Intrapericardial Aortico-Pulmonary Artery Shunt

By S. Frank Redo, M.D., and Roger R. Ecker, M.D.

SYSTEMIC artery to pulmonary artery shunts for the alleviation of cyanotic heart diseases, especially tetralogy of Fallot, have utilized essentially the Blalock-Taussig\textsuperscript{1} or the Potts\textsuperscript{2, 3} techniques. More recently Glenn\textsuperscript{4, 5} has advocated anastomosis of superior vena cava to right pulmonary artery in side-to-end fashion for patients with certain cyanotic heart conditions. A shunt between the ascending aorta and the right or left main pulmonary artery via a branch of the pulmonary artery itself or with an interposed segment of prosthesis was reported in 1962 by Shumacker and Mandelbaum.\textsuperscript{6} Sirak and Hosier\textsuperscript{7} utilized an aortic homograft covered with a sleeve of seamless Dacron cloth over each end to create an artificial ductus for decompression of the pulmonary artery in patients with ventricular septal defect associated with severe pulmonary hypertension. The Blalock-Taussig and Potts procedures have been more extensively employed and are generally satisfactory. With the advent of open-heart surgery, shunting procedures lost popularity initially. It soon became apparent, however, that many severely cyanotic children, including those with well-authenticated tetralogy of Fallot, although in need of corrective surgery, might not tolerate complete correction. Attention was then redirected to shunting procedures for palliation and also as preparation for subsequent totally corrective procedures employing extracorporeal circulation. In addition, a large number of infants too young or small to undergo open-heart surgery may require a shunting procedure.

In this latter group our experience indicated that frequently the branches of the main pulmonary artery were too small to be used successfully for Blalock-Taussig or Potts operations or for the Glenn procedure. We therefore directed our attention to devising still another type of shunting procedure that might be applicable in small patients or those with very small pulmonary arteries, as demonstrated by angiocardiography, and that might deliver blood to the main pulmonary

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{figure1.png}
\caption{Artist's drawing of operation. At upper left the aorta has been encircled with a heavy ligature and is retracted to the right. The small pulmonary artery lies posterior and to the left. In the upper right sketch the pulmonary artery has been occluded, opened, and the anastomosis with the prosthesis begun. The lower left drawing shows the partially occluding clamp on the aorta and the start of the aortico-Teflon Anastomosis. At the lower right the prostheses is shown after completion of the aortic and pulmonary artery anastomoses.}
\end{figure}

From The New York Hospital-Cornell Medical Center, Department of Surgery, New York, New York. Supported in part by a grant from the New York Heart Association and by Grant H-4131 (C), U. S. Public Health Service.

Circulation, Volume XXVIII, October 1963
artery in order to enlarge that structure over a period of time. This report describes the development of such a procedure in the laboratory and the results of the clinical application of the operation in six patients.

Materials and Methods

The operations to be described were performed in 15 mongrel dogs weighing 12 to 30 Kg. These were anesthetized with pentobarbital, and positive-pressure respiration was used. Exposure was through the third intercostal space on the left side. The operation consisted in creating a shunt between the aorta and the pulmonary artery inside the pericardium.

In five dogs a direct aortico-pulmonary artery shunt was created by anastomosing the aorta to the pulmonary artery in side-to-side fashion, with use of partially ocluding clamps on these vessels. This technic was unsatisfactory, however, because the clamps were awkward to apply and the anastomosis was difficult to make. All these animals died soon of bleeding. An intrapericardiae aortico-pulmonary artery shunt was then made in 10 dogs with use of a woven Teflon prosthesis 3/16 inch in diameter to bridge the gap between the vessels in end-to-side fashion. Postoperatively the animals received penicillin for 5 days.

Detailed Description of Operation (with Use of a Teflon Prosthesis)

After entering the left chest, the pericardium was opened widely. Dissection was carried out between the aorta and the pulmonary artery intrapericardially (fig. 1). A partially ocluding clamp was then applied to the pulmonary artery and a 3/16-inch Teflon graft was sutured to this structure in end-to-side fashion using 00000 silk on an atraumatic needle. Following this the clamp on the pulmonary artery was released. A non-crushing clamp was then applied to the graft just proximal to the line of anastomosis. The opposite end of the graft was then sutured to the aorta by a similar technic. In both instances the anterior and posterior anastomoses were performed with continuous sutures. After release of the clamp on the aorta, the clamp on the graft near the pulmonary artery was released. A strong thrill in the pulmonary artery indicated patency of the shunt.

Figure 2

A. Retrograde aortogram in experimental animal. The arrow points to the aortic end of the prosthesis with contrast material as it curves downward toward pulmonary artery.

B. A later phase in the angiogram. The arrows indicate the shunt. Note that the aorta and pulmonary artery are well visualized and simultaneously filled.

Circulation, Volume XXVIII, October 1963
Results

Two of the 10 dogs died of bleeding. The remaining eight survived without evidence of cardiac failure and appeared normal. There were no thromboembolic phenomena in any of the survivors. Examination of the graft in animals killed up to 6 months later revealed it to be smooth-lined, patent, and free from clots. One dog is being observed as a long-term survivor. Retrograde aortogram in this animal after 1 year revealed the shunt to be patent (fig. 2). Pulmonary artery pressure at that time was 35/15 with a right ventricular pressure of 32/5 mm. Hg. This animal has shown no untoward cardiac or pulmonary effects of the operation.

Clinical Experience

After this experience in the dog, the operation was performed in six patients. These ranged in age from 2 months to 14 years. Five had tetralogy of Fallot and the sixth was a 2-month-old girl with transposition of the great vessels, tricuspid stenosis, and a patent foramen ovale.

The first patient was an 11-month-old girl with a hematocrit value of 84. In her, the graft, which was 2/16 of an inch in diameter, apparently thrombosed in 3 or 4 days. In the five remaining patients, the shunts functioned well. The longest follow-up is in a 5-year-old boy with a nonfunctioning Blalock-Taussig anastomosis who was admitted with a hematocrit value of 76. A shunt was made with a prosthesis 4/16 of an inch in diameter (fig. 3). He was markedly improved following surgery and has continued well and active, the hematocrit level 10 months later being 50 per cent.

Changes in his pulmonary vasculature can be seen in conventional chest x-rays. Whereas he had been almost chair-bound before surgery, he is now very active. A loud to-and-fro murmur is apparent on a phonocardiogram (fig. 4). There has been no evidence of cardiac failure.

A 3/8-inch prosthesis was employed in making the shunt in the oldest patient, a 14-year-old girl with tetralogy of Fallot. Despite this large shunt, she has done well without evidence of cardiac decompensation. Only in the infant 2 months of age was it necessary to use digitalis postoperatively.

Discussion

The operation described has been successfully applied in dogs and has proved to be of benefit to cyanotic patients. In patients, it has been performed through a midline sternotomy incision. In all but one case the main pulmonary artery was occluded proximally at its origin and distally close to its bifurcation to permit excision of a button of pulmonary artery at the site of construction of the anastomosis with the graft. In one case it was necessary to apply a partially occluding clamp on the pulmonary artery, but this was not difficult technically.

The operation is more easily performed than the Blalock-Taussig or Potts procedure. It may have advantages over these two operations: (1) blood delivered into the main pulmonary artery should lead to enlargement of...
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this structure; (2) the shunt is easily accessible for interruption when subsequent complete correction (in cases of tetralogy of Fallot) is carried out; (3) the main pulmonary artery rather than one of its branches is used for the anastomosis, and this is usually a larger vessel, especially in infants; (4) the operation is performed through a midline sternum-splitting incision so that entry into a pleural space is avoided. Thereby pulmonary complications are decreased and interference with important collateral bronchial blood vessels is avoided.

The disadvantages of the procedure are, first, that the pericardium must be entered. This may lead to fibrosis which may make subsequent cardiac surgery more difficult. However, this objection must be weighed against the difficulty in interrupting a Blalock-Taussig or Potts anastomosis at the time of open-heart surgery. Second, a foreign body is used. This objection cannot be discounted but is less worrisome in light of the number of patients in whom vascular prostheses have been placed without serious consequences.

In small infants it may be necessary to use grafts 2/16 of an inch in diameter, although those with a diameter of 3/16 or greater are preferable in older children. When small grafts are used, subsequent operation will undoubtedly be required. This is true, however, even when a Blalock-Taussig or Potts procedure is employed in very young patients.

The operation described should carry no more risk than a Blalock-Taussig or Potts procedure. It is considered to be another, perhaps better, method for increasing pulmonary blood flow in cyanotic infants and children.

Summary

An operative procedure for the creation of an aorticopulmonary artery anastomosis with use of a Teflon prosthesis was developed.

After laboratory trial in animals, the operation was performed in six patients varying in age from 2 months to 14 years. In all but one instance the shunt remained patent. The longest observation in dogs is 111/2 years. In this animal the shunt has remained open and there has been no evidence of pulmonary or cardiac embarrassment.

One child, 5 years of age, has lived 10 months after the operation. He has had marked improvement in his cyanosis and club-

Figure 4

Phonocardiogram 3 weeks after surgery. There is a continuous murmur at the second left interspace.
bing, his hematocrit value remains less than 50 per cent, and he is generally well.

The operation should carry no more risk than a Blalock-Taussig or Potts procedure and is thought to be another, perhaps better, method for increasing pulmonary blood flow in cyanotic infants and children.

Acknowledgment

We wish to thank Dr. Mary Allen Engle and Dr. Henry P. Goldberg, Pediatric Cardiologists at The New York Hospital-Cornell Medical Center, for their interest in this procedure and their help in the management of the patients.

References


Congenital Heart Disease

Cardiac malformations have been noted since the first treatise devoted to heart disease, Senac's *Traité de la structure du coeur, de son action et ses maladies*, published in 1749, in which a case of complete absence of the interventricular septum was recored, the cyanosis being explained as due to admixture of venous and arterial blood, and the time of Morgagni (1761), who reported pulmonary stenosis and ascribed the cyanosis to venous stasis. Bouillaud (1835) recognized the two origins—arrest of development and foetal endocarditis; Hope (1834) believed that far the most frequent cause was a defect or premature cessation in the process of development, but it was not until 1906 that the cause of congenital heart disease was shown by Keith to be due, in the majority of cases, to an arrest of development of the bulbus cordis, and not to foetal endocarditis, as suggested by Kreysig (1817) and urged by Rokitansky. The morbid anatomy of congenital heart lesions was specially investigated by Louis, Bouillaud, Peacock (1858), Rokitansky (1875), and Maude Abbott (1908).—Sir Humphry Davy Rolleston. *The Harveian Oration*. Great Britain, Cambridge University Press, 1928, p. 38.
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Circulation. 1963;28:520-524
doi: 10.1161/01.CIR.28.4.520

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/28/4/520

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