The Clinical Evolution of Shunt-Operations for Morbus Caeruleus: Results of 150 Operations, in a Long-Term Follow-Up

C. A. Mahaim, M.D., C.L.C. van Nieuwenhuizen, M.D., H.A.H. D'heer, M.D., and F. Slooff, M.D., Utrecht, Netherlands

INTRODUCTION

The classical operations of Blalock,[4] Potts,[25] and Brock[6] which have been used for more than 10 years in treating the tetralogy of Fallot are purely symptomatic. Their aim is to augment the pulmonary circulation in order to increase the oxygenation of the blood. However, they do not, properly speaking, correct the malformation. In fact, with the procedures of Blalock and Potts a fifth malformation is created in a heart that already has four. It is well known that an operation which creates an artificial ductus arteriosus must, in the long run, produce a significant overloading of the heart. In any event, the immediate benefits of the operation, in so far as the general status of the patients and the amelioration of the cyanosis are concerned, are so evident that the undeniable usefulness of this type of operation is universally recognized.

TABLE I

AUTHOR AND YEAR	NUMBER OF PATIENTS	PROCEDURE USED (IN ORDER OF FREQUENCY)	OVER-ALL MORTALITY (PER CENT)	GOOD RESULTS (PER CENT)	FOLLOW-UP
Potts, 1956	514	Potts	9	?	?
Johnson, 1951	144	Blalock, Potts	12	?	?
Bret, 1952	172	Potts, Blalock, Brock	20	74	?
Derra, 1952	242	Blalock, Brock	19	76	?
Dubost, 1954	333	Blalock, Potts, Brock	16	78	?
Brock, 1955	140	Brock	11.5	76	?
Sellors, 1950	93	Blalock, Potts, Brock	10.5	68.5	6 mo. and more
Campbell, 1953	200	Blalock, Brock, Potts	16.5	68	From 1 to 4 yr.
Taussig, 1952	1,000	Blalock	15.7	77.3	From 18 mo. to 7 yr.
Potts, 1956	100	Potts	14	84	From 6 to 8 yr.

From the Department of Cardiology and Cardiac Surgery, St. Antonius Hospital, Utrecht, Netherlands. (The operations were performed by Prof. A. G. Brom and Dr. A. Schaepkens van Riempst. The anesthesiologist was Dr. H. De Zwaan.)

Received for publication Feb. 17, 1959.

But, what is the future of these patients? Since, thanks to the heart-lung apparatus (Lillehei[20]), we may now foresee the possibilities of plastic repairs within the heart of patients with tetralogy of Fallot, it seems necessary to analyze the long-term results of the palliative operations that we have used until now. There have been very few such studies in the literature up to the present time. Among the principal articles pertaining to this subject, we found only four which mentioned the evolution of the patients 6 months or more after the operation.[8,24,27,29] For the sake of comparison, Table I shows the over-all results of the most important studies that have been published.[5,8,10,11,13,15,23,24,27,29]

MATERIAL AND RESULTS

The material presented in this article was drawn from 141 cases, beginning with our first surgical intervention in 1948, and including those cases up to and through 1956. One patient emigrated to Canada, after being seen twice during the 10 months following his operation, and 2 died, 8 months and 6 years, respectively, after their operations, without having returned for checkups before death. All the others were examined on convocation in 1956 or 1957. Three fourths of them were regularly controlled every first or second year. The object of these examinations was to obtain precise information in order to learn: (1) whether avoidable errors in the evaluation of the operability of our patients were committed; (2) whether it was possible to establish for each case the optimal size of the shunt to be made; (3) whether there were reasons to prefer one of the procedures used (Blalock, Potts, or Brock) to the others; and (4) whether these operations still benefited the patients years afterward.

The results were based primarily upon the ensemble of the clinical symptomatology. The results were called *excellent* in those patients whose physical capabilities were in no way limited after surgery; they were called *good* in those patients whose condition showed a marked improvement, allowing them to lead normal lives for their ages, with the exception of violent or prolonged physical efforts. The results were considered as *insufficient* in those patients in whom there was no appreciable change seen after surgery. Finally, *mortality*, whether precocious or tardive, and no matter of what origin, constituted the fourth category.

Fig. 1 shows the over-all results of our cases and provides the key to our schemata, wherein the failures (deaths and insufficient results) are always compared in per cent to the successes (excellent and good results). Fig. 1 is interpreted as follows: deaths: 33 cases, or 23.5 per cent; insufficient results: 5 cases, or 3.5 per cent; good results: 81 cases, or 57.5 per cent; excellent results: 22 cases, or 15.5 per cent.

Besides those total results, we have attentively analyzed several factors which may influence favorably or unfavorably the postoperative evolution of our patients. These factors are discussed below.

FACTORS INFLUENCING PROGNOSIS

Diagnosis.—Patients with different types of congenital cyanosis were operated upon, including 10 who had tricuspid atresia or stenosis with atrial and ventricular septal defects, without operative death. It is possible to obtain very good results in these cases, even after 6 years or more. The results may be very spectacular, as in the case of the 13-year-old boy suffering from pulmonary tuberculosis with cavitation, who, after a Potts operation, recovered rapidly in a sanatorium, and who, at the age of 17-½ years, could work and lead a normal life.

Six patients presented a rare malformation such as tetralogy of Fallot with a large monoatrium (2 cases) or complicated by an atrioventricularis communis

(1 case), a pseudotruncus arteriosus, a valvular and infundibular pulmonary stenosis with cor biloculare, a transposition of the great vessels with pulmonary stenosis and monoventricle. There were 5 operative deaths in this series. The indication for surgical intervention in each of these cases was the right-to-left ventricular shunt and the insufficiency of the outflow of the pulmonary artery.

Eleven patients had no precise preoperative diagnosis. All seemed to fall within the framework of the tetralogy of Fallot, while presenting such atypical manifestations as an enlarged heart due to a large interauricular septal defect, a monoventricular form, or an excessively overriding aorta. Here too, there were 5 operative deaths.

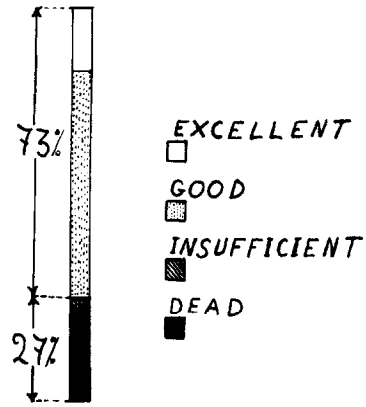

Fig. 1.

One patient with a transposition of the great vessels, who was not catheterized, underwent only a useless explorative thoracotomy.

Excluded from our study were the cases of pulmonary stenosis with intact ventricular septum (trilogy of Fallot), in which shunt-operations were contraindicated.

Finally, there were 113 typical examples of the tetralogy of Fallot. Fig. 2 shows that the results were much better in patients with the tetralogy of Fallot (right side) than in those with the rarer forms of cyanotic heart disease (left side).

We also noted, as have others,[14,18] that the absence of a whisper is a bad prognostic sign. This generally indicates a serious malformation accompanied by pulmonary atresia or extreme pulmonary hypoplasia. We did not hear at all the usual systolic whisper in the patient with pseudotruncus arteriosus mentioned above, nor in another patient, 27 years old, in whom we could reach the aorta but not the pulmonary artery by catheterization, although he presented all the clinical, radiologic, and electrocardiographic features of a classic tetralogy of Fallot. Both patients died during the operation.

The importance of a preoperative diagnosis as exact as possible is still to be pointed out. For that reason, a catheterization or angiocardiographic study, or both, has been systematically carried out in all of our patients, without any important accident. In all, 130 angiocardiographic studies and 139 catheteriza-

tions were made. An overriding aorta was evident in 73 of the angiocardiograms. Typical angiocardiograms were obtained in our 10 cases of tricuspid atresia or stenosis with auricular and ventricular septal defects. However, generally, the information obtained by angiocardiography was not so precise as that obtained by catheterization. Angiocardiography is only indicated in children less than 1 year old, and when the desired information cannot be obtained by catheterization. It was in these cases that selective angiocardiography by intracardiac injection gave the most precise data. The two great vessels were sounded in 58 patients by catheterization, the pulmonary artery only in 7 cases, and the aorta only in 3 cases.

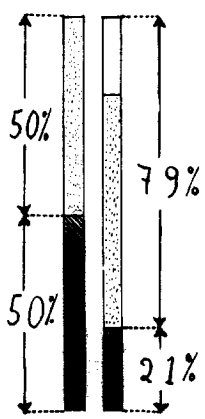

Fig. 2.

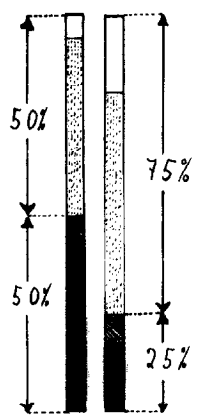

Fig. 3.

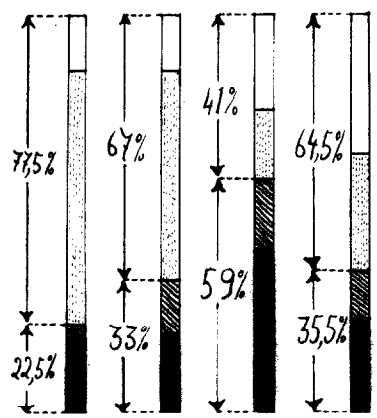

Fig. 4.

In our 141 patients we were able to get 123 exact diagnoses, and only an indication for surgical procedure in 17 instances, in cases of insufficiency of the outflow of the pulmonary artery and right-to-left ventricular shunt. We had only one erroneous diagnosis (a transposition of the great vessels) in an 8-month-old child, resulting in a useless thoracotomy. Taussig,[29] who referred to a time when catheterization was not done systematically, described 40 grossly erroneous diagnoses resulting in 33 operative deaths in her series of 1,000 cases.

Age at Time of Operation.—The patient's age at the time of operation was also an important factor. The younger the children the greater are the risks of failure. The risks are also greater in adults than in adolescents. The left-hand column of Fig. 3 represents the 38 operations performed on patients who were less than 2.5 years or more than 17 years old, and the right-hand column represents the 112 operations performed on patients between these two ages. Similarly, we noticed that the sooner the clinical manifestations appeared, the worse were the results.

Type of Operative Procedures.—In 9 of the 141 cases a second operation was performed because of insufficient results obtained from the first operation. The distribution of the 150 operations performed was as follows: 88 Potts, 42 Blalock, and 17 Brock procedures, 1 explorative thoracotomy, and 2 deaths under narcosis before surgery was begun. Fig. 4 illustrates, from left to the right, the results obtained with the Potts, Blalock, and Brock methods; the last column on

the right represents the 17 very first operations we did (only Potts or Blalock methods used). That last comparison has convinced us that, in spite of some excellent results, the operative mortality was clearly greater with the Brock procedure than with the two other procedures. Six of the patients surviving after the Brock procedure were recatheterized within 7 months and 5 years postoperatively. All showed the persistence of a considerable gradient between the systolic pressure in the pulmonary artery and that in the right ventricle (from 65 to 105 mm. Hg). These considerations led us, as well as others,[3,9,15,28] to use exclusively the usual shunt-operations, and to abandon the Brock procedure.

Nine other catheterizations (6 using the Potts procedure and 3 using the Blalock procedure) were performed from 8 months to 6 years postoperatively. The pressure in the right ventricle was always in equilibrium with the pressure in the aorta, between 95 and 120 mm. Hg. The oxygen saturation of the arterial blood was always higher than before the operation. A right-to-left shunt was already predominant preoperatively, while after the operation the shunt was left-to-right. Little importance was attached to the quantitative evaluation of the outflow of the shunts, because we found this calculation to be too easily subject to great error.

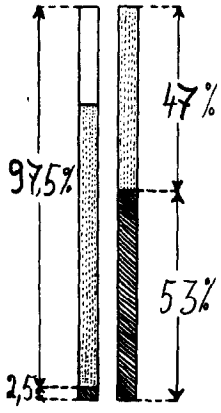

Fig. 5.

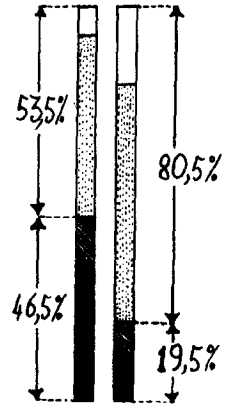

Fig. 6.

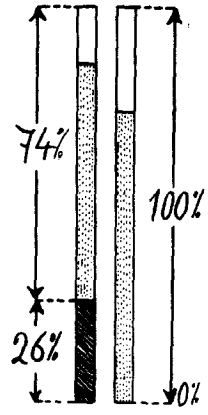

Fig. 7.

Causes of Death.[2,8,11,19,24,27,29,31]—Table II lists the causes of death, which have been divided into three groups. It is to be noted that 4 fatal ventricular fibrillations took place during the Brock operation, which number represents a large proportion.

On the other hand, 3 of the patients who died from asystole had obtained too large a shunt (more than 6 mm. in diameter) with the Potts procedure. But postoperative results were frequently insufficient when a small shunt (less than 4 mm. in diameter) was created by operation (Blalock or Potts procedure). The most adequate shunts were always found between the values of 4 and 6 mm. in diameter. Of all the patients who underwent the Potts or Blalock procedure, the systolodiastolic whisper of the artificial shunt was absent in only 2 cases (children who died from postoperative complications). It is probable that the occlusion of the shunt played a major role in the fatal evolution in these cases.

Finally, it is to be noted that only 1 case of sepsis caused a late death; this was a very small number in view of the reputation that shunt-operations have of favoring the appearance of such an infection.

TABLE II. CAUSES OF DEATH

IMMEDIATE OPERATIVE DEATHS (DURING THE FIRST HOURS OR DAYS AFTER THE OPERATION)	DEATHS DUE TO POSTOPERATIVE COMPLICATIONS (FROM THE FIRST WEEK TO 6 MONTHS AFTER THE OPERATION)	LATE DEATHS (FROM 8 MONTHS TO 6 YEARS AFTER THE OPERATION)
(18 cases= 13%)	(11 cases= 8%)	(4 cases= 3%)
1. Cardiac arrest in preoperative narcosis (2)	1. High fever of unknown origin, 3 days postop. (1)	1. Accidental death by car, 8 months postop. (1)
2. Cardiac arrest during surgical procedure (4)	2. Capillary bronchiolitis, 1 week postop. (1)	2. Progressive cardiac failure by too large a shunt, 3 years postop. (1)
3. Hemorrhage from a bad joining in the first hours (2)	3. Hemopyopneumothorax, 1 week postop. (1)	3. Death 3½ years after a Blalock operation, complicated by a severe right hemiplegia, by too small a shunt (1)
4. Pulmonary edema during operation resulting in cardiac arrest in the following hours (2)	4. Severe bronchopneumonia, 3 weeks postop. (1)	4. Sepsis (hemolytic streptococcus) 6 years postop. (1)
5. Cerebral anoxia with death in the first 36 hours postop. (2)	5. Infectious hepatitis, 2 months postop. (1)	
6. Postoperative shock (1)	6. Death after 3 months from purulent pleuritis (*Staphylococcus aureus*) (1)	
7. Cardiac arrest in the first 48 hours postop. (5)	7. Thromboembolic disease resulting in fatal mesenteric thrombosis after 4 months (1)	
	8. Encephalitis with fatal issue, 5 months postop. (1)	
	9. Cardiac failure, by too large a shunt, 2 to 6 months postop. (3)	

Weight.[26]—The mortality was about twice as frequent in puny children who were underweight than in those whose weight remained within the normal values. In the postoperative evolution more than one year after the operation, we noted insufficient results four times less often in children whose weight was normal than in those remaining underweight.

Condition of the Blood.—Examination of the blood also gave a clear indication of the prognosis. There were twice as many deaths in 6 patients suffering from anemia (less than 80 per cent hemoglobin) than in the 22 patients having a particularly important cyanosis (more than 140 per cent hemoglobin). After operation, the hemoglobin level in 19 patients remained high as compared with the others in whom it was obviously lower or remained within normal limits. Fig. 5 shows the strikingly different results between the 19 unfavorable evolutions of the blood condition (right-hand column) and all the others (left-hand column).

Size of the Heart on X-Rays.[7,8,11,19,22,24,30,31]—Before operation, among all the patients submitted to surgery for congenital cyanosis, independent of the

exact diagnosis, it was striking to ascertain how much better was the prognosis of the patients whose heart was normal or small in size than was the prognosis of those with enlarged heart. The left-hand column of Fig. 6 shows the 41 cases in which the cardiothoracic ratio was higher than 52 per cent, and the right-hand column shows the others, in which it was lower than 52 per cent. On the contrary, after operation, the cases with unfavorable results were those 27 in which the heart did not become larger, probably because of the failure of an adequate shunt (Fig. 7, left-hand column); in the others the cardiothoracic ratio increased from 2 to 6 per cent, and the results were better (Fig. 7, right-hand column). Similarly, the x-ray pictures in the cases with good results show generally well the darker outline of the pulmonary vessels, which reflects the efficacy and utility of the shunt.

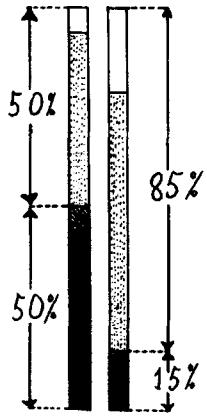

Fig. 8.

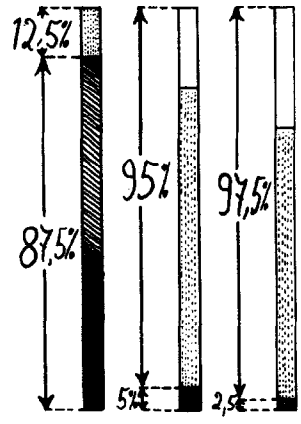

Fig. 9.

Electrocardiographic Features.[1,11,12,16,19,21,22,24,32]—The following electrocardiographic features have been pointed out before surgical procedure: (1) Left axis deviation between +20° and −90° or signs of hypertrophy of the left ventricle on the precordial leads, or both, were observed in 4 cases of the rare forms of cyanotic heart disease and in the 10 cases of underdeveloped right ventricle. We counted here neither the cases with doubtful left axis deviation without hypertrophy of the left ventricle nor the cases with left axis deviation due to situs inversus or other unusual rotations of the heart. (2) Extreme hypertrophy of the right ventricle was judged to exist if two of the following data were present: R_{V1} greater than 20 mm. or $R_{V1} + S_{V6}$ greater than 35 mm.; intrinsicoid deflection larger than 0.06 second in V_1; P higher than 5 mm. in the right precordial leads; extreme right axis deviation of more than +160°. These findings were seen in 10 of the cases of rare cyanotic heart disease, and in 24 of the cases of tetralogy of Fallot. (3) A third group of cases did not show any of the aforementioned features. Fig. 8 shows, in the left-hand column, the 48 bad cases of the first and second group in comparison, in the right-hand column, with the 89 others of the third group.

After operation, it was possible to distinguish three different electrocardiographic evolutions; they are represented from left to right in Fig. 9: (1) Of the

8 patients in whom clear signs of progressive right overloading appeared, 3 died, 4 had unsatisfactory results, and only 1 had good postoperative results. It is obvious that this type of evolution had a very unfavorable prognosis. (2) In 40 patients there was no appreciable modification of the electrocardiogram. (3) In 43 patients there was a clearly observable increase in the potentials of the left ventricle. It was this latter group which had the most favorable evolution.

It is important to point out that the radiologic increase in the size of the heart as well as the electrical increase in the potentials of the left heart reflect the overwork of the left heart, resulting from the creation of the operative shunt. Those two modifications indicate that the shunt works usefully. At first progressive, the signs usually stabilize after 1 or 2 years in each patient when a satisfactory hemodynamic equilibrium has been reached. It is only in the rare cases of progressive asystole that we have not observed stabilization of the signs of increasing work of the left heart.

Test of the Function of the Heart.—The test of the function of the heart, described elsewhere by Jongbloed, van Nieuwenhuizen and van Goor,[17] consists in a continuous recording of the oxygen consumption of a patient at rest and during moderate effort (pedaling a cycle with a known resistance). The graphic curves thus recorded permit the calculation of the oxygen debt due to the effort. The oxygen debt is considered to be normal when it is less than 16 per cent of the increase in oxygen consumption due to a standard effort of 60 watts during a period of 8 minutes. The time necessary for a return to basal conditions normally should not exceed 3 minutes. Extracardiac factors have little influence on the results of this test, and these results are considered an excellent reflection of the functional capacity of the heart. Unfortunately, only well-developed adolescents, who are at least 15 years old, can use the cycle which has been standardized for adults.

Before operation, the results of this test were always poor. A third of the patients who had excellent clinical results when examined postoperatively had a normal or almost normal test of cardiac function. The results of the test were fair in patients with good clinical results, and poor in 2 cases with poor clinical outcome. Fig. 10 illustrates the evolution of the results of the test of cardiac function in a 19-year-old boy. The top graph shows the results of the test before the operation. The patient was unable to exert effort for longer than 2 minutes and 40 seconds. The oxygen debt (striped part of graph) is large and lasts for 5 minutes and 30 seconds. The theoretical steady state (the horizontal line on top) has not been reached. This graph shows a very poor cardiac function. The middle graph shows the results of the test 3 months after a Potts operation. The patient is able to put forth effort for a longer time. The curve reaches the steady state. The oxygen debt is still large and lasts for 5 minutes and 5 seconds. This graph shows a mediocre cardiac function. The bottom graph shows the results of the test 20 months after the operation. The standard effort of 8 minutes can be made. The steady state has been reached, and the oxygen debt is 21 per cent and lasts for 3 minutes and 10 seconds. Even though this shows a good cardiac function, it is still not normal. Fig. 11 shows a test of the function

of the heart that was within normal limits 5 years postoperatively. The oxygen debt is 15 per cent, and lasts for 2 minutes and 50 seconds; the standard effort is made easily and the steady state is reached quickly.

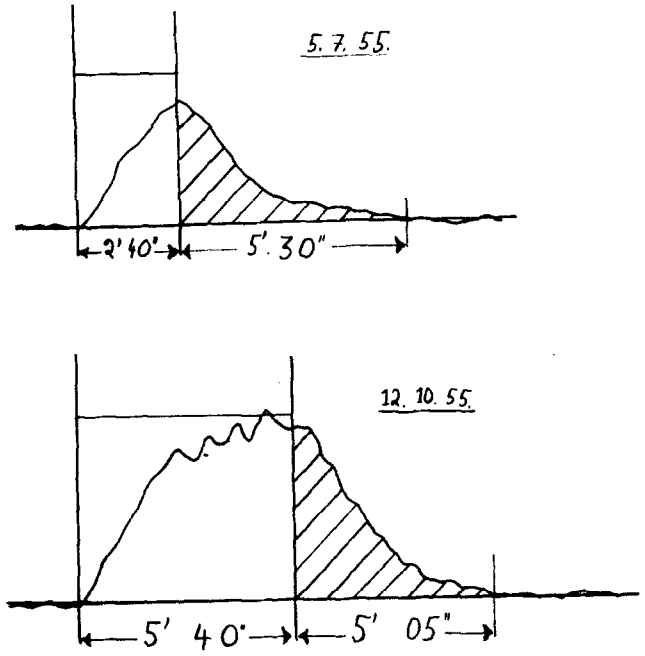

Fig. 10.

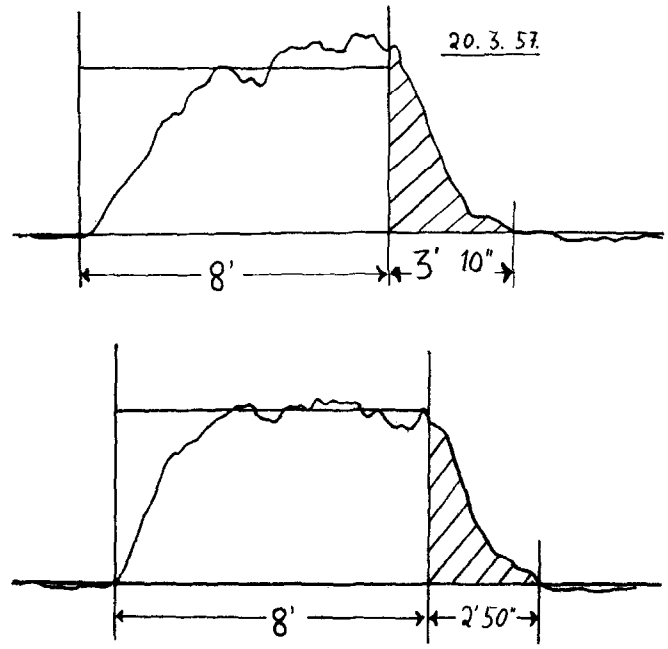

Fig. 11.

It is not surprising that the results of the test were below normal in patients who were considered clinically as having had good postoperative evolution, since the maximum that may be hoped for in these cases is an improvement of the hemodynamic conditions sufficient to permit a good adaptation. However, in 10 patients, results within normal limits were obtained. This is quite remarkable, because often the advances in the results of the test are progressive in character, and because our experience with the cardiac function test (in more than 1,000 cases) shows that it is very sensitive.

PROGNOSIS

As has been shown, there are many factors that seem to aggravate the prognosis. The following are the most important of these factors that adversely influenced the prognosis: (1) *Diagnosis:* cases in which the malformation found did not correspond to those found in a classic case of tetralogy of Fallot. (2) *Electrocardiogram:* cases which presented electrocardiographic features of a left or an extreme right ventricular hypertrophy. (3) *Age:* cases in which the patients were younger then 2.5 years or older than 17 years. (4) *Radiology:* cases in which there was a cardiothoracic ratio of 55 per cent or more. (5) *Hemoglobin:* cases in which the hemoglobin was more than 150 per cent or less than 70 per cent. (6) *Development:* cases in which the patients were underweight by more than 10 per cent of the normal values. (7) *Precociousness of symptoms:* cases in which the signs of circulatory disturbances were accentuated at birth.

On the basis of the foregoing criteria, we have divided our patients into three groups: I. *Cases with a good prognosis:* those patients who before surgical intervention had none of the seven factors listed above (49 cases, left-hand column of Fig. 12). II. *Cases with an average prognosis:* those patients who before surgery had only one of the factors listed above (52 cases, middle column of Fig. 12). III. *Cases with a poor prognosis:* those patients who before surgery had from two to six of the factors listed above (49 cases, right-hand column of Fig. 12).

If Groups I and III are compared, it is seen that the mortality ranges from 4 to 41 per cent, and in the cases with excellent results, from 29 to 4 per cent. Those cases that had a good prognosis had a mortality of only 4 per cent and had very good postoperative results.

LATE EVOLUTION OF THE RESULTS OBTAINED

The results of our study have a certain stability, because they have been calculated after an extended follow-up. In effect, it is during the first postoperative years that the majority of the unfavorable results were recorded. However, after 2 years or more, we reached a remarkable stabilization of the amelioration obtained from the operation. In certain cases this amelioration was progressive in character, even though at times momentarily halted by special circumstances (rapid growth during puberty, or too large an expenditure of energy in children who were too active). We were astonished by the fact that the majority of our patients became better and not worse as time passed. This was probably due to the following factors: (1) better oxygenation of the arterial blood, and

then of the myocardium; (2) better filling and functioning of the left ventricle, producing a more adequate outflow; (3) creation of the shunt by low pulmonary arterial pressure, that enables it to be efficient.

In those patients who survive, the results tend to stabilize. This is demonstrated by the analyses of Taussig[29,30] and Potts,[24] and holds true in our study. Fig. 13 shows that the number of failures did not increase as the years passed. In Fig. 13, one sees from the left to the right: (left-hand column) 141 patients who were followed up within the first 2 years after the operation; (middle column) 97 patients who were followed up for the last time from 2 to 5 years postoperatively; and (right-hand column) 50 patients who were followed up for the last time within 5 and 8 years postoperatively. However, after many years (10 to 15 years and probably longer) the mortality rate may again rise because of cardiac insufficiency. To be sure, our patients never regained a normal heart, but rather, they developed acceptable circulatory conditions that ought to permit them to live to a respectable age: 40 or 50 years or even longer. The remarkably good results of the test of the function of the heart confirms the optimism of those prognostics.

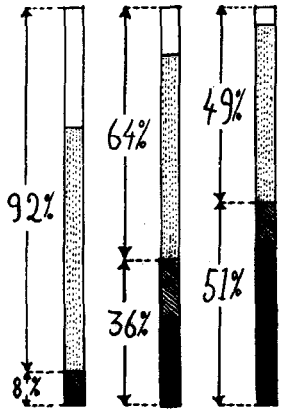

Fig. 12.

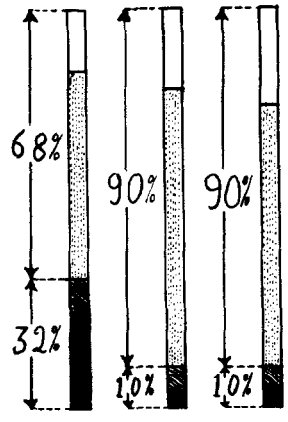

Fig. 13.

CONCLUSIONS

It is possible to establish criteria for making a good preoperative prognosis in cases of cyanotic malformations of the heart. The optimal size of the operative shunt to be made must range from 4 to 6 mm. in diameter. The best results are to be had with the Potts and Blalock procedures; the Brock operation should be avoided because of a high operative mortality, probably as a consequence of the frequency of the infundibular type of the stenosis in the tetralogy of Fallot. Finally, the shunt-operations still benefit the patients many years later.

The problem of treating congenital cyanosis still has not been resolved up to the present time. The prospects of surgical correction of these malformations with the aid of a heart-lung machine will enable us gradually to abandon the old methods of Blalock, Potts, and Brock. The aim of the surgeon always is

to try to reconstruct a normal anatomic situation. However, anatomic restoration does not necessarily correspond to normal physiologic function, nor to a good clinical state. The results of the newer methods have not been very encouraging in so far as congenital cyanotic disease is concerned. In 1957, Lillehei[20] presented a series of 60 cases of tetralogy of Fallot operated upon in this manner, in which the immediate operative mortality was 33.3 per cent. This mortality was quite high, in spite of the favorable choice of patients, who were always more than 3 years old, and who could not be too old, because of the small outflow that the artificial heart permitted at that time. When a stenosed pulmonary valve can be incised and a small interventricular communication can be sutured, it is certain that the result will be a heart that is practically normal, with maximal possibilities for the patient's survival; this result is certainly superior to that obtainable from the Potts operation. However, cases which are so favorable are rare, and until now, we know nothing about the long-term evolution of the patients who have survived such an operation. It is questionable whether the restoration of the outflow tract of the right ventricle would permit good hemodynamic function for many years. Also, sufficient information is not yet available to confirm whether the plastic material used in these operations will be perfectly well tolerated with the passing of time.

These objections are even more valid since the long-term results of the shunt-operations are even better than expected. The patients whose progress has been stabilized a year or two after the operation have acquired an astonishing physical capacity, sometimes even a normal physical capacity, as has been confirmed by the cardiac function test. This improvement is still present after a lapse of 6 to 8 years, with these patients showing neither a weakening of their general condition nor signs of the beginning of a cardiac failure.

The aim of this study was to bring up to date the information concerning shunt-operations and the postoperative evolution of patients undergoing such operations. In making our evaluation we have tried to find as precise criteria as possible in order to give a preoperative prognosis and to evaluate the results obtained. These criteria will permit us in the future to compare the new and the old methods. For the present we ought to be satisfied with the notable stability of our operative results, a stability which to a large extent conforms to the results of Taussig[30] and Potts.[24]

SUMMARY

This paper reports a study of the long-term results of 150 operations for congenital cyanosis in 141 patients. All living patients, except one, were reexamined in 1956 or 1957. A preoperative prognosis was made, taking various factors (age, hemoglobin content, electrocardiogram, roentgenogram, etc.) into account. In those cases having a favorable preoperative prognosis, 90 per cent had good postoperative results, one third of which were excellent, the mortality being 4 per cent. The mortality was 10 times higher in cases with unfavorable preoperative prognosis. The cases in which the Potts operation was used were the most successful. The successful postoperative results obtained from the

three operations used (Potts, Blalock, and Brock procedures) were seen to be durable during the years that followed. In general, the postoperative modifications in the clinical signs, the electrocardiograms, and the roentgenograms were stabilized within the first two years after the operation. Some patients, even after a period of several years, were considered to have normal cardiac function, according to their performance in a cardiac function test that is described in the text.

REFERENCES

1. Azevedo, A., Toledo, A., Roubach, R., and De Carvalho, A.: O electrocardiogramma da tetralogia de Fallot, Arch. Inst. cardiol. Mexico **23**:589, 1953.
2. Bahnson, H., and Ziegler, R.: A Consideration of Causes of Death Following Operation for Congenital Heart Disease of Cyanotic Type, Surg. Gynec. & Obst. **90**:60, 1950.
3. Blalock, A.: A Consideration of Some of the Problems in Cardiovascular Surgery, J. Thoracic Surg. **21**:543, 1951.
4. Blalock, A., and Taussig, H.: The Surgical Treatment of Malformations of the Heart in Which There Is Pulmonary Stenosis or Pulmonary Atresia, J.A.M.A. **128**:189, 1945.
5. Bret, J.: Indications et résultats des opérations de Blalock, de Potts et de Brock dans 200 cas de sténose pulmonaire, Arch. mal. coeur **45**:577, 1952.
6. Brock, R.: Pulmonary Valvulotomy for Relief of Congenital Pulmonary Stenosis: 3 Cases, Brit. M. J. **1**:1121, 1948.
7. Campbell, M.: Morbus Caeruleus and Its Surgical Treatment, Lancet **2**:647, 1951.
8. Campbell, M., and Deuchar, D.: Results of Blalock-Taussig Operation in 200 Cases of Morbus Caeruleus, Brit. M. J. **1**:349, 1953.
9. McCord, M., and Blount, S. G.: Complications Following Infundibular Resection in Fallot's Tetralogy, Circulation **11**:754, 1955.
10. Derra, E.: Moderne Verfahren der Herzchirurgie, Deutsches med. J. **3**:517, 1952.
11. Donzelot, E., and D'Allaines, F.: Traité des cardiopathies congénitales, Paris, 1954, Masson et Cié.
12. Donzelot, E., Metianu, C., Durand, M., Cherchi, A., and Vlad, P.: L'electrocardiogramme dans la tétralogie de Fallot (étude de 100 cas), Arch. mal. coeur **44**:97, 1951.
13. Ford, H.: International Symposium On Cardiovascular Surgery, Philadelphia, 1955, W. B. Saunders Company.
14. Hartleb, O.: Uber das Fehlen von Geräuschphänomenen bei Fallotscher Tetralogie, Ztschr. Kreislaufforsch. **45**:360, 1956.
15. Johnson, J.: Surgery of Congenital Heart Disease, Surg. Clin. North America **31**:1811, 1951.
16. Joly, F., Folli, G., and Carlotti, J.: Etude électrocardiographique comparée des trilogies et tétralogies de Fallot, Arch. mal. coeur **45**:1108, 1952.
17. Jongbloed, J., van Nieuwenhuizen, C., and van Goor, H.: A Heart Function Test With Continuous Registration of Oxygen Consumption and Carbon Dioxide Production, Circulation **15**:54, 1957.
18. Kjellberg, S., Mannheimer, E., Rudhe, U., and Jonsson, B.: Diagnosis of Congenital Heart Disease, Chicago, 1955, The Year Book Publishers, Inc.
19. Leininger, C., Gibson, S., and Potts, W.: Congenital Pulmonary Stenosis; Postoperative Observations on 214 Children, A.M.A.J. Dis. Child, **81**:465, 1951.
20. Lillehei, C.: Bruxelles-Médical **37**:1779, 1957.
21. Miller, R.: The Electrocardiogram in Congenital Malformation of the Heart, Pediat. Clin. North America **1**:51, 1954.
22. Nadas, A.: Pediatric Cardiology, Philadelphia, 1957, W. B. Saunders Company.
23. Potts, W.: The Surgical Treatment of Tetralogy of Fallot, Rev. méd. Suisse Rom. **75**:576, 1956.
24. Potts, W., Gibson, S., Berman, E., White, H., Miller, R.: J.A.M.A. **159**:795, 1955.
25. Potts, W., Smith, S., and Gibson, S.: J.A.M.A. **132**:627, 1946.
26. Richards, M.: Pediatrics **9**:77, 1952.
27. Sellors, T., and Belcher, J.: Lancet **2**:887, 1950.
28. Soulié, P.: Cardiopathies congénitales, Paris, 1956, Expansion scientifique française.
29. Taussig, H., and Bauersfeld, S. R.: Ann. Int. Med. **38**:1, 1953.
30. White, B., McNamara, D., Bauersfeld, S. R., and Taussig, H.: Circulation **14**:512, 1956.
31. Wilson, J.: Thorax **5**:73, 1950.
32. Woods, A.: The Electrocardiogram in Tetralogy of Fallot, Brit. Heart J. **14**:193, 1952.