Irreversible Pulmonary Hypertension after Correction of Tetralogy of Fallot*

Mauricio L. Roisman, M.D., Barry M. Beller, M.D., and James D. O'Keeffe, M.D.

Among the late complications of correction of tetralogy of Fallot, pulmonary hypertension is rare. In an isolated case pulmonary hypertension may be due to previously undetected agenesis of a pulmonary artery,1,2 thrombotic or embolic occlusion of the pulmonary vascular bed,3 peripheral pulmonic stenosis,4 and too large a shunt from a previous Blalock, or, more likely, a Pott's anastomosis leading to intractable left ventricular failure.5-8 Pulmonary hypertension may also be due to obstruction of the pulmonary vascular bed associated with inadequate closure of the ventricular septal defect and relief of the pulmonic stenosis.9,10 The following case illustrates the latter circumstance.

CASE REPORT

A 31-year-old Negro man, currently followed at the cardiology clinic of University of Texas Teaching Hospitals, has increasing ankle and leg edema, ascites, shortness of breath on minimal exertion and episodes of paroxysmal nocturnal dyspnea and orthopnea.

His past medical history goes back to his first few months of life when he was noted to be cyanotic. At age six, he was admitted to another hospital where a Blalock shunt with anastomosis of the left subclavian artery to the left pulmonary artery was performed. Following the operation his exercise tolerance improved and he did well.

When he was 16 years old, because of joint pains, fever and sore throat, he was admitted to a second hospital for probable rheumatic fever. No documentation of carditis was obtained.

Five years later (age 21) he had “dizzy spells” accompanied by blurred vision and chest pain. Clubbing and marked cyanosis were noted. He was found to be polycythemic (Hct 73 percent) and several phlebotomies were done. At age 23 he had severe headaches and lightheadedness and was again found to be polycythemic. Cardiac catheterization done at this time (Table 1) revealed tetralogy of Fallot with a nonfunctioning Blalock shunt. In May 1964, total correction of the tetralogy of Fallot was attempted elsewhere.

The operative report confirmed the existence of an enlarged heart (more in the right-sided chambers). The aorta was described as about 50 percent larger than the pulmonary artery; however, the latter vessel was not said to be smaller than normal. Under cardiopulmonary bypass and hypothermia, an infundibular obstruction 2 cm long and less than 0.5 cm in diameter was excised allowing the index finger to pass easily out into the pulmonary artery. The pulmonic valve was described as rudimentary and located in an abnormally high position in the pulmonary artery. It was not felt to be stenotic. The large ventricular septal defect was closed with a Dacron prosthesis, the surgeon noting that only a small rim of muscular septum was available for placement of sutures.

In 1969 he was readmitted to our hospital in severe congestive heart failure characterized by shortness of breath, paroxysmal nocturnal dyspnea, orthopnea, generalized edema and ascites. He was again cyanotic. His heart failure improved with medical therapy consisting of digitals and diuretics. A repeat cardiac catheterization was done (Table 1) which revealed systemic level pulmonary hypertension, patency of the ventricular septum with a bidirectional shunting and a widely patent pulmonary outflow tract.

Since then his course has been one of continuous worsening. The physical examination is now remarkable in showing cyanosis of the lips and fingers, and neck veins distented at 90° with a prominent A wave (Fig 1). A prominent right ventricular lift is present. The left ventricular impulse is located in the fifth intercostal space, 2 cm from the midesternal line. S1 is normal, S2 has an accentuated pulmonary
IRREVERSIBLE PULMONARY HYPERTENSION

Table 1—Cardiac Catheterization Results.

<table>
<thead>
<tr>
<th>Chamber</th>
<th>1964 Post-Blalock</th>
<th>1969 Post-total Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pressure*</td>
<td>O₂ Saturation</td>
</tr>
<tr>
<td>RA</td>
<td>(4)</td>
<td>47</td>
</tr>
<tr>
<td>RV</td>
<td>110/4</td>
<td>48</td>
</tr>
<tr>
<td>PA</td>
<td>10/3 (5)</td>
<td>46</td>
</tr>
<tr>
<td>LV</td>
<td>120/0</td>
<td>53</td>
</tr>
<tr>
<td>Aorta</td>
<td>116/88 (76)</td>
<td>58</td>
</tr>
</tbody>
</table>

Angiography
- Right ventricular angiogram revealed
  infundibular obstruction
- Left ventricular angiogram showed no
  mitral regurgitation

Dye Curves
- Right to left shunt at the ventricular level.
- Bidirectional shunting at the ventricular level.

*Mean pressures are in parentheses.
**Unchanged after inhalation of 100 percent O₂ for 20 minutes.

component. A grade II-VI early systolic murmur is heard best at the third intercostal space 8 cm from the midsternal line. The lungs are clear to percussion and auscultation. His abdomen is distended with ascites. The liver is enlarged and there is pitting edema of his legs.

Laboratory data show hemoglobin of 20.3 gm and hematocrit of 63 percent. The white cell count is 6,700. The electrocardiogram (Fig 2) shows a complete right bundle branch block, first degree AV block, bialtrial enlargement and right axis deviation. In comparison with a trace done in 1955 (Fig 2), the major change is in the development of the right bundle branch block. The present chest x-ray picture (Fig 3) shows massive cardiomegaly, prominent main pulmonary arteries and clear lung fields. Unfortunately, old chest x-ray films which would have been of value for comparison had been discarded.

DISCUSSION

When the immediate postoperative complications such as infection and bleeding are excluded, a poor clinical result following repair of tetralogy of Fallot is usually due to incomplete correction of the defect. Failure to relieve valvular or infundibular pulmonic stenosis, inadequate closure of the ventricular septal defect, or creation of free pulmonary insufficiency may contribute to postoperative morbidity as will undetected complete obstruction or absence of the left pulmonary artery, near pulmonary atresia or preexisting pulmonary hypertension associated with a previous Pott's anastomosis. In addition, preexisting left-sided disease such as mitral regurgitation or left ventricular failure associated with too large a Pott's anastomosis, other operative shunt, or the development of complete heart block or recurrent arrhythmias will lead to an unsatisfactory result.

Systemic level pulmonary hypertension as reported here is rare, but mild pulmonary hypertension has been reported by others. Lillehei and co-workers, Griffiths and Malm, Bristow and associates, and Gostman and colleagues each reported one or more cases, and in a review of the English

![Figure 1. Electrocardiogram, phonocardiogram and jugular venous pulse recording. A short, low amplitude systolic murmur (SM) and a prominent ejection click are noted. The second sound is multicomponented and accentuated pulmonic closure is noted. Although a fourth heart sound was not recorded, the jugular venous "A" wave is prominent.](http://journal.publications.chestnet.org/pdffile.ashx?url=/data/journals/chest/21541/ on 03/30/2017)
literature we have been able to determine an incidence of about 1.0 percent. Four cases have been associated with a remaining ventricular septal defect, five to absence of the left pulmonary artery, and in four cases, the cause was unknown.

Pulmonary thrombosis is a frequent complication of unrepaired tetralogy and may be due to sluggish pulmonary blood flow, polycythemia, and increased blood viscosity. From this, it would be expected that an effective shunt procedure would prevent or reduce the possibility of pulmonary thrombosis as has been emphasized by Ferencz. Failure of a shunt to remain open in our patient would, of course, be expected to have increased his risk of pulmonary thrombosis to that of the unoperated case. Despite the absence of pulmonary blood flow data that would have allowed us to calculate the pulmonary vascular resistance in our patient from the 1964 catheterization data, it is unlikely that the resistance was already elevated since the pulmonary artery pressure was only 10/3 (Table 1).

Analysis of our patient's objective data is helpful in excluding other causes of pulmonary hypertension. First, on chest x-ray examination, it is obvious that there is a prominent left main pulmonary artery and the original Blalock anastomosis was made to it. Second, there is no difference in the vascular pattern in the hilas and lung fields of the left and right sides. Both show large hilar vessels and peripheral pruning compatible with pulmonary hypertension of a severe degree. Although rheumatic mitral disease might be in part responsible for pulmonary hypertension, there is no evidence for this either clinically or historically. Left ventricular dysfunction due to the previous Blalock must also be considered, but pulmonary hypertension was not present in 1964, and there was no evidence at that
IRREVERSIBLE PULMONARY HYPERTENSION

Figure 3. Chest x-ray examination done in 1970. In addition to massive cardiomegaly, there is enlargement of the hilar portions of the major pulmonary arteries with peripheral pruning of the pulmonary vascular tree.

time of left ventricular failure or mitral insufficiency. These lesions were again ruled out at catheterization in 1969 and the physical examination at this time reveals no evidence for left-sided disease.

Examination of the factors responsible for the development of severe pulmonary hypertension in our patient indicates that failure to close the ventricular septal defect changed the patient's physiology from that of a "banded" ventricular septal defect to that of a large ventricular septal defect with reversal of shunt. Although a mild increase in pulmonary vascular resistance in the early postoperative period is often seen after a successful total correction, this is usually reversed with time.\(^1\) The presence of a residual ventricular septal defect has been responsible for the development of an irreversibly high pulmonary vascular resistance and systemic level pulmonary hypertension.

The mechanism by which a large shunt from the left ventricle to the right produces pulmonary vascular resistance changes is not completely understood. The early contributions of Edwards and Heath\(^1\) suggested that in the infant persistence of the fetal pulmonary arterial anatomy with high medial muscle to lumen ratios was induced by the high pressure flow from left pulmonary blood flow. Dammann and Ferencz,\(^2\) on the basis of their anatomic observations in a large number of patients, suggested that in some patients the pulmonary arterial musculature could regress normally and permit a large left-to-right shunt. Serial catheterization studies from a number of groups have confirmed this hypothesis. Hoffman and Rudolph\(^3\) demonstrated that a rise in pulmonary vascular resistance in infants with a patent ventricular septal could occur early in life and frequently in a short period of time. The mechanism of this resistance change has been hypothesized to be due to the elevation of left atrial and pulmonary venous pressures inducing perivascular edema in the small pulmonary arteries which in turn mechanically obstruct them. They further hypothesize that pulmonary venous hypoxia may help to induce such resistance changes, perhaps on a locally mediated, reflex basis. Other factors to be considered are the possible reactivity of a myogenic stretch reflex induced in the pulmonary arteries by a high pressure, high flow situation, and factors influencing thrombosis in the pulmonary tree. Theoretically, at some time after surgery, our patient could have been reoperated on and the pulmonary hypertension might have been reversed. Unfortunately, he was not thoroughly reevaluated until five years after this surgery, and at that time was found to have irreversible pulmonary vascular changes.

This patient's unfortunate outcome illustrates the great importance of careful follow-up of all patients who have undergone complete repair of tetralogy of Fallot and the need for repeat catheterization in the time when the clinical status is in doubt.

References

9. Sleeper JC, Orgain ES, McIntosh HD: Primary pulmonary hypertension. Review of clinical features and pathologic physiology with a report of pulmonary hemodynamics derived from repeated catheterizations. Circula-
Beryllium (Be), one of the most versatile metals known to metallurgy. Its prolific applicability, particularly in the form of alloys, is illustrated by partial listing of some of its uses: nuclear reactors; critical moving parts and inertial gyros for air crafts and submarines; radar insulators; missile, space vehicle and satellite structures, nose cones and optical parts; computers and other business machines; miniaturization of electrical and electronic devices; friction resistant products for power shift, clutch and brakes in trucks, mining equipment, farming machinery; high-temperature refractory material; nonsparking tools; nonmagnetic alloys; electrical relays; window material for x-ray tubes; camera shutters; precision instruments; fluorescent powders, lamps and radiotubes. The source of Be is beryl, a silicate of beryllium and aluminum, Be₃Al₂Si₂O₈. As a corollary it may be added that a variety of beryl of pure, intense green color is highly prized as a precious stone, emerald. First reports on beryllium disease appeared in the 1930s (Weber, HH et al, Zentralbl Gewerbehyg 10:41, 1933; Fabroni, SM, Med del Lavoro 26:297, 1935; Gelman, IJ, J Indus Hyg 18:371, 1936). Exposure to beryllium may occur in processing plants, handling Be, its compounds and alloys, ceramics containing Be, fluorescent lamps and neon signs. Acute pulmonary manifestations due to inhalation of these chemicals are considered a disease of hypersensitivity (Sterner, JH et al, Occup Med 4:123, 1951). Dyspnea is the presenting symptom. It may be noted a few days after exposure and is associated with unproductive cough and chest pain. In one to four weeks, x-ray films reveal diffuse, bilateral symmetrical haziness in the lungs, with subsequent irregular areas of light infiltration. After varying periods of latency, chronic form of the disease may be detected. Interstitial, granulomatous changes bring about alveolar-capillary block, with consequent low arterial oxygen tension. Initial fine, sand-like x-ray appearance of the lung fields is followed by widely distributed coarse nodules which closely resemble those seen in miliary tuberculosis. This may be followed by reticular fibrosis, pulmonary hypertension and cor pulmonale. Scheppers (in Advances in Cardiopulmonary Diseases, 1:96, 1963) states that experimental studies with Be compounds established sequential relationship between alveolar epithelization caused by these compounds and certain types of lung cancer. Since 1950 preventive measures have been carried out in the United States limiting in-plant exposure to 2 gamma per cubic meter throughout an eight-hour day and to 25 gamma per cubic meter for any period, however short. Thus, according to the highly authoritative conclusions of Van Ordstrand (Postgrad Med 36:499, 1964; personal communication, 3-10, 1972) berylliosis has been essentially eliminated as a health hazard both inside and outside of the producing and refining areas.

Andrew L. Banyai, M.D.