Postoperative Angiographic Assessment of Modified Blalock-Taussig Shunts Using Expanded Polytetrafluoroethylene (Gore-Tex)


ABSTRACT Thirty-six of 87 modified Blalock-Taussig shunts done with expanded polytetrafluoroethylene (Gore-Tex) were restudied angiographically. In 7 patients the study was carried out within 1 month of the shunt operation because the patients failed to make satisfactory clinical progress. Two shunts were occluded and 1 was stenosed; all 3 were in neonates. The remaining 29 patients were reinvestigated electively between 5 and 29 months postoperatively and had a 97% shunt patency rate. Because of the rather high incidence of irregular or stenosed shunts among neonates with 4 mm conduits, we now prefer to use a larger conduit even in this age group.

A subclavian–pulmonary artery shunt constructed on the side opposite the aortic arch offers the best palliation among the various systemic–pulmonary artery shunts. However, when the anatomy is considered unsuitable for direct anastomosis between the subclavian and pulmonary arteries, classic shunt operations have been accomplished only with a substantial risk of failure [9, 12] or later development of pulmonary vascular disease [16] and distortion of the pulmonary arteries [17, 19]. Since April, 1975, we have been using the modified Blalock-Taussig anastomosis described here when the classic shunt was unsuitable. A prosthesis with a diameter greater than that of the subclavian artery is sutured end-to-side to the undivided subclavian artery and to the pulmonary artery. Thus, blood flow through the shunt is initially limited by the diameter of the subclavian artery, and there should be a potential for flow to increase with growth. In order to assess the validity of these concepts, we have reviewed the postoperative angiograms performed in some of these patients.

Clinical Material
Prostheses of woven Dacron were used in 13 patients in the early part of our experience. Since October, 1976, we have utilized prostheses of expanded polytetrafluoroethylene (PTFE) (Gore-Tex), and by the end of December, 1979, we had carried out 87 modified Blalock-Taussig anastomoses with this material.

The operation may be performed on either side through a lateral thoracotomy in the fourth intercostal space. The pulmonary artery is dissected as for the classic Blalock-Taussig shunt. A side-biting clamp is placed on the origin of the dissected subclavian artery, and the obliquely trimmed prosthesis is anastomosed end-to-side on the subclavian artery with continuous Prolene. Heparin, 1 mg per kilogram of body weight, is given intravenously before the Gore-Tex conduit is anastomosed to a transverse arteriotomy made on the anterior aspect of the pulmonary artery near its upper edge.

Thirty-six shunts (41.4%) have now been investigated with selective angiography. In 7 cases, cardiac catheterization was carried out within 1 month of the shunt operation because the patients failed to make satisfactory clinical progress. The remaining patients were reinvestigated electively between 5 and 29 months (mean, 15.6 ± 5.5) postoperatively. These are more representative of the group of patients being studied. Biplane cineangiograms were reviewed for shunt patency, irregularities of the inner surfaces of the prosthesis, distor-
tion of pulmonary arteries, and anastomotic stenosis. Enlargement of the pulmonary arteries following systemic-pulmonary anastomosis was calculated in 9 patients by measuring the diameter of the main right and left pulmonary arteries just proximal to their lobar branching and comparing the diameter with that of the descending thoracic aorta at the level of the diaphragm [7]. Measurements were made on the same frame of the angiogram or, when this was not possible, on frames taken at the same part of the cardiac cycle. All data are given as mean ± 1 standard deviation; the significance of difference was estimated by unpaired t test.

Because 1 Dacron shunt occluded shortly after direct cannulation at cardiac catheterization, it has been assumed that the neointima could be dislodged from the Gore-Tex prosthesis as well. For this reason, catheters were not passed through the shunt for pressure measurements or injection of contrast medium.

**Results**

**Early Reinvestigation**

Among the 7 patients reinvestigated early (Table 1), the shunt was occluded in 2 and stenosed in 1. The first occlusion occurred in an infant with pulmonary atresia and intact ventricular septum who at the age of 1 day underwent transpulmonary valvulotomy and left shunt using a 4 mm Gore-Tex prosthesis. On the first postoperative day the shunt murmur had disappeared and a fall in oxygen tension was noted. She was subsequently maintained by prostaglandin infusion. Postoperative angiography demonstrated occlusion at the subclavian anastomosis. The patient underwent reoperation at the age of 8 days. The shunt was found to be occluded on the subclavian end but was still patent distally. The anastomosis was successfully reconstructed, and the patient was well 11 months postoperatively.

The second patient had a univentricular heart with left atrioventricular valve atresia and pulmonary stenosis, and was operated on at the age of 3 weeks while in low cardiac output. His condition was fair postoperatively but a shunt murmur could not be heard. On this basis he was reexplored on the same day. The shunt was incised transversely and found to be patent; the incision was closed by direct suture. The following day the patient was still in low cardiac output, and an angiogram was performed. The shunt was now occluded by a thrombus, which at postmortem examination was seen to originate at the level of the incision made in it at reexploration (Fig 1).

The stenosis occurred in an infant with tricuspid atresia who had a shunt performed at the age of 9 days. Increasing cyanosis was noted three weeks postoperatively, and angiograms revealed anastomotic stenosis at the subclavian end. A left modified Blalock-Taussig anastomosis was performed successfully, and the patient was well 17 months postoperatively.

**Elective Reinvestigation**

The 29 patients who underwent elective reinvestigation have been followed in outpatient clinics for 12 to 38 months postoperatively (mean, 25.7 ± 7.1). The diagnoses are summarized in Table 2. All initially improved in

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Age</th>
<th>Weight (kg)</th>
<th>Status of Shunt</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary atresia + VSD</td>
<td>12 days</td>
<td>2.2</td>
<td>Patent</td>
<td>Died</td>
</tr>
<tr>
<td>Pulmonary atresia + IVS</td>
<td>1 day</td>
<td>3.6</td>
<td>Occluded</td>
<td>Reoperated</td>
</tr>
<tr>
<td>Univentricular heart + PS</td>
<td>3 wk</td>
<td>3.8</td>
<td>Occluded</td>
<td>Died</td>
</tr>
<tr>
<td>Tricuspid atresia + PS</td>
<td>4 mo</td>
<td>3.3</td>
<td>Patent</td>
<td>Died</td>
</tr>
<tr>
<td>Pulmonary atresia + VSD</td>
<td>19 days</td>
<td>3.8</td>
<td>Patent</td>
<td>Reoperated</td>
</tr>
<tr>
<td>Tricuspid atresia + PS</td>
<td>9 days</td>
<td>2.0</td>
<td>Stenosed</td>
<td>Reoperated</td>
</tr>
<tr>
<td>Pulmonary atresia + VSD</td>
<td>5 yr</td>
<td>19.0</td>
<td>Patent</td>
<td>Improved</td>
</tr>
</tbody>
</table>

VSD = ventricular septal defect; IVS = intact ventricular septum; PS = pulmonary stenosis.
exercise tolerance and exhibited good shunt murmurs on physical examination. No clear correlation emerged between the degree of cyanosis or exercise tolerance and shunt function. A moderate degree of congestive heart failure necessitated treatment with digoxin and diuretics in 6 patients (20.7%). In addition to the modified shunt, 2 of these patients had patent Waterston shunts and 2 had multiple aortopulmonary collateral vessels. During the initial outpatient follow-up period, the shunt murmur diminished in 1 patient and disappeared in another. The former had had a severely stenosed shunt at cardiac catheterization, and in the latter the shunt was occluded.

Angiocardiographic findings are summarized in Table 3. The Gore-Tex prosthesis was said to be irregular if a filling defect was seen in two dimensions or if more than one such defect was present (Fig 2); this change occurred most frequently in 4 mm shunts. A similar appearance resulted from kinking of an

| Table 2. Diagnoses of Patients Having Elective Postoperative Angiograms following Modified Blalock-Taussig Shunts (Gore-Tex) |
|---|---|
| Diagnosis | No. of Patients |
| Tricuspid atresia + PS | 4 |
| Concordant transposition | 3 |
| Pulmonary atresia + VSD | 8 |
| Tetralogy of Fallot | 6 |
| Pulmonary atresia + IVS | 2 |
| Univentricular heart + PS | 3 |
| Miscellaneous | 3 |
| Total | 29 |

Abbreviations same as for Table 1.

| Table 3. Angiographic Findings 5 to 29 Months (Mean, 15.6) Postoperatively in 29 Patients with Modified Blalock-Taussig Shunts (Gore-Tex) |
|---|---|---|---|---|
| Conduit Size (mm) | No. of Patent | No. Occluded | No. Irregular | No. Stenosed Subclavian Anastomoses |
| 4 | 8 | 1 | 3 | 3 |
| 5 | 2 | 0 | 0 | 0 |
| 6 | 18 | 0 | 1 | 0 |
| Total | 28 (97%) | 1 (3%) | 4 (14%) | 3 (10%) |

Fig 1. Aortogram showing the right conduit occluded by a thrombus (arrow), which at postmortem examination was found to have originated at the level of the incision made in the conduit at reoperation.

Fig 2. Irregular contour (arrow) of a 4 mm Gore-Tex conduit.
Fig 3. Kinking (arrow) of an elongated 6 mm Gore-Tex shunt where a stay suture had been placed to anchor the shunt on the anterior pericardium. This was done to improve access during subsequent complete repair from a midline sternotomy.

Fig 4. Stenosis (arrow) of the subclavian anastomosis of a modified 4 mm Blalock-Taussig anastomosis performed during the first week of life of the patient.

elongated shunt in which a stay suture had been placed to anchor the shunt in the anterior mediastinum so as to improve access during subsequent repair through a midline sternotomy (Fig 3). Stenosis of the subclavian anastomosis (Fig 4) was seen in 3 conduits, all 4 mm, performed in the first week of life. The shunt was occluded in an infant with pulmonary atresia, ventricular septal defect, and hypoplastic confluent pulmonary arteries who was perfused through large collateral arteries. This patient underwent a right modified Blalock-Taussig anastomosis at the age of 5 months. When restudied 18 months later, the shunt was seen to be occluded. The patient then received a central shunt, which also failed to improve her status.

Growth of the pulmonary arteries relative to that of the descending thoracic aorta is summarized in Table 4. The mean increase in this ratio was 0.19 ± 0.308 on the right side and 0.19 ± 0.292 on the left (p = 0.10 and 0.09, respectively). Considering just the 6 patients shunted as neonates, the mean increase was 0.28 ± 0.287 on the right (p = 0.007) and 0.32 ± 0.173 on the left (p = 0.006). However, in an 8-month-old boy with tetralogy of Fallot whose arteries failed to grow, there was stenosis of the shunt and narrowing of a previously patent ductus arteriosus at the time of reinvestigation. Despite irregularities in the 4 mm shunts, the majority of patients in whom this size prosthesis was used showed a marked increase in diameter of the pulmonary arteries.

Among the 28 patients with patent shunts, 1 with a stenosed subclavian anastomosis had increasing cyanosis and was not considered suitable for repair at the time of reevaluation; a second modified shunt procedure was done successfully. Four patients have undergone successful palliation for lesions that are not correctable. Another 4 have undergone repair of the defect, and 17 are presently awaiting repair with adequate palliation. (No difficulty has been encountered in ligating the shunt at the time of repair.) Two 6 mm shunts were recovered 15 and 28 months after implantation,
Table 4. Changes in the Right and Left Pulmonary Arteries Relative to the Aorta Following Modified Blalock-Taussig Shunt

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Age</th>
<th>Shunt Size (mm)</th>
<th>Diameter Changes in RPA/DAo</th>
<th>Diameter Changes in LPA/DAo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetralogy of Fallot</td>
<td>3 d</td>
<td>4</td>
<td>+0.57</td>
<td>+0.20</td>
</tr>
<tr>
<td>Tetralogy of Fallot</td>
<td>12 d</td>
<td>4</td>
<td>+0.52</td>
<td>+0.10</td>
</tr>
<tr>
<td>Tricuspid atresia</td>
<td>2 d</td>
<td>4</td>
<td>-0.02</td>
<td>+0.45</td>
</tr>
<tr>
<td>Pulmonary atresia + VSD</td>
<td>4 d</td>
<td>4</td>
<td>+0.36</td>
<td>+0.27</td>
</tr>
<tr>
<td>Pulmonary atresia + IVS</td>
<td>2 d</td>
<td>4</td>
<td>-0.14</td>
<td>+0.31</td>
</tr>
<tr>
<td>Pulmonary atresia + IVS</td>
<td>4 d</td>
<td>4</td>
<td>+0.29</td>
<td>+0.58</td>
</tr>
<tr>
<td>Tetralogy of Fallot</td>
<td>8 mo</td>
<td>4</td>
<td>-0.33</td>
<td>-0.38</td>
</tr>
<tr>
<td>DORV + banded pulmonary artery</td>
<td>2 yr</td>
<td>5</td>
<td>+0.38</td>
<td>+0.30</td>
</tr>
<tr>
<td>Univentricular heart + PS</td>
<td>10 yr</td>
<td>6</td>
<td>+0.10</td>
<td>-0.12</td>
</tr>
</tbody>
</table>

Mean change in diameters of pulmonary arteries/DAo = +0.19 ± 0.302

*p = 0.10.

RPA = right pulmonary artery; DAo = descending thoracic aorta at level of diaphragm; LPA = left pulmonary artery; DORV = double-outlet right ventricle; other abbreviations same as for Table 1.

respectively, following death at corrective operation. Both shunts had smooth neointima covering the suture lines and the Gore-Tex conduit.

Comment

Because of a high patency rate, improvement in systemic oxygenation, low incidence of pulmonary overperfusion, and satisfactory management at the time of repair, the Blalock-Taussig shunt remains the procedure of choice for most systemic-pulmonary anastomoses. In neonates and infants, however, a small degree of tension caused by a short subclavian artery can easily kink and occlude the pulmonary anastomosis; this applies as well to patients with hypoplastic pulmonary arteries. Also, results of Blalock-Taussig anastomosis are less satisfactory when the anastomosis is performed on the side of the aortic arch. Early results with the modified Blalock-Taussig anastomosis in these situations have been encouraging.

Angiography in this study confirmed the clinical impression of a high patency rate in Gore-Tex shunts between the subclavian and pulmonary arteries between one and three years postoperatively (97% patency rate among patients restudied electively). Clinical observation was a good guide to pulmonary perfusion. In those patients in whom cyanosis increased, exercise tolerance decreased, or shunt murmurs disappeared, stenosed or occluded shunts were encountered. Reinvestigation is indicated for such patients, particularly in the early postoperative period, because occlusion at the subclavian anastomosis can be successfully managed by reoperation. Of particular importance was the rapid occlusion of 1 shunt following exploration. Suture in PTFE tubing has caused thrombosis of a 5 mm central shunt [13], and thrombosis has been initiated experimentally by needle puncture of a graft [21]; it would appear that any damage to the prosthesis predisposes to occlusion. Persistent cyanosis postoperatively can be related to pulmonary venous obstruction, however, and surgical exploration of the shunt should not be undertaken without angiographic evidence of shunt failure.

In spite of the 97% patency rate found on elective angiography, the high incidence of irregular or stenosed shunts—particularly among neonates with 4 mm conduits—is cause for concern. Theoretical predictions of a high patency rate for small-caliber PTFE conduits were based on its nonwettable electronegative surface [8, 22] and a porosity that allows limited endothelialization by a viable neointima [26, 57]. These predictions have been substantiated in experimental work of limited duration [4, 10, 14, 21] and in clinical use for hemodialysis [21], recon-
structive peripheral vascular surgery [3, 6, 24, 25], and replacement of the portal vein [18] as well as in small numbers of cerebral [23, 25] and myocardial [15, 16, 20, 27] revascularizations. However, follow-up beyond two years has been reported only with 6 mm grafts, for which life-table analysis showed a cumulative patency of 76% at 28 months in lower limb revascularization. Our experience with late failures in patients with a modified Blalock-Taussig anastomosis to date is insufficient for determining if they result from a technical error that predisposes to intimal thickening, from the characteristics of the graft itself, or from their use in neonates. The failures do serve to emphasize the need for careful patient follow-up, however, with awareness that clinical deterioration has been accompanied by neoointimal changes and narrowed anastomoses after 12 to 18 months.

We now believe that the success rate of the modified Blalock-Taussig shunt would be increased by using conduits of at least 5 mm in diameter even in neonates. If the shunt can be performed on either side, our preference in neonates is for the side of the aortic arch, where there is less risk of damaging the recurrent laryngeal nerve and where the length of the subclavian artery before its branching tends to be greater. In addition, given the possible need for a second shunt procedure before repair is carried out, it would seem advisable to use the side of the arch for the modified shunt in neonates, thus preserving the other subclavian artery for a classic Blalock-Taussig shunt when the child has grown.

Judging from the angiocardiographic findings in patients in whom 4 mm grafts were used, it is clear that by the age of 1 year the diameter of the subclavian artery is similar to or even greater than that of the conduit. Therefore, our expectation that flow would increase as the patient grew is not applicable for more than a few months when a 4 mm graft is utilized. This is another reason for using conduits of at least 5 mm, even in neonates, when the palliative operation is expected to last for several years.

The importance of the pulmonary arteries in achieving successful repair of congenital heart defects is generally recognized [1], and palliative operations in both tetralogy of Fallot [2, 7, 11] and pulmonary atresia with ventricular septal defect have been found to increase the size of these vessels. While previous shunts and discontinuous pulmonary arteries precluded measurements in most patients reinvestigated in this series, the small number of patients in whom this estimation was possible showed an increase similar to that observed after Blalock-Taussig shunting in tetralogy of Fallot [7]. Among neonates this increase in size of the pulmonary arteries was comparable to that achieved with the Waterston anastomosis [2]. Equally important was the preservation of the pulmonary arteries after a modified Blalock-Taussig anastomosis and the fact that in no case has kinking or distortion of the vessel occurred.

References
10. Heydorn WH, Geasling JW, Moores WY, et al: Changes in the manufacture of expanded microporous polytetrafluoroethylene: effects on patency and histological behavior when used to

Discussion

DR. HENRY T. BAHNSON (Pittsburgh, PA): I am grateful to Dr. McKay for presenting this work to us and for the opportunity to read the manuscript. In the third of a century since I helped Dr. Blalock and then was helped by him to do Blalock operations, there have been many alternatives to his original procedure. I think this is one of the most promising.

One of the early harbingers occurred when Denton Cooley, then in Houston, reported to his chief that he had been successful in doing a Blalock anastomosis in a 6-day-old child. Operations at that age now are commonplace, often with the help of magnification and other techniques that have been honed by experience with coronary artery bypass. At present, one of the major targets of the Blalock, or systemic pulmonary, shunt is the newborn.

Our experience at the University of Pittsburgh, like that of others, has invariably shown that when comparison is made, the Blalock shunt comes out best in terms of patency, freedom from congestive failure, relief of cyanosis, and freedom from the need of an additional procedure. In 1979, we used the Blalock shunt exclusively, and a third of them were in patients in the first day of life.

I really have nothing but compliments for Dr. McKay's presentation. I think particularly intriguing is the postulate—for which I believe she is now beginning to get evidence—that a larger than ideal conduit in the newborn may not grow but that the subclavian artery may grow to it, and that the subclavian will continue to govern the size of the shunt. I think this is one of the major reasons why a subclavian shunt does not lead to congestive failure.

The number of operations that this group has reported, nearly half of them since Mr. Stark mentioned this in discussion at this meeting last year, suggests that perhaps they have widened the indications for this type of procedure. It also suggests perhaps that there are some operations in which Gore-Tex is used where previously a direct anastomosis would have been done. This is the basis of my only question. Have you broadened your indications to use Gore-Tex in virtually all patients so that you now can study the direct shunt and that done with Gore-Tex in comparable patients? When I use prostheses or vein grafts, it is always in the more difficult patients. Therefore, it has been impossible to compare the direct shunt with one using a prosthesis.
I hesitate to make a technical comment about results that are so good, but it was pointed out some time ago, I think by Dr. Blalock that, at least in his hands, a longitudinal incision in the pulmonary artery seems to lead a little less frequently to narrowing of this artery. It is one of the complications that may arise from any type of systemic-pulmonary anastomosis.

Miss McKay has presented exciting results with a procedure that should be added to the armamentarium of all surgeons dealing with the critically cyanotic neonate. However, I think final judgment must await more long-term results and experience at subsequent repair before this becomes a procedure of first choice in all or even most patients.

DR. ANTHONY R. MOULTON (Baltimore, MD): Miss McKay is to be commended for a fine presentation of an impressive series. Having spent a year at Great Ormond Street and having had the opportunity to perform some of the procedures described today, I can attest that the use of these prosthetic tubes is quick, easy, and reproducible. Miss McKay has just demonstrated that long-term patency rates are also high.

But Mr. de Leval and Mr. Stark also taught me that a primary Blalock-Taussig anastomosis can be safely and reproducibly created, even in tiny neonates. I would like to underline Miss McKay's statement that the Blalock-Taussig anastomosis therefore remains the shunt of first choice in patients with cyanotic congenital heart disease. There were 20 neonates in the series presented this morning, 13 less than 1 week old, and most of the early deaths were in this group.

Among the infants who had a shunt procedure at the University of Maryland Hospital in the past five months were 7 neonates less than 3 days old. A primary Blalock-Taussig anastomosis was created in all of them, with gratifying rises in the partial pressure of oxygen. The only shunt-related death was in a baby weighing 1,900 gm in whom a prosthetic graft was placed after the Blalock shunt had thrombosed ten days postoperatively during a hypotensive episode. Findings at postmortem examination demonstrated a couple of technical problems that can adversely affect the outcome of the use of prosthetic tubes for shunts in tiny neonates.

In patients with tiny pulmonary arteries, the semirigid prosthetic tube often has a much larger diameter than the pulmonary artery. Mobilization and incision of adequate length must be made in the pulmonary artery. Like Dr. Bahnson, I believe that a transverse incision may not provide adequate length. Though the anterior wall of the pulmonary artery will stretch to accommodate the graft, it may result in flattening of the posterior wall with a decrease in the effective cross-sectional area of the pulmonary artery. Furthermore, because of the relative rigidity of the prosthetic tube, the end of the graft must be fashioned in a semicircular shape because simple beveling of the end may produce an angle that could prevent retrograde flow into the pulmonary artery. This would produce distortion and cause subsequent problems.

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DR. TIMOTHY J. GARDNER (Baltimore, MD): In support of the experience with Gore-Tex shunts in children presented so nicely here, I will review very briefly our experience with Gore-Tex shunts for the treatment of severe cyanosis in infants and mention our current anatomical preference for shunt placement based on this experience.

In the past two and a half years at the Johns Hopkins Hospital, we have placed Gore-Tex shunts in 30 infants, 16 of whom were neonates at the time of operation. The average age at operation was 5 days. Our early use of Gore-Tex involved central shunting from the ascending aorta to the pulmonary artery. More recently, we have used the descending aorta–left pulmonary artery position or alternately the subclavian–pulmonary artery position for shunts in larger infants.

There were 5 hospital deaths, 2 shunt-related. Both of these deaths occurred when we were using the ascending aorta–main pulmonary artery position. One death was related to severe overflow to the lungs and the other, to a shunt occlusion. There have been 2 late deaths, neither related to the shunt. In both instances, the shunts were patent at postmortem examination. There was one late shunt thrombosis in an infant with tetralogy of Fallot who was successfully repaired. We have no problems with significant congestive heart failure after shunt placement in the descending aortic position. Because of this favorable experience, the descending aorta–left pulmonary artery position has become our shunt position of choice.

DR. JURO WADA (Tokyo, Japan): I enjoyed this beautiful presentation from Great Britain and highly appreciated it. Through 1979 at the Tokyo Women's Medical College, Heart Institute of Japan, we had 59 patients who underwent a shunt operation with use of expanded polytetrafluoroethylene (PTFE) tube. Average age of the patients is 4 years 5 months, and average follow-up is 2 years 8 months.

There were 26 right and 20 left modified Blalock anastomoses done. Overall operative mortality was 10.25% and late death was 3.4% (1.5% per 100 patient-years). Early occlusion (less than a month) occurred in 5 patients and late occlusion in 5, an incidence of 2.2% per 100 patient-years. Graft patency four years postoperatively was 76.6%.

It is my impression that the modified Blalock shunt with PTFE showed late occlusion in increased num-
bers over time compared with the original Blalock procedure. To close the shunt at the following surgical setting, I do recommend use of a Weck clip, which is easy and timesaving.

DR. MCKAY: I thank all the discussants for their comments. In answer to Dr. Bahnson's question about broadening our indications, we actually have limited them in view of the late results with the 4 mm shunts. We strongly believe that whenever a satisfactory, classic Blalock-Taussig anastomosis can be performed, it is the procedure of choice. The large number of modified Blalock-Taussig shunts this past year reflects a high proportion of neonates and patients with previous operations; but, it still represents less than one-third of all systemic-pulmonary anastomoses done at the Hospital for Sick Children during this period.

I thank Drs. Moulton, Gardner, and Wada for reviewing results from their respective institutions. We agree with Dr. Moulton that technical details assume increasing importance with hypoplastic pulmonary arteries. However, we have not had problems with the transverse pulmonary arteriotomy and can say only that, in our experience, it has given satisfactory results. This includes a number of patients whose pulmonary artery measured 1.5 to 2.0 mm in diameter at the time of operation.

As regards management of the modified Blalock-Taussig shunt at the time of complete repair, we have had experience with 5 patients. On the side opposite to the aortic arch, the shunt was approached as a classic Blalock shunt without difficulty. On the side of the arch, it seemed to lie more anterior than a direct subclavian-pulmonary artery anastomosis, and dissection along the arch did not give good exposure. We identified these shunts from the pulmonary artery. It is also helpful to realize that Gore-Tex feels very firm and may have little pulsation on palpation. In these patients, the shunt was occluded by double ligature with ductus silk. However, we do not know if leaving prosthetic material between the subclavian and pulmonary arteries will result in later distortion of these vessels.

The subclavian artery was selected for the systemic anastomosis for several reasons: (1) its orifice may act as a flow regulator, permitting larger shunts to be used in small infants; (2) the prosthesis lies in a straight line without risk of kinking; (3) the pericardium is not opened; and (4) the shunt is accessible at the time of cardiopulmonary bypass. We would be concerned about the risk of congestive heart failure with a prosthesis from the descending aorta and the chance that these shunts might prove difficult to take down.

Finally, the incidence of 2.2% closure per year reported by Dr. Wada is very much in keeping with our own experience and again emphasizes the need for careful follow-up of these patients.