Pulmonary Artery Banding in Infants with Congenital Heart Defects Other than Ventricular Septal Defect

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MANY CONGENITAL heart defects are not correctable by present surgical technics. Large systemic to pulmonary shunts with resulting pulmonary plethora are a frequent cause of early death in these infants. The observation that some patients with anatomically similar defects survive for several years, and the ever present hope that developments in surgical technic will allow correction of these defects, stimulate interest in surgical methods of prolonging the life of infants who otherwise will die in the first few months of life. Pulmonary artery banding has been carried out in a small group of desperately ill infants with large systemic to pulmonary intracardiac shunts and experience with these patients is the subject of this communication.

Materials and Methods

Data from 12 patients are recorded in Table 1. The oldest patient in the series was eight months and the youngest six weeks. In all patients development was slow, and weights at the time of operation were all below the third percentile.

From the listed anatomic diagnoses (Table 1) it is apparent that these lesions are not correctable at present. The anatomic and physiologic criteria for the diagnosis of the Taussig-Bing Complex are discussed in another communication.7

The clinical picture encountered in this group of infants was uniform. There was universal failure to gain weight in the neonatal period, and nine of the 12 infants were cyanotic when crying. The mothers almost invariably noted that the infants’ respiratory rate appeared to be more rapid than normal. Respiratory infections were common and when seen at the Children’s Hospital all patients were or had been in clinical cardiac failure requiring digitalization. A diagnosis was established in each infant by cardiac catherization and angiocardiography. The physiologic feature common to all infants in this group was a large systemic to pulmonary shunt. The size of this shunt when it could be calculated even roughly from the available data is listed in Table 1.

All patients were critically ill at the time operation was carried out. Although an attempt was made to achieve maximum benefit of medical treatment for respiratory infection and failure prior to operation, 10 of the 12 infants were in oxygen at the time of operation. Operation was carried out as an emergency in three patients and in several others was semi-emergent. It was the opinion of all observers that these infants could not survive for more than a few weeks without surgical intervention. An indication of the severity of the clinical condition of this group of patients is the fact that several infants died between the time the decision to perform pulmonary banding was made and the operation attempted (never more than a few days).

In ten infants the operation originally planned was pulmonary artery banding. In nine, the pulmonary artery was constricted using umbilical tape sutured to itself at the point of constriction. In one patient (No. 12) the pulmonary artery was constricted by sewing

pledges of Teflon felt to sutures through the pulmonary artery. In the remaining two infants a pulmonary band was removed after exploration of the cardiopulmonary bypass anomaly could not be corrected (No. 9) enlargement of the using inflow occlusion was banding. In the procedures entered banding was planned opened through a short fourth interspace thoracotomy incision which has not been accomplished in the two patients operate pulmonary bypass the midline incision has been employed throughout this incision is excised to the midline incision is excised by entering the ductus of the pulmonary artery to umbilical tape around it to Valsalva is ordinarily not the abnormal arrangement in these infants makes mandatory. Significant hemodynamic abnormalities in the pulmonary artery were encoun-

Results

The results obtained in 12 patients in Table 1. Six infants failed to survive postoperative period died of pulmonary blood flow or band placement developed cardiac arrest when band was applied to the heart and effective heart beat could not be restored. Three patients died several hours without ever appearing to experience cardiac output. One infant a died by operation but death occurred during a sudden respiratory distress. At autopsy banding appeared to be effective for the sudden clinical condition was recognized.
Six patients survived the immediate postoperative period. Patient 5, a child with the Taussig-Bing Complex, underwent pulmonary banding at two months of age and seemed to be clinically improved for a short period of time. He continued to have episodes of pulmonary infection and died 20 months after operation with extensive bronchial pneumonia. Patients 4 and 6 have been followed for 25 and 18 months, respectively, since operation. Both are improved clinically with increasing exercise tolerance and freedom from respiratory infections. Neither has gained weight normally. However, both show x-ray evidence of decreased heart size and marked decrease in pulmonary vasculature when compared with preoperative x-rays. Patient 10 has been followed for seven months after operation and although her weight gain has not been normal she is also improved clinically and there has been a decrease in cardiac size and pulmonary vascularity on chest x-ray. Patients 11 and 12 have been followed for three months only. Patient 11 appears to have an increase in exercise tolerance and has gained four pounds in the three months since operation. There seems to be some diminution of vascularity by chest x-ray but this is not striking. Patient 12 has not shown any change in chest x-ray and his clinical course suggests that the degree of pulmonic stenosis is less than optimum. Reoperation has been discussed but has not been accepted by the parents. It is possible that as the patient grows the pulmonary constriction will become more effective as it becomes relatively more marked.

**Discussion**

Partial constriction of blood vessels was studied by Halsted and Reid using various methods of producing permanent partial constriction of the aorta. The history of attempts to partially constrict vessels and the problems encountered in these attempts has been reviewed by Clatworthy et al. Experimental constriction of the pulmonary artery by excision of a portion of the wall was reported by Muller and Dammann, and experimental production of infundibular pulmonic stenosis was reported by Sabiston. Albert et al. produced pulmonic stenosis in dogs using umbilical tape banding and reported the re-
### Table 1. Preoperative Findings

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age at operation (mo.)</th>
<th>Diagnosis*</th>
<th>Systemic to Pulmonary Weight** Systemic to Pulmonary Blood Flow***</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. S.F.T.</td>
<td>8</td>
<td>Truncus arteriosus</td>
<td>12 (18) 8 (12) 2:1</td>
<td>Attempted banding. Cardiac arrest on constricting PA. Banding. Constriction to tolerance of heart.</td>
</tr>
<tr>
<td>3. D.B.P.</td>
<td>2</td>
<td>Incompl. transpos. of great vessels, VSD (Taussig-Bing)</td>
<td>6 (12) 8 (12) 4:1</td>
<td>Banding. PA narrowed to smaller diameter than aorta, 20% drop in distal PA O₂ saturation. Banding. PA diameter equal to aorta. Further constriction poorly tolerated. 10% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>4. M.C.J.</td>
<td>2</td>
<td>Incompl. transpos. of great vessels, VSD (Taussig-Bing)</td>
<td>6 (11) 8 (12) 4:1</td>
<td>Banding. PA narrowed to smaller diameter than aorta, 20% drop in distal PA O₂ saturation. Banding. PA diameter equal to aorta. Further constriction poorly tolerated. 10% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>5. B.A.P.</td>
<td>2</td>
<td>Incompl. transpos. of great vessels, VSD (Taussig-Bing)</td>
<td>9 (12) 6 (12) 3:1</td>
<td>Banding. PA narrowed to smaller diameter than aorta, 20% drop in distal PA O₂ saturation. Banding. PA diameter equal to aorta. Further constriction poorly tolerated. 10% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>6. J.K.S.</td>
<td>4</td>
<td>Transpos. of great vessels, single ventricle.</td>
<td>6 (14) 8 (14)</td>
<td>Cardiomyotomy using cardiopulmonary bypass. PA banded to diameter of aorta. Banding. PA reduced 50% from original diameter, 20% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>7. R.A.M.</td>
<td>7</td>
<td>Transpos. of great vessels, single ventricle.</td>
<td>(19) 3:1</td>
<td>Banding. PA reduced 50% from original diameter, 20% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>8. M.L.H.</td>
<td>8</td>
<td>A. V. communis with single AV valve, PDA hypoplastic descending aorta</td>
<td>8 (20) 13 (20) 5:1</td>
<td>Banding and enlargement of ASD. Pulmonary artery constricted to diameter of aorta. Banding. PA diameter equal to aorta. 40% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>9. W.G.H.</td>
<td>2</td>
<td>Transpos. Tricuspid atresia, ASD</td>
<td>10 (12) 3:1</td>
<td>Banding and enlargement of ASD. Pulmonary artery constricted to diameter of aorta. Banding. PA diameter equal to aorta. 40% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>10. M.L.B.</td>
<td>5</td>
<td>A. V. communis</td>
<td>7 (14) 4 (14) 5:1</td>
<td>Banding and enlargement of ASD. Pulmonary artery constricted to diameter of aorta. Banding. PA diameter equal to aorta. 40% drop in distal PA O₂ saturation.</td>
</tr>
<tr>
<td>11. S.B.</td>
<td>7</td>
<td>Transpos. Single ventricle</td>
<td>13 (18) 8:1</td>
<td>Cardiomyotomy using cardiopulmonary bypass. PA banded to size of aorta. Distal PA pressure 25 mm. Hg. Pulmonary artery lumen reduced by teflon pledges sutured together. Diameter reduced to less than aorta.</td>
</tr>
<tr>
<td>12. T.G.B.</td>
<td>5</td>
<td>Single ventricle</td>
<td>9 (17) 7 (17) 3:1</td>
<td>Cardiomyotomy using cardiopulmonary bypass. PA banded to size of aorta. Distal PA pressure 25 mm. Hg. Pulmonary artery lumen reduced by teflon pledges sutured together. Diameter reduced to less than aorta.</td>
</tr>
</tbody>
</table>

*Diagnosis established by catheterization, angiocardiology, and operative findings or autopsy.

**Weights in parenthesis are predicted normals.

***Calculated with assumed oxygen consumption in most instances.

The results of operations to release this pulmonic constriction.1

Blalock discussed the possibility of producing pulmonic stenosis in the treatment of congenital heart disease in 1950 and Muller and Dammann reported the first successful production of pulmonic stenosis in the treatment of congenital heart disease.3, 10 Albert et al., Muller and Dammann, and Morrow and Braunwald have subsequently reported series of patients with congenital heart disease treated by production of pulmonic stenosis 2, 9, 11 Most patients reported have had ventricular septal defects and the results in this group of patients have been promising. One problem in the production of pulmonic stenosis is in determining which small in ameter was encount ered which small in ameter produced...
Postoperative Course

<table>
<thead>
<tr>
<th>Follow up (mos.)</th>
<th>Clinical Condition</th>
<th>X-ray</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Improved respiratory status, poor weight gain.</td>
<td>Reduced heart size &amp; pulmonary vascularity</td>
<td>Died 5 hrs. postop after continued respiratory distress.</td>
</tr>
<tr>
<td>20</td>
<td>Initial improvement followed by repeated episodes of pneumonia and death.</td>
<td>Moderate decrease in heart size.</td>
<td>Died</td>
</tr>
<tr>
<td>18</td>
<td>Improved general condition, poor weight gain.</td>
<td>Reduced heart size &amp; pulmonary vascularity</td>
<td>At autopsy banding seemed effective (PA over one-half constricted)</td>
</tr>
<tr>
<td>6</td>
<td>Improved.</td>
<td>Decrease in heart size &amp; pulmonary vascularity</td>
<td>Sudden death 48 hours postoperatively.</td>
</tr>
<tr>
<td>3</td>
<td>May be improved.</td>
<td>Some decrease in pulmonary vascularity.</td>
<td>Died several hours after operation. Operation complicated by hemorrhage.</td>
</tr>
<tr>
<td>3</td>
<td>Unchanged.</td>
<td>No change.</td>
<td>Died shortly after procedure. Technical difficulty during operation.</td>
</tr>
</tbody>
</table>

and operative findings or autopsy.

and Morrow and subsequently reported series with congenital heart disease such as the effects of pulmonary stenosis. Mann et al. studied the effects of constriction of blood vessels on flow, and found that little change in flow through the vessel was encountered until the external diameter was reduced about 40 per cent, following which small increments of decrease in diameter produced marked changes in flow. The problem encountered in patients with functional single ventricle is complicated by the presence of an alternative route of blood flow. Moedjono et al. have reported studies of the murmur produced by acute pulmonary artery constriction in the dog and concluded that the murmur produced by gradual constriction of the pulmonary artery increases up to approximately 40 per cent reduction of lumen. Beyond this point changes in the murmur varied. Morrow and Braunwald have measured the pressure simultaneously in the...
right ventricle and pulmonary artery and depended upon production of a pressure gradient to determine the desirable degree of pulmonary banding. They have reduced pulmonary arterial pressure 30 to 40 per cent and produced a right ventricular to pulmonary artery gradient of about 50 mm. Hg. This has usually been attained when the pulmonary artery was reduced approximately two-thirds in diameter. These authors mentioned the use of ear oximetry but abandoned the method because of technical difficulties. We have used several methods of determining the optimum degree of pulmonary artery banding. Initially the pulmonary artery has been constricted to a diameter equal to or slightly smaller than that of the aorta. A palpable thrill in the pulmonary artery distal to the constricting band has been achieved in all instances. We have not used pressure measurements extensively for several reasons. One of these is the widely known objection to the use of pressure as an estimate of flow, and in these critically ill infants there was always considerable doubt about the cardiac output (systemic pressure was not being monitored). In addition, we have been reluctant to insert a needle into the right ventricle in many irritable hearts. Nevertheless, the results reported by Morrow and Braunwald are excellent and their method may well be the most practical technic provided its limitations are understood. In several patients we have measured oxygen saturation in the distal main pulmonary artery before and after production of pulmonic stenosis. A drop in pulmonary saturation of 20 to 40 per cent has been considered satisfactory, but the data are not sufficiently complete nor the series sufficiently large to fully evaluate this method of judging the optimum degree of pulmonary artery constriction.

In discussing the results obtained it seems necessary to mention the selection of patients for operation. The criteria for advising operation in these patients was the demonstration of a large systemic to pulmonary shunt in an infant whose clinical condition indicated that pulmonary plethora was likely to limit survival to a few days or weeks. Even in retrospect we are not able to pick out clinical or physiological features which would separate the patients who succumbed from those who survived. The technical operative procedure seems to be important and it may not be coincidental that the first three experiences with this procedure were unsuccessful. In Patient 9 technical difficulties at operation very clearly contributed to the unsatisfactory outcome and in Patient 8 the procedure was slightly prolonged and more complicated than usual. In both patients blood loss occurred which would not ordinarily seem excessive but was poorly tolerated by these patients. Unfortunately we are not able to correlate the degree of pulmonary artery constriction with success or failure in this series of patients. In one patient the constriction is clearly inadequate in degree. It is obvious that the results reported are preliminary and that a longer period of follow up will be necessary to evaluate the place of this procedure. We are, however, encouraged that a number of these patients can survive operation with moderate improvement for periods at least up to two years.

Summary

1. Twelve patients with congenital heart defects other than ventricular septal defects have had surgical constriction of the pulmonary artery.
2. In all infants the principal physiologic defect was a large systemic to pulmonary intracardiac shunt.
3. The clinical condition of all patients made it seem unlikely that they would survive for more than a brief time.
4. Six patients survived operation and the immediate postoperative period, and five are alive at periods ranging from three to 25 months.
5. The ultimate evaluation of this procedure depends upon accumulated experience over a longer period of time as well as the development of operative procedures of lasting benefit for this type of congenital heart lesion.

References


Curvatures of the Spine.
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This contribution to curvature of the spine i many years’ experience. approach to the treatme spines is a conservative on tions of the mechanics an patient are those of the terpretation. For the most part the neulous clinical entity orthopaedic surgeons hav
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Book Review

Curvatures of the Spine. Emil D. W. Hauser,
M.S., M.D.; Springfield, Illinois. Charles C
Thomas.

This contribution to the understanding of
curvature of the spine is made by a man of
many years' experience. Basically, the author's
approach to the treatment of curvatures of the
spine is a conservative one. Many of the descrip-
tions of the mechanics and changes in a scoliotic
patient are those of the author's individual
interpretation.

For the most part the book deals with the
nebulous clinical entity which, over the years,
orthopaedic surgeons have referred to as idio-
pathic scoliosis. The author defines this as a
metabolic scoliosis resulting from a functional
decomposition of the back. Both of these terms
are defined at some length, but they cannot be
defined with exactness since they are generalities.

The information available in the text is cer-
tainly "food for thought," but this reviewer
cannot recommend this text to the general field of
those who might encounter scoliotic patients,
due to the fact that it represents an approach to
the treatment of curvature of the spine which is
controversial. It is recommended for those who
are constantly working with scoliosis in the
hope that it may broaden their views of this
entity.—A. Gibbon Packard, Jr., M.D.