Pulmonary Artery Banding

A Treatment for Infants with Intractable Cardiac Failure due to Interventricular Septal Defects

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Infants born with interventricular septal defects may encounter little difficulty during the first year of life. Although a number develop varying degrees of cardiac failure, most of these respond to digitalization so that by the end of the first year retarded growth and cardiac failure are no longer significant problems. A few, however, within the first weeks of life, develop cardiac failure that is refractory even to vigorous medical therapy. They are likely to die early and suddenly. Surgical management of this type of case is the subject of this report.

Ideal treatment for these infants should be closure of the interventricular septal defect. Unfortunately, they are poor candidates for open-heart surgery. Reported results indicate an unfavorable prognosis in those under 2 years of age so treated. Even in experienced hands mortality is 40 per cent or higher. There are no reports of such a series in infants under 1 year of age, but the mortality would probably be higher. What is needed, then, is a relatively simple operation to tide the child over this critical period so that curative surgery can be accomplished at a later date.

Muller and Dammann, basing their technic on the experimental work of Holman and Beck, and Hufnagel, Roe, and Barger reported the production of pulmonary stenosis by wedge and suture of the pulmonary artery. Inasmuch as the patients were desperately ill and the operations extensive, mortality was 50 per cent. Their technic has been modified by us so that it consists of merely banding the base of the pulmonary artery with tape.

In the case of a large interventricular septal defect, the separate ventricles with a free communication act in many ways as a single chamber. Ordinarily vascular resistance is low in the pulmonary and high in the systemic circulation. Thus, most of the blood makes its way into the circulation of low resistance, i.e., the pulmonary circulation.

By placing a band around the main pulmonary artery, flow in the lesser circulation is impeded. Hence, excessive flow through the lungs, which leads to cardiac decompensation, is diminished. In addition, buildup of pressure within the pulmonary circuit, which may lead to increased pulmonary resistance with ensuing vascular changes, is prevented.

Twenty infants with interventricular septal defects producing intractable cardiac failure have had banding of the pulmonary artery. Their ages ranged from 3 weeks to 18 months. All but two were under 6 months of age. All were extremely ill, dyspneic, underdeveloped babies. Repeated respiratory infections were common, and treatment of bronchiolitis and pneumonitis was difficult because of concomitant cardiac failure.

The diagnosis of interventricular septal defect was suspected in each because of the presence of a rough systolic murmur, cardiomegaly, hepatomegaly, and splenomegaly associated with radiologic evidence of plethoric lung fields. The electrocardiogram showed either right or combined ventricular hypertrophy. Cardiac failure and respiratory infection were treated intensively. As soon as infection was controlled, cardiac catheterization was performed to confirm the diagnosis. In each instance, large left-to-right shunts

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were found at the ventricular level and pulmonary hypertension was invariably present. Although an initial improvement usually followed the administration of digitalis and diuretics, cardiac failure could not be completely controlled. Even with the most vigorous medical treatment, these patients remained in moderate to severe cardiac failure. Only under such circumstances were patients considered for surgery.

Technic

With the infant supine or rotated slightly to the right, the left hemithorax was entered through an anterolateral incision in the third or fourth interspace. Patent ductus arteriosus was excluded by appropriate exploration.

The pericardium was opened widely to expose the right ventricle and pulmonary artery. The left atrial appendage was moved aside and the grooved indentation between the base of the pulmonary artery and aorta was found with the tip of a Mohnihan clamp. At this point only two layers of visceral pericardium separate the vessels so that the clamp was easily passed around the pulmonary artery at its base. Umbilical tape was placed to encircle the pulmonary artery and the ends were passed through a Rummel tourniquet (fig. 1A).

Nineteen-gage needles attached to transducers were introduced into both the pulmonary artery and right ventricle for continuous monitoring of pressures. With the aid of the Rummel tourniquet, the tape was tightened (fig. 1A) gradually until pressure in the pulmonary artery dropped to slightly above normal limits and the pressure curve showed some flattening. Simultaneously the right ventricular pressure increased to approximately that of the left ventricle (fig. 2). The heart was watched closely during this process, since excess tightening is reflected by slight dilatation of the right ventricle, abrupt slowing, and weakening of the heart. If this occurred, the tourniquet was released, the heart was allowed to recover, and the procedure was repeated. An acceptable degree of stenosis was usually reflected by a slight decrease in size of the right ventricle with little change in cardiac rate. If marked elevation of pulmonary vascular resistance has already occurred, the changes in pressure which can be accomplished are much less conspicuous and should not be pursued over-zealously. A small gradient with flattening of the pulse wave may be accepted under such circumstances.

Once the desired gradient was achieved, the tape was fixed in position by ligating it with silk between the tip of the metal tourniquet and the pulmonary artery. On removal of the tourniquet, the tape was permanently fixed with silk sutures (fig. 1B). Occasionally on removal of the tourniquet the tape slipped. This was recognized immediately by a rise in the pulmonary artery pressure. When slipping occurred, additional narrowing was accomplished by placing another suture in the tape to tighten it. The band having been fixed at the correct degree of stenosis, the excess tape was cut off, leaving the ends a quarter of an inch long to facilitate removal at a later date. It should be noted that the band was placed at the base of the pulmonary artery so that no chamber intervened between the pulmonary valve and the band. The vessel was constricted from 60 to 80 per cent of its original diameter in order to effect adequate diminution in pressure distal to the constriction.

Typical Case History

This white baby boy (M.H., L.S.U. 58-307144) was born by spontaneous delivery following an uncomplicated pregnancy. No abnormality was noted until 7 weeks of age, when he was treated...
by his family physician for an upper respiratory infection and a murmur was noted.

At the age of 3 months he developed another respiratory infection. The murmur was noted to be louder, the pulse rate was very rapid, and the liver was enlarged. The child was digitalized, but did not improve, so he was sent to the hospital.

Physical examination revealed a poorly nourished boy in obvious respiratory distress. The pulse and heart rate were 140 per minute, and the respirations were 100 per minute and grunting with intercostal retraction. Loud sibilant, bubbling and crepitant rales as well as coarse rhonchi were heard throughout both lung fields. There was a thrill as well as a grade II to III harsh, systolic murmur along the left sternal border, loudest at the fourth intercostal space. The apex beat was palpable in the anterior axillary line.

The liver was palpable at the level of the umbilicus. The spleen and kidneys were palpable. The femoral pulses were normal. Physical examination was otherwise normal. The clinical impression was interventricular septal defect with pulmonary hypertension and congestive failure.

He improved with digitalis and antibiotic therapy and was discharged.

He was readmitted at the age of 6 months with a story of repeated bouts of upper respiratory infections and frequent cyanosis with crying.

Physical examination revealed an underweight infant with cardiomegaly, hepatomegaly, and splenomegaly, pulse rate of 120 and respiratory rate of 35 per minute. A grade II to III harsh systolic murmur was heard best in the fourth and fifth left intercostal spaces and it was transmitted to the left and back toward the angle of the scapula. Other than mild otitis media, the remainder of the physical examination was normal.

While awaiting cardiac catheterization, the child developed severe bronchiolitis and congestive failure that responded to treatment.

Data from cardiac catheterization were compatible with interventricular septal defect with a large left-to-right shunt. The pulmonary blood flow was calculated to be $3\frac{1}{2}$ times the systemic flow. There was also pulmonary hypertension.

He again developed pneumonitis and congestive failure 1 week later and gradually responded to

**Figure 2**

Typical pressure tracings before and after pulmonary artery banding. Note rise in left ventricular pressure after banding.
Typical growth curves. Note rapid upswing in curve after banding of pulmonary artery.

On March 3, 1959, surgery was performed following the technic described. Pressures measured prior to banding were 95/0-15 in the right ventricle and 60/15 in the main pulmonary artery. Aortic pressure was 100/50. At the conclusion of the procedure pressures were 110 to 115/0-6 in the right ventricle and 40/20 in the pulmonary artery.

Postoperatively the child was overtransfused through error and developed severe pulmonary edema, necessitating phlebotomy. Otherwise his postoperative course was uneventful. Five weeks after operation he had gained over 3 pounds in weight and had had no evidence of respiratory difficulties since discharge. He continued to do well and gain weight. He had experienced one or two mild episodes of upper respiratory infection but no serious illness and no cyanosis. Digitalis was discontinued. He was last seen 1 year after surgery and was doing well, with no evidence of failure and no further attacks of respiratory disease.

Results

Of 20 infants subjected to banding of the pulmonary artery, one died a few hours after operation due to unrecognized bleeding from the chest wall. Another died at home 2 months after operation following an acute illness. There was no autopsy, and the cause of death was not determined. Through error in pressure reading insufficient stenosis was produced in one infant so that rebanding was necessary 3 weeks after the first attempt. His subsequent convalescence was uneventful.

The postoperative course of the survivors has been remarkably smooth and the early change has been striking. The precordial heave...
has usually diminished or disappeared at once. Within a few days the liver, which preoperatively had usually been quite large, has decreased in size until hardly palpable.

In a few, cardiac failure, which had been intractable prior to operation has completely disappeared within 2 weeks. In the remainder, failure has been easily controlled with digitalis and, after a period of readjustment of weeks to a few months, the drug has been stopped.

After a stabilizing period of about 3 months, the babies have made rapid strides until attaining a normal growth curve (fig. 3). There were two sets of twins and in each set, one twin was normal while the other required banding. After operation, both have caught up with their counterparts in height, weight, and activity.

Indications are that these children do well for approximately 3 to 5 years, then evidence a right-to-left shunt, and show the typical picture of a mild tetralogy of Fallot. When this occurs, the septal defect should be closed and the size of the pulmonary artery restored.

Discussion

To do a temporizing procedure when it is technically feasible to do a curative one may seem old fashioned. We believe, nonetheless, that the very low mortality associated with banding of the pulmonary artery, even though the infants are tiny and have intractable cardiac failure, makes the procedure attractive. The children come out of failure, grow, and approach the status of a standard risk for closure of the interventricular septal defect. Anticipated adhesions will admittedly make the definitive operation more difficult and possibly increase morbidity and mortality. Experimental work, however, has indicated that removal of the band and restoration in size of the pulmonary artery are not formidably, so that the mortality from the two operations should be less than that from initial septal closure in these critically ill babies. An insufficient number of bands have been removed and defects closed to draw conclusions about comparative mortality.

Summary

The technique of banding the pulmonary artery is described.

Twenty infants with intractable cardiac failure secondary to interventricular septal defects have had banding with one operative and one late death.

The operation is palliative, and definitive surgery probably must be done when the child is 3 to 5 years of age.

Banding the pulmonary artery is a relatively safe procedure but the mortality of banding plus ventricular closure and unbanding remains to be evaluated.

References


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