnosis of a transposition with posteriorly placed overriding pulmonary artery is considered to be established. The data of these cases are summarized in table 2. Three of these patients had angiographic findings that were considered to be diagnostic of transposition of the great vessels (cases 1, 3, 4) and 1 was also studied by cardiac catheterization alone (case 4). In 1 case the diagnosis seems to be certain on the basis of cardiac catheterization alone (case 2). Cases 1, 3, and 4 were proved at autopsy. In 3 additional patients, the diagnosis of a posteriorly overriding pulmonary artery was made on clinical grounds alone. The distribution of the 73 cases which have been reviewed is shown in table 3. The age of the 4 patients with the diagnosis of an overriding posteriorly placed pulmonary artery ranged from 3 months to 6 years. In all of them cyanosis was present since birth, and in all but 1 a cardiac murmur was heard at birth or shortly thereafter.
### Table 1

**Clinical Data of Fourteen Cases of Taussig-Bing Transposition**

<table>
<thead>
<tr>
<th>Case no., initials, sex</th>
<th>Age first ex.</th>
<th>Cyanosis, clubbing, spells</th>
<th>Murmur, thrill</th>
<th>Blood count</th>
<th>X-ray</th>
<th>Angiocardiogram</th>
<th>Catheterization</th>
<th>Autopsy</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) P.M. Female</td>
<td>2 yr., 1948</td>
<td>Since birth</td>
<td>Loud systolic, 3 plus</td>
<td>Hb. 22</td>
<td>Prominent pul. conus, increased pul. vascularity</td>
<td>Simultaneous filling of aorta and pul. artery. Aorta anterior in LAO. Both vessels side by side</td>
<td>Pul. artery not entered</td>
<td>No</td>
<td>1954 artificial ASD. Vessel position at operation thought to be typical</td>
</tr>
<tr>
<td>A-61459</td>
<td>12½ yr., 1958</td>
<td>LSB</td>
<td>Yes</td>
<td>Hct. 72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) N.H. Female</td>
<td>4 yr., 1946</td>
<td>Systolic apex</td>
<td>Slight</td>
<td>Hb. 21</td>
<td>Very prominent pul. conus, increased pul. vascularity</td>
<td>No</td>
<td>Pre and postop cath. Aorta and pul. artery entered. AoO&lt;sub&gt;2&lt;/sub&gt;=17.5 P 114/98 PAO&lt;sub&gt;2&lt;/sub&gt;=23.9 P 114/86 O&lt;sub&gt;2&lt;/sub&gt; step-up in RV</td>
<td>No</td>
<td>First diagnosed as Eisenmenger. 1947 artificial ASD. Vessel position at operation typical</td>
</tr>
<tr>
<td>A-45637</td>
<td>15½ yr., 1958</td>
<td>No</td>
<td>No</td>
<td>Hct. 71.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) E.J. Male</td>
<td>27 yr., 1949</td>
<td>Since birth</td>
<td>Systolic LSB, diastolic. No</td>
<td>Hb. 23</td>
<td>Prominent pul. conus, increased pul. vascularity</td>
<td>Simultaneous filling of aorta and pul. artery. Pulmonary artery and aorta side by side</td>
<td>PA systemic pressure and highest O&lt;sub&gt;2&lt;/sub&gt; content. AoO&lt;sub&gt;2&lt;/sub&gt;=21.4 PAO&lt;sub&gt;2&lt;/sub&gt;=27.0 O&lt;sub&gt;2&lt;/sub&gt; step-up in RV</td>
<td>No</td>
<td>Angio and cath, data offer good evidence of Taussig-Bing</td>
</tr>
<tr>
<td>A-66583</td>
<td>8 yr., 1951</td>
<td>LSB</td>
<td>No</td>
<td>Hct. 72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) M.H. Female</td>
<td>6 yr., 1949</td>
<td>Since birth</td>
<td>Systolic, LSB</td>
<td>Hb. 25</td>
<td>Full, prominent pul. conus, increased pul. vascularity</td>
<td>Aorta more anterior as normal and in lateral, side by side to pul. artery</td>
<td>Pul. artery not entered</td>
<td>Both vessels side by side. Large VSD and overriding pulmonary artery</td>
<td>Died at operation for artificial ASD</td>
</tr>
<tr>
<td>A-66655</td>
<td>8 yr., 1951</td>
<td>3 plus</td>
<td>No</td>
<td>Hct. 82.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) I.B. Female</td>
<td>4 yr., 1949</td>
<td>Since birth</td>
<td>Harsh syst., LSB</td>
<td>Hb. 20</td>
<td>Prominent pul. conus, increased pul. vascularity</td>
<td>Both vessels side by side</td>
<td>PA higher O&lt;sub&gt;2&lt;/sub&gt; cont. than FA PA=16.88 P=104/90 FA=15.63 O&lt;sub&gt;2&lt;/sub&gt; step-up in RV</td>
<td>No</td>
<td>Cath. and angio, conclusive</td>
</tr>
<tr>
<td>A-74720</td>
<td>6 yr., 1951</td>
<td>2 plus</td>
<td>No</td>
<td>Hct. 53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) H.D.S. Male</td>
<td>1 yr., 1951</td>
<td>Since birth</td>
<td>Systolic, LSB</td>
<td>Hb. 9</td>
<td>Full pul. conus, increased pul. vascularity</td>
<td>Aorta more anterior as normal</td>
<td>PA higher O&lt;sub&gt;2&lt;/sub&gt; cont. than FA PA=12.9 P=160/75 FA=8.8 O&lt;sub&gt;2&lt;/sub&gt; step-up in RV</td>
<td>No</td>
<td>Cath. and angio, conclusive. Anemie</td>
</tr>
<tr>
<td>A-94158</td>
<td>2 yr., 1952</td>
<td>2 plus</td>
<td>No</td>
<td>Hct. 38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) W.W. Male</td>
<td>4 mo., 1952</td>
<td>Since birth</td>
<td>Systolic, LSB</td>
<td>Hb. 19</td>
<td>Full pulmonary conus, increased pul. vascularity</td>
<td>Typical vessel position. Aorta and pul. artery side by side</td>
<td>Pul. artery not entered</td>
<td>No</td>
<td>1956 artificial ASD. At operation, vessel position thought to be typical</td>
</tr>
<tr>
<td>A-98556</td>
<td>6 yr., 1958</td>
<td>3 plus</td>
<td>No</td>
<td>Hct. 59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8) G.L.P. Male</td>
<td>12 da., 1953</td>
<td>Since birth</td>
<td>Systolic, LSB</td>
<td>Hb. 14.9</td>
<td>Full pulmonary conus, increased pul. vascularity</td>
<td>Aorta and pul. artery side by side</td>
<td>No</td>
<td>Aorta off right vent. FA anterior &amp; overriding a large VSD. Muscular ridge as described by Taussig-Bing</td>
<td></td>
</tr>
<tr>
<td>B-2427</td>
<td>4½ mo., 1953</td>
<td>3 plus</td>
<td>No</td>
<td>Hct. 56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Case</td>
<td>Gender</td>
<td>Birth</td>
<td>Age</td>
<td>Systolic</td>
<td>RBC</td>
<td>Hb</td>
<td>Hct</td>
<td>Pulmonary No.</td>
</tr>
<tr>
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</tr>
<tr>
<td>(9)</td>
<td>B-12931</td>
<td>Female</td>
<td>4 mo.</td>
<td>1954</td>
<td>2½ yr.</td>
<td>1957</td>
<td>None</td>
<td>1 plus</td>
<td>Systolic</td>
</tr>
<tr>
<td>(10)</td>
<td>B-29688</td>
<td>Female</td>
<td>1 yr.</td>
<td>1957</td>
<td>2 yr.</td>
<td>1958</td>
<td>Systolic, LSB</td>
<td>3 plus</td>
<td>Faint</td>
</tr>
<tr>
<td>(11)</td>
<td>A-51911</td>
<td>Female</td>
<td>5 yr.</td>
<td>1946</td>
<td>10 yr.</td>
<td>1951</td>
<td>Cyan. 1 mo. Systolic, LSB</td>
<td>2 plus</td>
<td>No</td>
</tr>
<tr>
<td>(12)</td>
<td>A-56331</td>
<td>C.E.G.</td>
<td>2 yr.</td>
<td>1947</td>
<td>10 yr.</td>
<td>1955</td>
<td>Systolic</td>
<td>2 plus</td>
<td>No</td>
</tr>
<tr>
<td>(13)</td>
<td>A-32953</td>
<td>Female</td>
<td>3 yr.</td>
<td>1946</td>
<td>15 yr.</td>
<td>1958</td>
<td>Systolic, LSB</td>
<td>1 plus</td>
<td>No</td>
</tr>
<tr>
<td>(14)</td>
<td>B-48092</td>
<td>D.G.</td>
<td>10 mo.</td>
<td>1958</td>
<td>1½ yr.</td>
<td>1958</td>
<td>Systolic</td>
<td>1 plus</td>
<td>No</td>
</tr>
</tbody>
</table>

**Discussion**

In 1949 Taussig and Bing published their original case of complete transposition of the pulmonary arteries. This case had been studied by cardiac catheterization, angiography, and angiocardiography. The authors gave a clear picture of the pulmonary arteries. However, the cases described in this paper were similar to the findings in the Taussig-Bing group. The data obtained that special studies were carried out in the Taussig-Bing group and 4 were identical to those in the transcatheter pulmonary artery. The pressures showed a right ventricular position in the pulmonary artery. The pressures were taken in the pulmonary artery, and the pressures were usually higher than that of the pulmonary artery.

Growth and development were slow. On physical examination, the patient had a systolic murmur along the left sternal border and 3 had a systolic murmur at the Apex. Two patients had no systolic murmur. All had right axis deviation and right ventricular hypertrophy by fluoroscopy. The x-rayograms showed that the hearts were moderately prominent and markedly enlarged. Each showed very prominent pulmonary conus, and each had right heart axis deviation and right ventricular hypertrophy. The pulmonary artery was least. One patient had a fourth left intercostal space. On physical examination, the patient had a systolic murmur along the left sternal border and 3 had a systolic murmur at the Apex. Two patients had no systolic murmur.
ters the left ventricle is directed into the pulmonary artery. Physiologically this malformation is characterized by a higher oxygen content in the pulmonary artery than in the right ventricle and in the aorta. There is systemic pressure in the pulmonary artery.

At the time of the first publication, the existence of a second transposition with overriding pulmonary artery with the same abnormal physiology had not been reported. In the Taussig-Bing heart, both great vessels are side by side, whereas in the second type of transposition with overriding pulmonary artery, the great vessels are completely transposed; that is, the pulmonary artery lies behind the aorta (figs. 4, 8, and 9). During recent years, no clear-cut separation has been made between these 2 anatomically different malformations; in several publications the latter malformation was considered as Taussig-Bing transposition.\textsuperscript{1, 10, 12, 14} Keith\textsuperscript{21} published in 1958 drawings of the 2 different transpositions and pointed out that they are not identical. He even separated the 2 malformations in regard to life expectancy and prognosis.

It may be pointed out that in these anatomically different types of transpositions, the terms “complete” or “incomplete” transposition of the great vessels may have 2 different meanings. First, the terms “complete” or “incomplete” are used to stress that a vessel originates completely or incompletely from the opposite ventricle. In this sense, both transpositions under discussion are incomplete transpositions because of the biventricular origin of the pulmonary artery. Secondly, the terms “complete” or “incomplete” may be used in order to characterize the relation of the 2 great vessels to each other. In this case, the original Taussig-Bing heart again is an incomplete transposition but the transposition with posteriorly placed overriding pulmonary artery is a complete transposition. Keith\textsuperscript{21} seems to prefer the second point of view, since he used the term “complete” transposition for the latter group and “incomplete” for the Taussig-Bing heart. This differentiation appears to be useful, despite the fact that the pulmonary artery is overriding the ventricular septal defect and is biventricular in origin.

\textbf{Figure 5}

Plain x-ray Taussig-Bing transposition. Case 7. Top, anteroposterior view; middle, left anterior oblique view; bottom, right anterior oblique view.
in both instances. Furthermore, the relation of the 2 vessels to each other is of greater diagnostic importance than the biventricular origin of the pulmonary artery.

The patients included in this study all had a history and clinical findings characteristic of transposition of the great vessels. The outstanding findings that permit the suggestive diagnosis of a Taussig-Bing transposition are the x-ray and fluoroscopic findings. As Taussig in a clinical analysis of complete transposition has pointed out, the vascular shadow is narrow in the posteroanterior view and widens in the left anterior oblique view. This sign is present only if the transposition of the great vessels is complete and the counterclockwise rotation is 180 degrees and both great vessels are of normal size. If there is a very prominent pulmonary artery segment and a wide vascular shadow, the differential diagnosis lies between a Taussig-Bing transposition or a transposition with dilated posterior pulmonary artery. The decision whether cardiac catheterization or angiocardiography is superior in establishing the correct diagnosis is a difficult one. Catheterization data may offer a clue as to the diagnosis of a Taussig-Bing transposition provided the pulmonary artery is entered and the oxygen content is higher than in the aorta. This finding alone does not differentiate between the 2 types of transposition. At cardiac catheterization, either a spot film taken in the posteroanterior or right oblique view with the catheter in the pulmonary artery, or the observation of the course of the catheter is necessary in order to differentiate the position of the vessels. The catheterization data should show a step-up in oxygen content of several volumes per cent in the right ventricle, (6 volumes per cent in the original case) and a lower oxygen content in the aorta than in the pulmonary artery. In the original case the oxygen content in the pulmonary artery was 4.4 volumes per cent higher than that in the right ventricle and 7.6 volumes per cent higher than that in the aorta. This has been a constant finding in our series of cases.

Angiocardiography usually gives clear information about the position of the great vessels. The posteroanterior and right lateral projection are the most informative ones. In this study, angiocardiography usually showed better opacification of the aorta than of the

Figure 6
Top. Lateral angiocardiogram of the original Taussig-Bing case. Bottom. Anteroposterior angiocardiogram of the original Taussig-Bing case.
Figure 7
Angiocardiogram Taussig-Bing transposition. Case 7. Top, anteroposterior view; bottom, lateral view. Note in lateral view that aorta is in same position as in original Taussig-Bing heart, shown in figure 6. The aorta is not so far anterior as in complete transposition (see fig. 9).

The differentiation of the Taussig-Bing transposition from a complete transposition with a large ventricular septal defect is possible if both angiocardiography and cardiac catheterization are carried out. The plain x-ray and spot films taken during catheterization and angiocardiography in the anteroposterior and lateral projection are the most helpful means of differentiation.

This malformation also requires differentiation from a single ventricle with transposition.
### Table 2
Data of Four Cases of Complete Transposition with Overriding, Posterior Pulmonary Artery

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Initials, sex</th>
<th>Age first ex.</th>
<th>Cyanosis, clubbing, spells</th>
<th>Murmur, thrill</th>
<th>Blood count</th>
<th>X-ray</th>
<th>Angiocardiogram</th>
<th>Catheterization</th>
<th>Autopsy</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A-70174 P.H.</td>
<td>3 mo., 1949</td>
<td>Systolic, LSB</td>
<td>RBC 4.9</td>
<td>Hb. 14.3</td>
<td>Full pulmonary conus, increased pul. vascularity. Right aortic arch</td>
<td>Aorta arising far anteriorly</td>
<td>No</td>
<td>Complete transposition with posteriorly placed, overriding PA. Single cor. artery</td>
<td>Died at operation for artificial ASD</td>
</tr>
<tr>
<td>2</td>
<td>A-52845 B.J.H.</td>
<td>5 yr., 1947</td>
<td>Systolic, LSB, distolic</td>
<td>RBC 8.78</td>
<td>Hb. 19.3</td>
<td>Prominent pul. conus, increased pul. vascularity</td>
<td>No</td>
<td>Highest O₂ content in PA PA=23.3 P=88/35</td>
<td>No</td>
<td>At operation for artificial ASD the aorta was seen to arise far anteriorly</td>
</tr>
<tr>
<td>3</td>
<td>A-50164 E.C.P.</td>
<td>6 yr., 1947</td>
<td>No</td>
<td>RBC 9.14</td>
<td>Hb. 24</td>
<td>Prominent pul. conus, increased pul. vascularity</td>
<td>Aorta arising far anteriorly</td>
<td>Pul. artery not entered</td>
<td>Complete transposition with large, posteriorly placed, overriding PA</td>
<td>Typical case</td>
</tr>
<tr>
<td>4</td>
<td>A-73852 G.W.</td>
<td>6 mo., 1949</td>
<td>Systolic, LSB</td>
<td>RBC 6.27</td>
<td>Hb. 16</td>
<td>Prominent pul. conus, increased pul. vascularity</td>
<td>Aorta arising far anteriorly</td>
<td>Highest O₂ content in PA PA=13.39 P=92/84 FA=5.70 O₂ step-up in RV</td>
<td>Complete transposition with large, posteriorly placed, overriding PA</td>
<td>First diagnosed as Taussig-Bing. Died at operation for artificial ASD</td>
</tr>
</tbody>
</table>

The observation that the patients with the Taussig-Bing transposition usually lived for many years and had a good clinical course suggests that the anatomical variations in the pulmonary arteries may be less important than previously believed. The development of such pulmonary vascular lesions depends on the duration of the postnatal period. The pulmonary branches are at first dilated and hypertrophied, and later the vessels are frequently found in single ventricle, which is helpful.

There is probably no difference in the incidence of associated lesions in complete transposition of the Taussig-Bing type. The most common defect is the overriding aorta with a coartation of the aorta. An atrial septal defect is usually present in the right ventricle but no real value in the differentiation from a Taussig-Bing heart. In the Taussig-Bing type, a very large step-up in oxygen content in the right ventricle has frequently been found in single ventricle, which is helpful.
origin of the 2 vessels show how these vessels are projected upon the plane of the screen. In the posteroanterior view, the Taussig-Bing heart has a wide vascular shadow with a prominent pulmonary segment, since both vessels are side by side. In the transposition with a posterior pulmonary artery, the vascular shadow may also be wide because of the huge pulmonary artery. The usual position of the pulmonary segment may be occupied by the aorta as shown in figure 4, or it may be very prominent due to the large posterior pulmonary artery. Thus, it may be difficult on fluoroscopy in the posteroanterior projection to decide whether the vessel occupying the pulmonary segment is the aorta or the pulmonary artery. If the 2 vessels are side by side, as in the Taussig-Bing heart, it is quite obvious that in the right anterior oblique view the left vessel, which in this instance is the pulmonary artery, is in front and in the left anterior oblique view, the right vessel (aorta), is in front. Since in this particular case the pulmonary artery is usually the larger vessel, in the lateral views its shadow may extend beyond the aorta anteriorly. Metianu33 mentioned in his publication of a Taussig-Bing heart that there was a very prominent vascular shadow in the right anterior oblique view. He pointed out that this shadow may be a pulmonary artery but an anteriorly displaced aorta could not be excluded. In the photograph of the specimen, which certainly is a Taussig-Bing heart, it can be seen that this vessel indeed was the pulmonary artery. Figure 3 shows how far anteriorly the shadow of this vessel may be projected in the right anterior oblique view. In the left anterior oblique view, however, figure 3 shows clearly that the aorta is projected anteriorly in this position. In contrast, as is shown in figure 4, in the transposition with posteriorly placed pulmonary artery, the projection of the aorta upon the screen is always anterior to the pulmonary artery. In this type of transposition, in the left anterior oblique view the anterior border of the 2 vessels may be only slightly separated and the huge pulmonary artery usually dominates the picture. Thus, these differences in x-ray projec-

longer may explain the occurrence of these lesions.

Since fluoroscopy so often gives a clue in the diagnosis of congenital heart disease, it may be expected that such a fundamental difference in the position of the great vessels as is found in these 2 transpositions can be differentiated during fluoroscopic observation. In order to demonstrate the projection of the shadow of the great vessels upon the screen of the fluoroscope, the drawings of the normal heart and the 2 malformations in figures 2, 3, and 4 were made. The lines beginning at the

**Figure 8**

*Posterior pulmonary artery, Case 2, table 2. Plain x-ray: Top, anteroposterior view; bottom, lateral view.*
The clear differentiation between the Taussig-Bing transposition and a complete transposition with posteriorly placed overriding pulmonary artery may be a most difficult problem. Differential diagnosis during life is possible if on angiography the position of the aorta is typical of either malformation or if there is sufficient opacification of the pulmonary artery. Gasul\textsuperscript{25} pointed out that the differential diagnosis on angiography in this group of transpositions may be so difficult that he included the complete transpositions with large ventricular septal defects in the Taussig-Bing group. The example of a Taussig-Bing angiogram published by Gasul certainly is that of a complete transposition with posteriorly placed pulmonary artery. In the angiogram published by Adams and Kaplan\textsuperscript{26} as a Taussig-Bing heart, the aorta lies far anterior to the pulmonary artery and the 2 vessels are not side by side as in the Taussig-Bing heart. Kjellberg, Mannheimer, et al.\textsuperscript{27} reported in their series 3 patients with a Taussig-Bing transposition; in one instance this malformation was associated with a coarctation of the aorta. One angiogram published by these authors also shows a posterior pulmonary artery. Chiechi\textsuperscript{1} in his critical review article on this subject added 4 autopsied cases of his own. As he pointed out and can be seen in the photographs of his paper, the aorta was far anterior to the pulmonary artery in cases 1 and 2. The 180-degree counterclockwise rotation of the pulmonary artery in his case 1 is the reason that the plain x-ray of this case is not the typical x-ray of the Taussig-Bing heart. The relationship of the 2 great vessels to each other is not mentioned in the remaining 2 cases. Thus, in 2 of his cases the position of the vessels was not like that in the Taussig-Bing transposition. Furthermore, Chiechi does not mention the 2 anatomically different types of transposition that are identical in regard to their physiology. Case 1 of the report by Van Buechem\textsuperscript{10} has a posterior pulmonary artery. The case reported by Martin and Lewis\textsuperscript{12} also has a posterior pulmonary artery. The same position of the vessels is present in the 2 cases of Maxwell and Crumpton.\textsuperscript{14} In contrast to the above reports, the case published by Lev and Volk\textsuperscript{9} is certainly a typical Taussig-Bing heart. The vessels are side by side in this specimen. An interesting case was published by Falholt and Pedersen\textsuperscript{17} in 1952. This case was diagnosed by cardiac catheterization. There was a very full and prominent pulmonary conus on x-ray. At catheterization both the pulmonary artery and the aorta were entered and the oxygen content in the pulmonary artery was highest. The authors mentioned that this would not exclude a transposition with large ventricular septal defect, but at cardiac catheterization the catheter was seen to enter the pulmonary artery directly from the right ventricle in a straight course probably through an over-

\textbf{Figure 9}

Table 3
Distribution of the Seventy-three Reviewed Cases with Possible Taussig-Bing Transposition in the Cardiac Clinic, Johns Hopkins Hospital

<table>
<thead>
<tr>
<th>Taussig-Bing transpositions</th>
<th>3 proved by autopsy</th>
<th>1 exact position of great vessels not mentioned in autopsy report</th>
<th>11 diagnosed by catheterization, angiocardiogram, or both</th>
<th>17 clinically diagnosed, not proved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete transpositions with posteriorly placed, overriding pulmonary artery</td>
<td>3 proved by autopsy</td>
<td>1 diagnosed by catheterization</td>
<td>3 clinically diagnosed, not proved</td>
<td></td>
</tr>
<tr>
<td>Complete transposition with ventricular septal defect</td>
<td>7 with catheterization data similar to Taussig-Bing transposition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data incomplete</td>
<td>25 cases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>1 single ventricle</td>
<td>1 dextrocardia with incomplete transposition</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

riding pulmonary orifice. The pulmonary artery was located at its normal place. Thus, this is a true Taussig-Bing transposition.

As pointed out above, with the aid of cardiac catheterization or angiocardiography a differential diagnosis between the transposition as originally described by Taussig and Bing and the transposition with a posterior overriding pulmonary artery may be possible during life. Frequently it is necessary to perform both cardiac catheterization and angiocardiography. The differential diagnosis is desirable from a clinical point of view and accurate anatomic classification will be of great importance if total correction of these 2 malformations becomes possible.

A detailed discussion of the theories of embryologic development of transposition of the great vessels is not a subject of this paper. Theories about the development of transpositions have been published long before clinical diagnosis was attempted. These theories do not aid in the clinical approach but are of considerable interest. The modification of Spitzer’s theory by Lev and Saphir seems to be a plausible compromise between Spitzer’s phylogenetic theory and the ontogenetic theory of Perukopp and Wirtinger. According to the latter authors, at the end of the first phase of the bulbar ridges and their absorption into the ventricle that are responsible for the twist-formed, the bulbar ridges and the atrial region are already twisted, whereas the truncus is still a straight tube. During the second phase, a torsion occurs at the bulbus-truncus ostium and a “back torsion” in the region of the ventriculobulbar junction. It is the twist of the bulbar ridges and their absorption into the ventricle that are responsible for the twisting of the great vessels and their correct position. It is the opinion of Lev and Saphir that the bulbar ridges may be malformed; thus the hemodynamic forces postulated by Spitzer cause an abnormal absorption of the bulbus. Consequently, the hemodynamic forces could lessen the degree of torsion of the ostia to any possible extent and thus cause the various forms of transpositions. It also would explain the hyperplasia of either one of the great vessels as, for instance, the hyperplasia of the pulmonary artery in the Taussig-Bing heart.

Summary

The Taussig-Bing transposition bears the name of the authors who described for the first time the clinical, physiologic, and anatomic findings. It has been recognized that the malformation is physiologically not so distinct as it is anatomically and that a transposition with the same physiologic pattern but different anatomy has been observed. Several case reports have appeared in the literature in which no clear differentiation was made in regard to the second type of transposition with overriding pulmonary artery. In the latter instance there is a complete transposition of both great vessels with a posteriorly placed overriding pulmonary artery in contrast to the original Taussig-Bing heart in which the 2 vessels are side by side, the pulmonary artery being in its normal place.

Following the original case report, 14 cases were seen in this clinic in which the diagnosis...
TAUSSIG-BING HEART

was established either by catheterization, angiocardiography, or autopsy. In 4 other cases, the diagnosis of a transposition with a posterior overriding pulmonary artery was made. Criteria for the differential diagnosis of these 2 lesions are pointed out. The differentiation of these 2 transpositions is of particular importance for possible surgical correction.

Appendix

Summary of the Autopsy Reports of the Taussig-Bing Cases

Case 4: J.H.H. Autopsy No. 23083, performed by Dr. Reynolds. Autopsy showed the typical position of the great vessels as seen in Taussig-Bing hearts, the pulmonary artery and aorta being side by side. The pulmonary artery overrode a large ventricular septal defect. The pulmonary valve was bicuspid. There was also a muscular ridge similar to that in the original case. The coronary arteries were normal. The medial and smaller pulmonary arteries showed thrombi in various stages of organization and recanalization. There was marked intimal proliferation. The smallest arteries and capillaries were enormously dilated. No additional lesions beside the surgically created atrial septal defect were present.

Case 8: J.H.H. Autopsy No. 24472, performed by Dr. Bunnell. The pulmonary artery and aorta were side by side and the pulmonary artery overrode a large ventricular septal defect. A muscular ridge separated the origin of the 2 great vessels. The coronary arteries were normal. There is no description of changes in the pulmonary vessels.

Case 11: J.H.H. Autopsy No. 23098, performed by Dr. Iber. The patient died 3 days after the creation of an atrial septal defect. Autopsy showed a probe-patent foramen ovale. The artificial atrial septal defect measured 2.5 cm. in diameter. There was marked right ventricular hypertrophy. The aorta arose side by side to the pulmonary artery. It came off the right ventricle. The pulmonary artery arose from the left ventricle and definitely overrode a ventricular septal defect of 2.5 cm. in diameter. The aortic and pulmonary artery leaflets were normal. The pulmonary artery at its origin measured 8.7 cm. in circumference, the aorta 4.5 cm. The coronary arteries were normal. The ductus arteriosus was patent. The pulmonary arterioles were thickened and showed intimal proliferation.

Summary of the Autopsy Reports of the Cases with Posterior Pulmonary Artery

Case 1: J.H.H. Autopsy No. 501909, performed by Dr. Berthrong. There was a surgically created atrial septal defect of 1.2 cm. in diameter and inferior to that another atrial septal defect of 1 cm. in diameter, which was present prior to operation. The right ventricle was hypertrophied and the aorta came off the right ventricle, anterior to the pulmonary artery. The aortic valve had 3 cusps. There was only 1 coronary artery, branching directly toward the right ventricle as well as circumflex branches passing in both directions in the atrioventricular groove. The aorta arched to the right and descended on the right. The pulmonary artery arose posteriorly from the left ventricle and overrode a ventricular septal defect of 1.2 cm. in diameter. The ventricular septal defect was directly beneath the pulmonary valve ring. The pulmonary artery was greatly dilated. The pulmonary arterioles showed thickening of the media.

Case 3: J.H.H. Autopsy No. 428660, performed by Dr. Brown. Autopsy showed the aorta approximately in the normal position of the pulmonary artery and the pulmonary artery posterior to the aorta. The pulmonary artery overrode a ventricular septal defect of 3 by 1.5 cm. There was no crista or muscular ridge.

Case 4: J.H.H. Autopsy No. 22095, performed by Dr. Wolfson. There was a surgically created atrial septal defect. The foramen ovale was sealed. The right ventricular wall was thick (18 mm.) and its chamber was dilated. The aorta arose from the anterior part of the right ventricle. The aortic valve was normal, its ring measuring 3 cm. in circumference. The coronary arteries were normal. Immediately behind the aorta the crista appeared; it was a good-sized muscular band but was incomplete. The inferior margin led to a ventricular septal defect of 1 by 1 cm. in diameter. The left ventricle measured 8.5 mm. in thickness. From the left ventricle arose the pulmonary artery and overrode the ventricular septal defect by 20 per cent. Its valve ring measured 3.3 cm. in diameter, the main pulmonary artery 3.8 cm., and the left pulmonary artery was greatly dilated, measuring 20 cm. in diameter. There was a probe-patent ductus arteriosus. The pulmonary vessels were thickened.

Acknowledgment

The author wishes to express his sincerest thanks and appreciation to Drs. Helen B. Taussig, Richard J. Bing, and Charlotte Ferenz for the invaluable help and many discussions during the course of this study.

Summario in Interlingua

Le transposition de Taussig-Bing portà le nomine del autores del prime description del constatations clinic, physiologic, e anatomic caracteristic de illo. On ha notate que iste malformation es minus distinte physiologicamente que anatomicamente e que
il occorre un transposition con le mesme complexo de manifestaciones physiologic sed un differente configuration anatomiche. Pluris reportos de casos se trova in le litteratura in que nullo precise differentiation esseva facite inter le transposition de Taussig-Bing e le altere typo de transposition in que le arteria pulmonar se distingue per su disbordamento posterior. In le secunde du duo situationes il ha un transposition complete du duo grande vasos con disbordamento posterior del arteria pulmonar, per contrasto con le syndrome de Taussig-Bing in que le duo vasos es placiate in juxtaposition con le arteria pulmonar in sito normal.

Post le caso del reporto original, 14 exemplos de corde de Taussig-Bing esseva observate a iste clinica, con diagnoses estabite per catheterismo, per angio-cardiographia, o al necropsia. In 4 casos additional, le diagnose esseva transposition con disbordamento posterior del arteria pulmonar. Es signalate criterios pro le diagnose differential de iste 2 lesionis. Le importanta de un correcte differentiation es apparente ab le puncto de vista de un possibile correction chirurgie.

References
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Medical Eponyms

By Robert W. Buck, M.D.

Bowman's Capsule. William Bowman (1816-1892) F.R.S., Assistant Surgeon to the King's College Hospital, and Demonstrator of Anatomy in King's College, London, read before the Royal Society on February 17, 1842, a paper "On the Structure and Use of the Malpighian Bodies of the Kidney, with Observations on the Circulation through that Gland." This was printed and may be found in the Philosophical Transactions of the Royal Society of London for the year 1842, part I, pp. 57-80 (vol. 132).

"The Malpighian bodies I saw to be a rounded mass of minute vessels invested by a cyst or capsule (first particularly pointed out by Müller, who conceives it to be perfectly closed, except at one point where perforated by the vessels) of precisely similar appearance to the basement membrane of the tubes. Seeing these similar tissues in such close proximity, it was not easy to resist the conviction that the capsule was the basement membrane of the tubes expanded over the vessels. . . . Having, during last summer, been made acquainted, through the kindness of Dr. Milne Edwards, with a new method of injection employed with great success by M. Doyère of Paris." (This consists of two fluids which mingle in the small vessels, and cause a precipitation there. The best fluids are saturated solutions of bichromate of potass and of acetate of lead. They are injected in succession through the same vessel, whence the method is termed that by double injection. Krause published an account of it two years ago, but M. Doyère appears to have arrived at it after a laborious trial of numerous solutions. Both deserve the thanks of anatomists for so valuable an addition to the means of investigation.)—I injected some kidneys through the artery, by this method, in order to notice the nature of the vascular ramifications in the Malpighian bodies. I not only found what I sought, but the clearest evidence that the capsule which invests them is, in truth, the basement membrane of the uriniferous tube expanded over the tuft of vessels."
Differential Diagnosis of the Taussig-Bing Heart from Complete Transposition of the Great Vessels with a Posteriorly Overriding Pulmonary Artery
ALOIS BEUREN

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