Isolated Total Anomalous Pulmonary Venous Drainage

FRANK R. DUTRA, M.D.*
Castro Valley, California

Anomalous pulmonary venous drainage is the condition in which blood leaving the lungs returns via systemic veins, or directly, to the right atrium. Complete anomalous connection of the pulmonary veins occurs as the only important abnormality of the cardiovascular system in some cases, but in others, additional congenital defects of the heart and great vessels are also present.

Classification

Anomalous pulmonary venous connections may provide channels for partial or for complete return of blood from the lungs to the right atrium. These are sometimes the only anomalies, but they also may be part of a complex of abnormalities. The isolated partial anomaly occurs in approximately 0.5 per cent of persons, but among patients with additional cardiovascular anomalies, partial abnormal pulmonary venous drainage is more common. About 15 per cent of patients with defects of the atrial septum requiring surgical therapy also have partial anomalous pulmonary venous connections.

There are approximately 100 previously reported cases of isolated total anomalous drainage,** but only one-half as many cases of the total anomaly associated with congenital cardiac abnormalities are recorded.¹

This general orientation leads to the convenient grouping of the cases of total anomalous venous drainage presented by Darling, et al.,¹ based upon the level of the junction of the anomalous drainage channels with the systemic circulation.

<table>
<thead>
<tr>
<th>Group</th>
<th>Level</th>
<th>Site of Connection</th>
<th>Distribution in 103 Cases</th>
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<tr>
<td>I</td>
<td>Supracardiac</td>
<td>A. Left Superior Vena Cava or Left Innominate Vein</td>
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<td></td>
<td></td>
<td>B. Right Superior Vena Cava</td>
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<tr>
<td>II</td>
<td>Cardiac</td>
<td>A. Coronary Sinus</td>
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<td>B. Right Atrium</td>
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<tr>
<td>III</td>
<td>Infracardiac</td>
<td>A. Portal Vein</td>
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<td></td>
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<td>B. Ductus Venosus</td>
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<td>C. Inferior Vena Cava</td>
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<td>Mixed</td>
<td>A. Superior Vena Cava and Right Atrium</td>
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<td>B. Coronary Sinus and Left Innominate Vein</td>
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<td></td>
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<td><strong>Total</strong></td>
<td>103</td>
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¹Adapted from Keith.²

²A patent foramen ovale is essential in all cases of total anomalous drainage, and it is implied in spite of the adjective "isolated." The latter term indicates absence of additional significant defects of the cardiovascular system.
Embryology

In the normal development of the pulmonary veins, the splanchnic plexus which surrounds the foregut communicates with the anterior cardinal, posterior cardinal, and umbilico-vitelline veins. Subsequently, a vascular channel forms to connect this plexus with the developing cardiac atrium and this is followed by disappearance of the connections between the splanchnic plexus and the cardinal and umbilico-vitelline veins. Meanwhile, growth of the lung buds extends into the splanchnic plexus and this plexus is established as the drainage system for the lungs. The single venous trunk between the lung buds and the left atrium is incorporated into the wall of the atrium as this latter structure enlarges, and as the single trunk is completely absorbed into the atrial wall, the four individual pulmonary veins come to have their own openings into the left atrium, thus establishing the normal postnatal condition.

The embryological basis for total anomalous pulmonary venous return results from retention of a connection with one of the anterior cardinal veins (which become the innominate veins and coronary sinus), with the umbilico-vitelline veins (which become the hepatic and portal veins), or because the venous trunk which connects with the developing atrium is incorporated into the right atrial wall rather than the left atrial wall.*

Pathology

In nearly all cases of the anomaly, the four pulmonary veins unite into a common trunk which proceeds to its union with the systemic vein or right atrium. Rarely, two or more veins progress to the right atrial wall or to veins at the supracardiac level. There are only three recorded instances of the connections being at two different levels.

Because all venous blood, both systemic and pulmonary, returns to the right atrium this chamber is invariably larger than the left. Usually the volume of the right chamber is 2 to 5 times that of the left. The left ventricle is also somewhat smaller than the right, but the thickness of the myocardium of each is similar. The mitral valve orifice, like the chambers of the left side of the heart, is smaller than usual.

The aorta and pulmonary artery are approximately the same size in about half the cases. In the others, the pulmonary artery is at least one-third again as large as the aorta.*

Diagnosis

The usual history of infants with this condition is as follows: health has been fairly good with essentially normal activity until a terminal episode begins with the development of cyanosis and dyspnea. When cardiac failure becomes manifest, it progresses rapidly to death.

In spite of the essential patent foramen ovale and the systemic circulation of some blood which has not cycled through the lungs, cyanosis is only slight or absent in nearly all patients until the terminal phase. Cyanosis is frequently first observed during episodes of crying or exertion. The oxygen saturation of arterial blood in thirteen patients was
recorded by Keith, et al.; it was 63 per cent in one patient who was cyanotic, while in the others it ranged from 80 up to 95 per cent. The majority were in the range where cyanosis would not be recognized.

Heart murmurs were present in two-thirds of the infants under three months of age who were observed by Keith, and among the ten patients who had audible murmurs the sound was most commonly a short systolic one of moderate intensity between the second and fourth intercostal spaces adjacent to the sternum. Murmurs of this type were present in nine of the ten, and four of the nine also had a diastolic murmur in the fourth left intercostal space between the cardiac apex and the sternum. The tenth patient, a boy 3 ½ years old, had a soft continuous murmur over the region of the pulmonic valve and partway down the left border of the sternum. Three additional children were observed subsequently with similar murmurs. All four of these patients had abnormal pulmonary venous drainage into the left innominate vein.

Radiologic examination is extremely useful in the cases in which the pulmonary veins connect with the left innominate vein. After the first few months of life, there is widening of the mediastinal shadow above the heart so that the heart and this shadow together appear like the figure eight. One author has referred to this as a "mediastinal mustache," another as a "snowman" appearance. The enlarged heart shadow in cases where the pulmonary veins enter the coronary sinus, right superior vena cava, right atrium, inferior vena cava, portal or hepatic veins is not diagnostic. In occasional instances of venous connection with the coronary sinus, a "box-like shelf" occurs at the upper right border of the heart shadow. When present, this is said to be characteristic of such abnormal drainage.

FIGURE 1 (Case 1): Postero-anterior film of chest taken one and one-fourth years prior to death. The "Figure 8" shadow of the heart and supraventricular vessels is characteristic. Increased vascularity of pulmonary hilar region.
Less often, the connection is via a trunk to an infracardiac vessel (Group III). These hearts are usually of normal size. Patients with infracardiac drainage have increased density of the lung fields, presumably reflecting pulmonary hyperemia, and this has aided some radiologists to consider the diagnosis from the chest films.

Angiocardiography may yield diagnostic information in cases of Group I, does not define the anomaly in Group II, and has not been reported in any case of the Group III type.

At fluoroscopy, the observation is often made that in spite of the prominent hilar vascular shadows, there is relatively little pulsation so that the enlargement may be recognized as being due primarily to venous rather than arterial engorgement.

Cardiac catheterization usually reveals elevation of the right atrial and ventricular pressures, although there are occasional patients with normal pressures. The pressure in the pulmonary artery is only slightly lower than that observed in the right ventricle. The oxygen saturation of blood in the right atrium is greater than normal, and passage of the catheter into the appropriate orifice may reveal the source of the oxygenated blood and hence the abnormal pulmonary venous connection. However, proof that the anomaly is a total one is not established by this procedure, since anomalous connection of a single vein can yield the same results.

The dilution curve of Evans blue dye in arterial blood following injection into a systemic vein is marked by a prompt appearance of dye shunted through the foramen ovale and a second rise in concentration as that portion circulated through the lungs is recirculated into the systemic vessels. However, this shunt pattern may be obscured in cardiac failure.

**Presentation of Cases**

The following case, an example of total anomalous connection via the left innominate vein, is noteworthy because the patient survived until she was 43 years of age. At the time of death, she was older by 16 years than any previously described patient with this condition.

**Case 1:** The final admission to the hospital of this 43 year-old patient was on January 20, 1959, for somnolence and jaundice.

Medical records of this patient date back to the age of seven, at which time her pediatrician had referred her to an internist for evaluation of slight cyanosis, cardiac enlargement, and a heart murmur. The patient had observed no related symptoms and the cardiac murmur is not described. Right axis deviation was indicated by a three lead electrocardiogram, while fluoroscopic examination revealed enlargement of the heart and hilar vessels. The internist saw her again when she was eleven years old and observed slight cyanosis, but there was no congestive failure nor digital clubbing. The heart was enlarged with bulging of the precordium. A faint systolic thrill and a grade III systolic murmur were noted in the upper left parasternal region over the second and third intercostal spaces.

At age 31, the patient was admitted to the hospital for evaluation of cardiac status. Since she had become addicted to alcohol, icterus which was present was ascribed to dietary deficiency and alcoholism. A grade III systolic murmur was present over the base of the heart bilaterally and it was also heard over the back. An electrocardiogram revealed evidences of right ventricular hypertrophy and incomplete right bundle branch block. Chest films indicated a large heart with the "figure eight heart shape as in abnormal venous return" (Fig. 1). Additionally, fluoroscopy indicated that the predominant pulmonary hilar vessels did not pulsate excessively.
Her nutritional habits continued to be poor and she was admitted to the hospital on several occasions prior to the last admission for treatment of hepatic cirrhosis. Approximately one month before her last admission, she again had begun to consume large amounts of alcohol and in the few days before admission, there had been marked bruising of the skin and bleeding from the gums. Jaundice in varying degrees had been present for a year prior to this last admission. The cardiac murmur was noted and a forceful apical thrust was described. The heart rate at this time was 134 per minute and the blood pressure was 130/80. The lower edge of the liver was 10 cm. below the costal margin.

Her temperature rose rapidly to 104.6 degrees F., she became completely unresponsive, and death occurred eight hours after admission.

Necropsy (E.H. 59-A-10)

The body was poorly nourished and the skin was greenish yellow. The globoid heart was estimated to weigh 400 gm. The right atrium and ventricle were unusually prominent, and were dilated to approximately three times the volume of the corresponding left chambers. The myocardium of the right and left ventricles was 7 mm. and 9 mm. in thickness respectively. The left atrial and ventricular chambers were slightly smaller than usual. The patent foramen ovale, septum secundum type, was 2.8 x 2.4 cm. (Fig. 2).

The right innominate vein was normal. The left innominate vein was approximately twice the diameter of the right, and in addition to receiving the usual veins of the left side of the neck and left upper extremity received a large common pulmonary venous trunk. The latter arose in the region of the hilum of the right lung by coalescence of the veins of the upper and lower lobes, crossed the midline dorsal to the parietal pericardium and anterior to the esophagus and aorta, and was joined by a large vein formed by the veins from the upper and lower lobes of the left lung. Thus, the veins from both lungs connected with the right atrium via the left innominate vein and superior vena cava. The coronary arteries and aorta were unchanged and the latter was 4.5 cm. in circumference. The circumference of the pulmonary artery was 5.5 cm. and a few atheromatous plaques were present in its intima.

The lungs showed no abnormalities other than the vascular ones previously described. The liver weighed 1755 gm. and had coarsely nodular surfaces.

There was an erosion of the mucosa of the cardia in a region 8 x 4 mm. and hemorrhage was present in the mucous membrane adjacent to this erosion. The stomach and intestines contained approximately 1000 ml. of partially clotted thick dark red blood.

Microscopically, the branches of the pulmonary artery were approximately half again the expected diameter and their walls were somewhat thicker than usual.

Anatomical Diagnosis

Congenital anomalies of cardiovascular system, with anomalous connection of all pulmonary veins to left innominate vein; widely patent foramen ovale; hypertrophy and dilatation of right chambers of heart; nutritional cirrhosis of liver; ascites; icterus; erosion of mucosa of the cardia, with massive hemorrhage.

In total anomalous venous drainage, the likelihood is greater that the common pulmonary venous channel will join a derivative of the anterior

![Diagram](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21357/)

**FIGURE 2 (Case 1):** Diagram of heart and great vessels to illustrate route of pulmonary venous return. Not illustrated is the relatively large size of the pulmonary artery as compared to the aorta.
cardinal than a derivative of the posterior cardinal veins. Our second case is of the latter type.

Case 2: This patient was a seven day-old white male infant when he was admitted to the hospital because of “somnolence, irregular respirations, and poor feeding.” The pregnancy and labor had been uneventful and the infant, which weighed five pounds thirteen ounces at birth, was described as lethargic following delivery and at twenty-four hours, was slightly icteric. The Coombs test was negative. Serum bilirubin concentration rose to 12 mg./100 ml., but then began to recede and the infant had been discharged at the age of five days in apparently good condition. At home, the infant drank only small amounts of milk. He was always somnolent, and this led to re-hospitalization for additional study. The only abnormality noted on admission was mild jaundice. Routine laboratory work yielded normal results. The cardiac shadow was not enlarged, and chest films were interpreted as diffuse pulmonary edema, more marked in hilar than peripheral regions, due to “some unrecognized congenital heart disease.” His condition was poor, and the possibility of brain damage was considered. At the age of 18 days, he was transferred to a hospital for children, where the heart sounds were clearly audible, without murmurs and the heart was not enlarged. The lungs were clear by auscultation. The lower edge of the liver was 1 cm. and the lower edge of the spleen 2 cm. below the costal margin. By chest film, the cardiac shadow was normal in size and shape, while the lung fields were described as “homogeneously dense, suggesting diffuse atelectasis.” While in the hospital, a machinery-like bruit was noted anteriorly and posteriorly over the chest, most prominent over the mid-epigastrium. The lower extremities developed pitting edema. There were episodes of shallow slow respiration in which the infant was described as appearing moribund, and during one of these he expired at the age of 28 days.

NECROPSY (C.H.E.B. 59-48)*

The well-developed body was poorly nourished and was 52 cm. long. There was pitting edema of the skin of the lower extremities. The lower edge of the liver was 6 cm. below the costal margin.

The estimated weight of the heart was 40 gm. The right atrium and ventricle were dilated. The foramen ovale was 9 x 7 mm. and the ductus arteriosus was 2 mm. in diameter. Pulmonary veins from each lobe joined together to form a common trunk posterior to the heart and the trunk penetrated the diaphragm posterior to the vena cava. This vessel was 6 mm. in diameter. It joined the vena cava in the region where the hepatic vein entered that vessel.

The myocardium of the right ventricle was 6 mm. and of the left 5 mm. in thickness. The left atrium and left ventricle had approximately half the volume of the chambers of the right side of the heart, but they were reasonably near the expected size for the age and size of the patient.

The lungs were reddish purple, relatively firm, and diffusely boggy.

The liver weighed 108 gm. and like the other organs of the abdomen was hyperemic.

ANATOMICAL DIAGNOSIS

Congenital cardiovascular disease with total anomalous pulmonary venous connection with inferior vena cava, atrial septal defect; patent ductus arteriosus; cardiac hypertrophy and dilatation; passive hyperemia of viscera.

The third case is one in which the pulmonary veins, derived from the splanchnic plexus, connected with the umbilical-portal veins, also a relatively rare route for abnormal pulmonary drainage.

Case 3: Following a normal pregnancy and delivery, this male infant had done well until three or four days prior to admission to the hospital at the age of 21 days, when exertional cyanosis was observed. Two days prior to admission, the baby was examined by a physician and an electrocardiogram and chest films were made. The only abnormality of the cardigram was non-specific flattening of the T-waves of standard leads I and II, while the chest film indicated slight enlargement of the right side of the heart and increased pulmonary vascular markings. When the infant entered the hospital, he was described as well developed and well nourished, the pulse rate 120, respirations 24 per minute. The skin was bluish gray. A grade II diastolic murmur was heard over the base of the heart, and soft posterior basilar rales were present bilaterally. The liver edge was 3 cm. below the right costal margin.

The infant was given stimulants and an endotracheal tube was passed so that positive pressure breathing could be instituted. These measures were to no avail and the baby died 35 minutes after admission to the hospital.

*Necropsy by Dr. A. J. McD Adams.
NECROPSY (C.H.E.B. 58-73)**

The well-developed and well-nourished body was 53 cm. long, and the only external abnormality was slight edema of the scrotum. The viscera were in their usual places and the body cavities contained no excess of free fluid.

The heart was estimated to weigh 28 gm. The right atrium and right ventricle were dilated, while the cavities of the left atrium and ventricle were slightly smaller than usual, so that the volumes of the former were estimated to be four times those of the latter. The patent foramen ovale was 1.5 x 1.0 cm. The ductus arteriosus admitted a small probe, but was almost completely closed.

The pulmonary veins arose as usual from the two lungs, and the four veins united into a common trunk behind the pericardium (Fig. 3). This trunk, which was 4 mm. in diameter, progressed caudally through the membranous portion of the diaphragm to enter the liver where it drained into a venous sinus approximately 1 cm. in diameter. The sinus, in turn, connected with the portal vein. The vascular sinus also received the umbilical vein, the luminal diameter of which was reduced to less than 1 mm. From the vascular sinus, six vessels ranging from less than 1 up to 2 mm. in diameter penetrated the substance of the liver. The communication to the portal vein had an internal diameter of approximately 4 mm.

The lungs were average in size and the only gross abnormality noted was accentuation of the lobular pattern.

The only lesion observed among the abdominal organs was a circumscribed reddish brown nodule 1 cm. in diameter within the substance of the pancreas. The contents of the cranium were normal.

The microscopic examination revealed only two remarkable facts. A thin layer of myocardial fibers surrounded the left superior pulmonary vein with some thickening of the subendothelial connective tissues of this vein, and the slide of the pancreas revealed that the nodular lesion was an adenoma which contained beta granules.

ANATOMICAL DIAGNOSIS

Congenital cardiovascular disease, with total anomalous pulmonary venous connection to umbilical and portal veins, and atrial septal defect; patent (partially closed) ductus arteriosus; passive hyperemia of viscera; small benign islet cell adenoma of pancreas.

Discussion

Nearly all persons with this anomaly die in infancy and the nature of the anomaly is determined only rarely prior to autopsy. Among the 58 cases tabulated by Keith, et al., 80 per cent of the patients died during their first year and only one survived the first decade. This exception was a patient 27 year old at the time of death. Among the 17 previously unreported cases described by Darling, et al., only three had survived more than a year, two of them dying at the age of 20 months and the third at

**Necropsy by Dr. W. M. Palmer.**
the age of four years. Two of our patients survived only a few weeks, while the third died of unrelated causes (alcoholic hepatic cirrhosis with gastric hemorrhage) at the age of 43 years.

It is possible that increased cognizance of the condition will lead to diagnosis and surgical correction in a significant proportion of these patients in future years. The principles of treatment have been summarized by Keith and they include the requirements that the common pulmonary vein be anastomosed to the left atrium, the connection between the common pulmonary vein and the systemic venous system be obliterated, and the defect of the interatrial septum be closed.

A number of attempts have been made to correct this anomaly and a few have yielded successful results. The most comprehensive discussion of surgical therapy at present is by Bahnson, Spencer, and Neill.\(^1\)

**SUMMARY**

The development of anomalous pulmonary venous connections with the right atrium is briefly reviewed and the several types of this anomaly are described. Methods useful in diagnosis include chest films, angiocardiography, fluoroscopy, cardiac catheterization, and the dilution curve of dye in peripheral arteries or capillaries following an intravenous injection. Three new cases are added to the 103 previously reported instances of isolated total anomalous pulmonary venous return.

**ACKNOWLEDGMENT:** The records pertaining to Case 1 were kindly supplied by Dr. Charles Peacock. Opportunity to examine the specimens and review the records from Cases 2 and 3 was through the courtesy of Dr. A. J. McAdams.

**RESUMEN**

El desarrollo de conexiones venosas pulmonares anómalas con la aurícula derecha se revisa brevemente y se describen las anomalías en sus varios tipos. Los métodos útiles para el diagnóstico incluyen: radiografía de tórax, angiocardiografía, fluoroscopía, cateterización cardíaca, y la curva de dilución de colorante en las arterias periféricas o en los capilares después de una inyección intravenosa.

Tres nuevos casos se agregan a los 103 anteriores relacionados con regreso venoso, pulmonar aislado total.

**RESUMÉ**

L'auteur fait une revue générale rapide des cas jusqu'aux écrits, oûse constitue un développement de connections pulmonaires veineuses anormales avec l'oreillette droite et il envisage les différents types de cette anomalie. Les méthodes nécessaires au diagnostic comprennent les clichés thoraciques, l'angiocardigraphie, la radioscopie, le cathétérisme cardiaque, et la courbe de dilutions colorées dans les artères périphériques ou les capillaires à la suite d'une injection intraveineuse.

Trois nouveaux cas sont ajoutés aux 103 antérieurement rapportés.

**ZUSAMMENFASSUNG**

Es wird eine kurze Übersicht gegeben über die Entwicklung anormaler Verbindungen von pulmonalen Venen mit dem rechten Vorhof, und es werden die verschiedenen Typen dieser Anormalität beschrieben. Für die Diagnostik nützliche Verfahren bestehen in Thoraxröntgenaufnahmen, Angiocardiographie, Durchleuchtung, Herzkatheterisierung und der Kontrastmittel-Verteilung-Kurve in den peripheren Arterien oder Kapillaren im Anschluß an die intravenöse Injektion.

Es werden drei neue Fälle mitgeteilt zusätzlich zu den 103 zuvor veröffentlichten Befunden von isolierten totalen, anomalen Rücklauf der pulmonalen Vene.

**REFERENCES**


