Five-Year Postoperative Results of First 500 Patients with Blalock-Taussig Anastomosis for Pulmonary Stenosis or Atresia

By B. Daniel White, M.D., Dan G. McNamara, M.D., S. Richard Bauersfeld, M.D., and Helen B. Taussig, M.D.

The evaluation of surgical corrective procedures depends to an important degree on the long-term benefits derived from the operation. Three hundred and eighty-nine of the first 500 patients with a Blalock-Taussig anastomosis for pulmonary stenosis or atresia survived 6 months or longer. Detailed information is now available on 244 of these patients, who were originally improved by operation and who have been followed for 5 years or longer. The results obtained on patients with tetralogy of Fallot are compared with those with other malformations. The alteration of the size of the heart over a period of years has been studied. A comparison between the preoperative and postoperative hemograms and arterial oxygen saturations is presented. The optimum age for operation, the causes of late deaths, and the incidence of bacterial endocarditis are discussed.

FIVE hundred patients were operated on for relief of pulmonary stenosis or atresia1, 2 by Dr. Alfred Blalock and his associates between November 29, 1944, and September 25, 1947. Eight-one of these patients died at or within the first 6 months of operation, and 30 patients had exploratory thoracotomies only. Thus there 389 patients among the first 500 who survived 6 months or longer after surgery. Sixty-seven of the 389 patients have been lost from follow-up. Eleven patients who survived surgery were unimproved by their first operation. In addition, there were 67 on whom a 5-year check-up was not completed at the time this study was closed. None of these patients are included. Therefore this study is concerned primarily with the 244 patients originally improved by surgery and whose present status is known. On all those living, a teleroentgenogram, at least 2 of the 3 standard measurements of the red blood cell count, and, in many instances, determination of the arterial oxygen saturation before operation and 5 to 8 years after surgery have been obtained. Most of these patients were examined by the physicians in the Cardiac Clinic of the Harriet Lane Home. For the remainder we are indebted to their personal physicians for sending us their reports.

As in a previous report,3, 4 the results are classified as good or fair. A good result means that after operation the exercise tolerance is virtually normal, and the red blood cell count, hemoglobin, and hematocrit have returned to nearly normal levels. A fair result means that although the patient showed some improvement after operation, he still suffered from limitation of exercise and polycythemia.

A review of the 244 patients originally improved showed that 226 (93 per cent) obtained a good result from operation, and 18 (7 per cent) obtained only a fair result. At 5 to 8 years after operation, 163 or 67 per cent of the 244 patients have maintained the benefit derived from operation. This number represents 72 per cent of the 226 who originally obtained a good result. Sixteen (7 per cent) are now fair, and 9 patients (4 per cent) are no longer improved. Twenty-three patients (9 per cent) have required and survived second operations, and 33 (14 per cent) have died. Furthermore, of the 18 patients who originally obtained a fair result, 2 have remained fair, 6 have had and survived a second operation, 2 no longer show any improvement, and 8 have died (last column of table 1).

It has been repeatedly emphasized that the long-term results have been better for patients...
with a tetralogy of Fallot than for those with other malformations such as tricuspid atresia, single ventricle with pulmonary stenosis, pseudotruncus arteriosus, transposition with pulmonary stenosis, etc. Therefore this group of 244 patients has been analyzed according to the type of cardiac malformation, i.e., whether they belong to the group with a tetralogy of Fallot, or whether they belong to the group with some other type of malformation. The results (table 1) confirm this observation. Two hundred and twelve patients were diagnosed as having a tetralogy of Fallot, and 32 had other malformations. Of those patients with a tetralogy of Fallot 69 per cent are still doing well, and only 11 per cent have died. Whereas in the small group of 32 patients with other malformations, only 16 or 50 per cent are doing well, and 31 per cent have died.

In order to evaluate further the results of operation, the changes in the size of the heart, the hemogram, and whenever possible, the arterial oxygen saturation have been studied in the 163 patients who are doing well 5 to 8 years after operation. On the basis of these findings, these patients have been divided into 3 groups.

Group Good A includes the patients whose exercise tolerance is virtually normal, and whose hearts are stationary in size, with a cardiothoracic ratio of 60 per cent or less. The hemograms are also stationary, with a maximum red blood count of 6.5 million, a maximum hemoglobin of 17 Gm., and a maximum hematocrit reading of 55 volumes per cent. To eliminate errors in technic at least 2 of these determinations were necessary to include a patient in the adequate followup group. The arterial oxygen saturation, when obtained, had to be 75 per cent or higher. Five to 8 years after operation, there were 126 patients in this group.

The criteria for group B differ from group A only in that the cardiothoracic ratio may be greater than 60 per cent, but in no instance has there been progressive cardiac enlargement. In most of these patients, the heart enlarged immediately after operation, and thereafter showed no further increase in size. Of the 23 patients now in group B, 5 had a cardiothoracic ratio over 60 per cent prior to surgery, 8 had a cardiothoracic ratio over 55 per cent, and 10 had a cardiothoracic ratio under 55 per cent. Consequently, although these patients now show considerable cardiac enlargement, there has been no great increase in the size of the heart.

Group C differs from group A in that the hemogram may be elevated. Nevertheless, the polycythemia appears to be stationary over a period of years. There are 14 patients in this group.

The various changes in the entire group of 163 patients who are doing well have been analyzed in detail. As previously mentioned, in order to consider that we had detailed information a preoperative and postoperative teleroentgenogram was required, but only 2 of the 3 measurements of the red blood cell count were considered necessary. Consequently, the number of patients with red blood cell counts, hemoglobins, and hematocrit readings varies slightly.

The size of the heart 5 to 8 years after operation was compared with the preoperative size (table 2). The postoperative cardiothoracic ratios are graded, as recommended by the Department of Radiology, as a decrease when the ratio is more than 5 per cent lower than the preoperative figure; no change when there is a plus or minus 5 per cent change; slight increase when there is an increase of between 5 and 10 per cent; and marked increase when the increase is more than 10 per cent over the preoperative figure. An analysis of the x-ray changes based on these criteria showed that among the patients with small hearts preoperatively there was a higher incidence of postoperative cardiac enlargement than among

<table>
<thead>
<tr>
<th>Group</th>
<th>Tetralogy of Fallot</th>
<th>Other malformations</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>147 (69%)</td>
<td>16 (50%)</td>
<td>163 (67%)</td>
</tr>
<tr>
<td>Fair</td>
<td>15 (7%)</td>
<td>1 (3%)</td>
<td>16 (7%)</td>
</tr>
<tr>
<td>No longer improved</td>
<td>8 (4%)</td>
<td>1 (3%)</td>
<td>9 (4%)</td>
</tr>
<tr>
<td>Second operation</td>
<td>10 (9%)</td>
<td>4 (13%)</td>
<td>23 (9%)</td>
</tr>
<tr>
<td>Late death</td>
<td>22 (11%)</td>
<td>10 (31%)</td>
<td>33 (14%)</td>
</tr>
<tr>
<td>Total</td>
<td>212</td>
<td>32</td>
<td>244</td>
</tr>
</tbody>
</table>
TABLE 2.—Postoperative Changes in Heart Size

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Patients</td>
<td>Decrease over 5%</td>
</tr>
<tr>
<td>Under 50%</td>
<td>69</td>
<td>1%</td>
</tr>
<tr>
<td>Over 50%</td>
<td>94</td>
<td>13%</td>
</tr>
</tbody>
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TABLE 3.—A Comparison of Preoperative and Postoperative Cardiothoracic Ratios in 163 Patients with Good Results

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Patients</td>
<td>Decrease over 5%</td>
</tr>
<tr>
<td>Under 45%</td>
<td>29</td>
<td>0%</td>
</tr>
<tr>
<td>45%-50%</td>
<td>40</td>
<td>0%</td>
</tr>
<tr>
<td>50%-55%</td>
<td>56</td>
<td>4%</td>
</tr>
<tr>
<td>55%-60%</td>
<td>29</td>
<td>7%</td>
</tr>
<tr>
<td>More than 60%</td>
<td>9</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>163</td>
<td>9%</td>
</tr>
</tbody>
</table>

those who already had cardiac enlargement preoperatively. Indeed, of 69 patients who had a preoperative cardiothoracic ratio of less than 50 per cent, 1 per cent have a postoperative decrease in cardiac size, 42 per cent show no change, and 57 per cent have an increase in cardiac size of varying degree 5 to 8 years after operation. Whereas among the remaining 94 patients with preoperative cardiothoracic ratios over 50 per cent, 15 per cent now have a decrease, 60 per cent show no change, and only 26 per cent have an increase 5 to 8 years after surgery. A detailed analysis of the postoperative changes in cardiac size is shown in table 3.

A review of the auscultatory findings of the 163 patients who were doing well showed that in most instances a continuous murmur was present. In 146 patients a continuous murmur of varying intensity was heard. In 15 instances the examining physician failed to comment on its presence or absence. In 2 patients no continuous murmur was audible. One of these patients was extremely obese, and it was thought that the thickness of the chest wall rendered the continuous murmur inaudible. In the other there is grave doubt that the original diagnosis of a tetralogy of Fallot was correct. Broadly speaking, the presence of a continuous murmur indicates that some blood is flowing from the aorta to the lungs, but it is not a reliable index of the amount. In our experience, it may still be audible when the exercise tolerance has dropped and the hemogram has risen. Its absence, however, is usually of grave prognostic import.

Preoperative and postoperative red blood cell counts were obtained on 156 patients who maintained a good result from the initial operation. Of the 34 patients who had preoperative red blood cell counts of under 6.5 million, only 2 have subsequently shown an increase in polycythemia. Of the 58 patients with counts of 6.5 to 8 million preoperatively, only 4 remain that high. Furthermore, of the 64 patients who had preoperative counts of 8 million or more, only 6 now show polycythemia with red blood cell counts between 6.5 and 8 million. Thus, of the entire group of 156 patients only 12 have counts over 6.5 million 5 to 8 years after operation. The exact number of patients in each group before and after operation is shown in figure 1.

The analyses of the preoperative and post-
operative hemoglobin determinations show similar changes. Of the 35 patients with preoperative hemoglobin determinations under 17 Gm., only 3 have shown an increase in the level of the hemoglobin. Of 37 with preoperative hemoglobin of 17 to 20 Gm., only 7 still have hemoglobin levels in the same range. Furthermore, of the 59 patients who had a hemoglobin level of 20 Gm. or more preoperatively, only 4 now have a hemoglobin which approaches 20 Gm. Thus, of this group of 131 patients, 14 now have seriously high hemoglobin levels. Further details of the number of patients in each group are shown in figure 2.

A similar analysis of the hematocrit readings is shown in figure 3. Although 56 patients had hematocrit readings over 65 per cent before operation, only 7 now have hematocrit readings between 55 and 65 per cent. Indeed, of the entire group only 14 patients show postoperative readings between 55 and 65 per cent. A hematocrit of 55 per cent or a red blood cell count of 6.5 million is admittedly high, but all present evidence indicates that this mild degree of polycythemia is well tolerated.

When obtained, an arterial oxygen saturation was required to be at least 75 per cent in order to classify the patient as having a good result.

Ninety-five patients are now known to have an arterial oxygen saturation of this level or above, regardless of the preoperative level, which in 3 instances was less than 20 per cent and in an additional 15 was under 35 per cent. It was indeed remarkable to find 28 patients now with an arterial oxygen saturation at rest of between 90 and 100 per cent. Twenty patients

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**Fig. 2.** Preoperative and 5-year postoperative hemoglobin levels in 131 patients with good results.

**Fig. 3.** Preoperative and 5-year postoperative hematocrit readings in 126 patients with good results.

**Fig. 4.** Preoperative and 5-year postoperative arterial oxygen saturations in 95 patients with good results.
were operated on because of polycythemia or severe limitation of exercise rather than a low arterial oxygen saturation. Eight of these patients now show an arterial oxygen saturation at rest of 90 to 100 per cent. The others have shown little or no change after operation. Further details appear in figure 4.

The age at operation and the number of patients in each age group who are doing well 5 to 8 years after operation were analyzed (table 4). The best results were obtained among the children who were 8 to 12 years old at the time of operation. Of the patients operated upon between the ages of 8 and 10 years 81 per cent are doing well, and 85 per cent of those operated upon between 10 and 12 years are also doing well at the present. Between 2 and 8 years, however, approximately 64 per cent of the patients are doing well. The age group of 12 to 20 years is almost equally good, 62 per cent. Although the groups under 2 years of age and over 20 years of age are too small to be of statistical significance, we believe the figures reflect the great difficulty encountered in operations on patients of these age groups.

Second operations have been performed, in the group of 244 patients originally improved, on 23 patients who failed to maintain improvement from their first anastomosis. Of this number, 19 (83 per cent) had their original Blalock-Taussig anastomosis under the age of 8 years, and 3 (13 per cent) had the original procedure between the ages of 12 and 20 years. Indeed, only 1 patient originally operated upon between the ages of 8 and 12 years required a second operation, and this patient did not have a tetralogy of Fallot. This finding is in line with the previous observation that the best long-term results from operation were obtained between the ages of 8 and 12 years. Of the 23 second operations, 9 were performed less than 5 years after the first anastomosis, 7 were necessary 5 years later, 3 were performed 6 years later, and 4 were performed 7 years later.

Subacute bacterial endocarditis has been suspected more often than it has been proved. Although it is well known that in the early postoperative period these patients are extremely susceptible to subacute bacterial endocarditis, there is no evidence of increased susceptibility to infection after the wound has healed. To the best of our knowledge, between May 1945 and September 1952 this infection has been diagnosed in 15 patients (6 per cent) out of the 244 originally improved by operation. The diagnosis was, however, definitively established by blood culture in only 8 patients. Fortunately, only 1 of the 15 patients has died from the infection.

During this same period of time, there have been 33 late deaths in this group of 244 patients who were originally improved by an anastomosis. Twenty-five of the deaths occurred among the 226 patients who obtained a good result from operation and 8 deaths occurred among the small group of 18 patients who were only moderately improved by operation. This is a mortality rate of 11 per cent in the former group and 44 per cent in the latter group. Thus the prognosis is infinitely better for the patient who has obtained a good result from operation.

At the time of death, 8 of the patients in the late death group were known to have maintained the good results derived from surgery, 6 were losing ground, and 19 were no longer improved. Seven patients among those no longer improved died at the time of a second operation. Of 5 others, 1 died of each of the following: acute anoxemia, pneumonia, cerebral thrombosis, coronary thrombosis, and postphlebotomy reaction. Furthermore, among the 8 patients who had maintained their original improvement, 1 died of leukemia, 1 of subacute bacterial endocarditis, 1 of a brain

<table>
<thead>
<tr>
<th>Table 4.—Age at Operation and Percentage of Good Results</th>
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<tbody>
<tr>
<td>Age in years ...........................................</td>
</tr>
<tr>
<td>No. of patients ..........................................</td>
</tr>
<tr>
<td>No. good results ..........................................</td>
</tr>
<tr>
<td>Per cent good results .....................................</td>
</tr>
</tbody>
</table>
abscess, 1 of meningitis, and 1 of an acute infection the nature of which was unknown. In the remaining 3 the cause of death is unknown to us.

Finally, it is noteworthy to find that only 2 patients of the entire group of 33 "late deaths" died of cardiac failure, and neither of these patients proved to have a tetralogy of Fallot. This finding presents strong evidence that a patient with a tetralogy of Fallot is not in danger of progressive cardiac enlargement and death from cardiac failure.

**SUMMARY AND CONCLUSIONS**

The 5 to 8-year follow-up on the first 500 Blalock-Taussig anastomoses shows the following figures: 81 patients died at, or within 6 months of, operation; 30 had exploratory thoracotomies only; 389 survived 6 months or longer. Sixty-seven patients have been lost to us, another 67 had not had recent or sufficiently complete check-ups at the close of the study, and 11 patients were unimproved by their first operation. There remain 244 patients who were originally improved by a Blalock-Taussig anastomosis, and on whom complete information is available; of these, 226 obtained good results and 18 obtained fair results from the first anastomosis. The good results have been maintained in 67 per cent 5 to 8 years after surgery and 7 per cent are fair; 4 per cent are no longer improved, 9 per cent of those originally improved have required and survived a second operation, and 14 per cent are known to have died between 6 months and 8 years after operation. A higher percentage of those patients in the tetralogy of Fallot group have maintained good results postoperatively than those in the group with other malformations of the heart, and the mortality rate is significantly lower in the former group. Of the 163 patients with good results who were analyzed for changes in cardiac size, changes in the hemogram, and, whenever possible, changes in the arterial oxygen saturation, it was found that 126 are excellent in all respects. Twenty-three patients from the group of 163 have considerable cardiac enlargement, which is not progressive. Fourteen patients have moderate polycythemia, which also is not progressive. In the vast majority of these patients a good continuous murmur was found. The optimum time for operation is from 8 to 12 years of age. The incidence of subacute bacterial endocarditis in the late postoperative group was 6 per cent. Of the 226 patients who originally obtained good results, 11 per cent have died, whereas of the 18 who obtained only fair results 44 per cent have died. Of the 33 patients who have died, 19 were no longer improved, 6 were losing ground, and 8 were doing well at the time of death. No patients with a tetralogy of Fallot have died from cardiac failure.

A patient with a pulmonary stenosis or atresia who has obtained a good result from a Blalock-Taussig anastomosis has a 67 per cent chance for the maintenance of that improvement 5 to 8 years after operation.

If the patient has a tetralogy of Fallot, his chance for maintenance of improvement increases to 69 per cent, whereas if he has some other malformation (tricuspid atresia or a single ventricle with pulmonary stenosis, etc.), his chance is but 50 per cent.

The late mortality rate is significantly higher for patients with other malformations than for those with a tetralogy of Fallot (30 per cent in the former group and 10 per cent in the latter group).

There is approximately a 20 per cent chance that the patient will need a second operation.

A patient with a small heart prior to operation is more likely to show cardiac enlargement after operation than a patient in whom the heart is at or above the upper limit of normal at the time of operation.

The absence of a continuous murmur usually indicates that the anastomosis is no longer functioning.

The optimum age for operation is between 8 and 12 years; 80 per cent of the patients in this age group have maintained their improvement 5 to 8 years after operation.

The risk of subacute bacterial endocarditis, although real, is not great, approximately 6 per cent, in a 5 to 8-year period.

A patient with a tetralogy of Fallot does not develop progressive cardiac enlargement after a Blalock-Taussig anastomosis.

Patients in whom the red blood cell count
RESULTS OF ANASTOMOSIS FOR PULMONARY STENOSIS

remains below 6.5 million, and hemoglobin below 17 Gm., and the hematocrit below 55 per cent have an excellent long-term prognosis. A patient with these findings who has a tetralogy of Fallot and a cardiothoracic ratio of 50 per cent or less has an especially good prognosis.

ACKNOWLEDGMENT

The authors of this paper are deeply grateful to Mrs. Norman Schaff, a volunteer at the Johns Hopkins Hospital, for her untiring efforts in making this study possible. Their thanks are also due to Mrs. Mary Linderman for her excellent figures.

SUMMARIO IN INTERLINGUA

Observationes de consecutione de 5 a 8 annos post le prime 500 anastomoses de Blalock-Taussig resulta in le sequente statistica: 81 patientes moriva al operatione o intra 6 menses postea; 30 habeva solmente thoracotomias explorator; 389 superviveva 6 menses o plus. Sexanta-septe patientes ha escapate; un secunde gruppo de 67 non eseva re-examine satis recente- o satis completamente al fin del presente studio; e 11 patientes habeva obtenite nulle beneficio ab lor prime operation. Remane 244 patientes in qui le anastomosis Blalock-Taussig resultava originalmente in meliorationes e pro qui complete informationes es disponibile. Iste gruppo include 226 patientes pro qui le resultatos del prime anastomose eseva bon e 18 pro qui illos eseva satis bon. Le bon resultatos ha remanite bon, 5 a 8 annos post le operation, in 67 pro cento del casos; in 7 pro cento del casos illos descendeva al nivell de satis bon e in 4 pro cento a non-meliorate. Nove pro cento del casos originalmente meliorate per le operation ha requirete un secunde operation e ha supervivite a illo. In 14 pro cento del casos de iste serie il es cognoscite que le patientes moriva inter 6 menses e 8 annos post le operation. Le procentage de bon resultatos perdurative es plus alte in le gruppo de patientes con tetralogia de Fallot que in le gruppos del patientes con altere malformationes del corde, e etiam le mortalitate es significativamente plus favorable in le gruppo a tetralogia de Fallot. Inter le 163 patients con bon resultatos, in qui analyses eseva facite pro alterate dimensiones cardiac, alterationes del hemato-
tion que le patiente qui veni al operation con un corde al limite superior o supra le limite superior del normal dimensiones cardiac.

Le absentia de un murmure continue indica in general que le anastomose ha cessate functionar.

Le riso de subacute endocarditis bacterial es real sed non grande. Illo amonta a circa 6 pro cento infra 5 a 8 annos post le operation.

Un patiente con tetrachia de Fallot non dis-voloppa progressive allargamento cardiac post anastomose Blalock-Taussig.

Patientes in qui le numeration erythrocytic remane infra 6,5 millions, le hemoglobina infra 17 g, e le hematocrite infra 55 pro cento ha excellente prognoses a longe durantia. Patientes qui satisface iste criterios e qui ha tetrachia de Fallot e un proportion cardio-thoracic de 50 pro cento es distinguite per specialmente bon prognoses.

REFERENCES

Medical Eponyms

By Robert W. Buck, M.D.


"There is a malformation of the heart unaccompanied by cyanosis, in spite of the communication between the ventricles and in spite of the free admixture of venous and arterial blood; this malformation, which is compatible with life and even with prolonged existence, is simple and is not accompanied by pulmonary stenosis; it consists in patency of the septum between the ventricles. . . ."

"It is revealed only by auscultation and shows itself by a physical sign with quite distinctive characteristics: this is a loud, prolonged whirring sound; it is a single murmur, beginning with systole and continuing in such a way as to entirely mask the normal rhythm; its maximum intensity is not at the apex . . . or at the right or left side of the base . . . but over the upper third of the pre-cordial region; it is central like the septum itself, and diminishes gradually from this central point the farther it from one listens; it is not transmitted; it corresponds to no other sign of organic disease except the purring thrill. An abnormal murmur which combines these characteristics is the pathognomonic sign of patency of the ventricular septum."