In an elderly patient with recent myocardial infarction, arterial flow was successfully restored to the small intestine 18 hours after the occurrence of mesenteric arterial thrombosis by endarterectomy of the superior mesenteric artery. Unfortunately, the shock farction, arterial flow was successfully restored to the small intestine 18 hours after the occurrence of a second operation and the myocardial infarction led to death of the patient 36 hours later.

Emphasis is placed on the diagnosis of mesenteric arterial insufficiency at an early stage when malabsorption or abdominal angina, rather than intestinal infarction, is the presenting complaint. In all cases of mesenteric insufficiency, the celiac and superior and inferior mesenteric arteries should be explored with preparation for endarterectomy or bypass graft. When it is possible, restoration of arterial flow is preferable to extensive resection of the intestine.

The authors are indebted to Dr. H. C. Robinson for referring the patient described in this report and for assistance in her management. The illustrations are the work of Mr. William Bending of the Art Department, University of Western Ontario Medical School.

REFERENCES

The Diagnosis and Treatment of Congenital Heart Disease:
Part II. Treatment of Congenital Heart Disease in the Infant and Neonate


In a previous communication, a classification of congenital heart disease was proposed, based on the predominance of the right or left ventricle, and the degree of pulmonary arterial plethora in the postero-anterior radiograph of the chest (Tables I and II). This classification is based on personal experience with patients who presented for consideration of surgical treatment, and, as such, is not completely applicable to all patients with congenital heart disease. For example, patients with pulmonary atresia suitable for surgical correction usually have a right ventricular predominance, but if all cases of pulmonary atresia are analyzed, less than 20% have a large right ventricle.

Part II of this study deals with the treatment of acute cardiac disability in the neonate and in the infant less than one year of age.

TREATMENT OF ACUTE CARDIAC FAILURE IN INFANTS LESS THAN ONE YEAR OF AGE

The mortality rate of infants under one year of age, who are in heart failure, is over 70% unless intensive therapy, and often surgical treatment, is instituted.

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†Surgeon, Cardiovascular Unit, London, Ont.
‡Surgeon, Cardiovascular Unit, London, Ont.
TABLE II.—Modified Classification of Congenital Heart Disease. The less common lesions, those with an incidence of less than 3%, have been omitted.

<table>
<thead>
<tr>
<th>Right ventricle</th>
<th>Left ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1. No plethora</td>
<td>1. Coarctation of aorta</td>
</tr>
<tr>
<td>2. Pulmonary valve stenosis</td>
<td>2. Aortic stenosis</td>
</tr>
<tr>
<td>2. Aortic stenosis</td>
<td></td>
</tr>
<tr>
<td>II. Plethora</td>
<td></td>
</tr>
<tr>
<td>1. Atrial septal defect</td>
<td>1. Patent ductus arteriosus</td>
</tr>
<tr>
<td>2. Transposition of great vessels</td>
<td>2. Ventricular septal defect</td>
</tr>
<tr>
<td>III. Oligemia</td>
<td></td>
</tr>
<tr>
<td>1. Fallot's tetralogy</td>
<td>1. Tricuspid atresia</td>
</tr>
</tbody>
</table>

MEDICAL TREATMENT OF HEART FAILURE IN THE NEONATE

Acute cardiac disease in an infant is usually manifested by dyspnea which is precipitated by feeding. Many infants are admitted to a children's hospital with the diagnosis of "feeding problem", when the underlying condition is, in fact, heart failure. The increased work of suckling precipitates their breathlessness.

Coughing, when it is evidence of another manifestation of heart failure (pulmonary edema), may be mistaken for respiratory infection; the latter is commonly found in infants with congenital heart lesions with a left-to-right shunt.

It is again emphasized that infants in heart failure, with rare exceptions, have enlarged hearts.

Three main points should be remembered in the treatment of congestive heart failure in the infant.

1. Infants tolerate large doses of morphine and digitalis well.
2. A fine polyethylene gastric feeding catheter greatly reduces the work of feeding and the resultant dyspnea.
3. The patient should be treated in the semi-erect position (35°).

The digitalizing dose of digitoxin for an infant is 0.05 mg. per lb. of body weight in divided doses over the first 24 hours. The maintenance dose (daily dose) is one-fifth of the digitalizing dose.

Morphine is the drug of choice for restlessness. It is also used preoperatively and postoperatively, and is given in doses of 0.1 mg. per lb. of body weight. This may be repeated every four hours.

Hydrochlorothiazide (Hydrodiuril) is occasionally useful. The danger of excess potassium loss while this drug is being administered appears to be less than in the adult receiving similar therapy.

In summary, in the medical treatment of congestive heart failure in infants, one must consider the use of the semi-erect position, tube feeding, and digitalis, morphine and diuretics (Table III).

TABLE III.—MEDICAL TREATMENT OF CONGESTIVE HEART FAILURE IN NEONATE

<table>
<thead>
<tr>
<th>Digitalis</th>
<th>Morphine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drugs</td>
<td>2. Tube feeding</td>
</tr>
<tr>
<td></td>
<td>3. Semi-erect position</td>
</tr>
</tbody>
</table>

SURGICAL TREATMENT OF THE NEONATE IN CARDIAC FAILURE

Operative treatment is frequently indicated for the infant in serious distress due to cardiac disease, and quite satisfactory results can often be anticipated. The indications for operation are usually one or more of the following:

1. Dyspnea that cannot be controlled by medical means.
2. Cyanotic attacks that may go on to unconsciousness.
3. Severe coughing in the presence of pulmonary edema (Table IV).

TABLE IV.—INDICATIONS FOR OPERATION

| 1. Dyspnea (severe) |
| 2. Cyanotic attacks (frequent) |
| 3. Coughing (severe) |

Operations in this age group may be divided into (A) those that are curative and (B) those that are palliative.

A. The curative group includes those with the following lesions:

1. Patent ductus arteriosus
2. Coarctation of the aorta
3. Aortic arch anomalies
4. Pulmonary stenosis with a normal aortic root
5. Total anomalous pulmonary venous drainage

These anomalies may be greatly benefited or completely cured by operative treatment during infancy.

1. Patent Ductus Arteriosus (Fig. 1)

Occasionally a persistent ductus arteriosus, occurring as a solitary lesion, will cause intractable heart failure in this age group. Operative treatment is strongly indicated in such cases. The patent ductus is usually a large one in this instance, and may on occasion be almost as large as the descending aorta. The operation is a straightforward one, and a total anesthetic time of less than one hour is required as a rule. The infants tolerate this procedure well, and their postoperative course is usually uncomplicated. Simple ligation of the ductus is carried out in many centres. It would appear that the danger of recanalization is not great in this age group.

In patients in this age group, we prefer a short anterior thoracotomy for the operative treatment of persistent ductus arteriosus because it is well tolerated both during the operation and in the postoperative period. Should a ventricular septal defect with a large left-to-right shunt be present in the same patient, the pulmonary artery can be banded without enlarging the incision or changing the position of the infant. When the ventricular septal defect is associated with a patent ductus arteriosus, the former is usually the more important lesion with respect to the etiology of the failure. It is im-
important to rule out associated anomalies when a patient with patent ductus arteriosus is operated upon, as some of these associated lesions may not be suspected preoperatively. In our experience, 20% of patients requiring a banding operation in this age group have had an associated patent ductus arteriosus. In all but one instance, the ventricular septal defect was the dominant lesion.

2. Coarctation of the Aorta

Occasionally coarctation of the aorta will cause intractable heart failure in the neonate and demand operative treatment. Infants with coarctation of the aorta who present in heart failure are usually less than six months of age because after the age of six months the collateral circulation is usually sufficient to relieve the strain on the left ventricle. The latter group may be operated upon under more ideal circumstances, preferably when the patient is five years of age (Fig. 2).

Coarctation of the aorta may be associated with sinister lesions such as the hypoplastic left heart syndrome, in which case operation would not be undertaken. Similarly, the presence of some types of pre-ductile coarctations will result in an unsuccessful outcome either because of an insurmountable anatomical problem or the persistence of a high pulmonary vascular resistance. The latter results in a right-to-left shunt through the persistent ductus arteriosus. Post-ductile coarctation, which causes heart failure in an infant under six months of age, is best treated by immediate operation with resection of the coarcted segment and end-to-end anastomosis. The results of operation in this type of coarctation are quite good (Case 1).

When a persistent ductus arteriosus or a coarctation of the aorta are suspected, the diagnosis can usually be confirmed by a retrograde aortogram. This is performed by placing a needle in the brachial artery just above the elbow and injecting 4 c.c. of 76% sodium and methylglucamine diatrizoate (Renografin) in a retrograde direction (Fig. 3).

Case Report

R.P., an 11-week-old male infant, was admitted to the War Memorial Children's Hospital, London, with dyspnea and tachycardia. On examination the blood pressure in the right arm varied between 160/90 and 190/100 mm. Hg. The blood pressure in the left arm varied from 140/90 to 150/90 mm. Hg. Examination
of the chest revealed the presence of bilateral fine basal rales. Femoral pulsations could not be felt. The electrocardiogram gave evidence of left axis deviation. The infant went progressively downhill in spite of medical therapy, and operation was considered to be indicated.

On June 4, 1957, a post-ductile coarctation of the aorta was resected and an end-to-end anastomosis was performed using interrupted 6-0 arterial silk suture. An associated patent ductus arteriosus 7 mm. in diameter was divided. The postoperative course was uneventful, and the patient was discharged asymptomatic on June 22, 1957. Examination in July 1960 revealed a healthy asymptomatic boy above average size. No murmurs were detected. The blood pressure in the right arm was 110/75 and the blood pressure in the left arm was 100/70 mm. Hg. Femoral pulsations were excellent.

3. Anomalies of the Aortic Arch (Fig. 4)

The most frequent anomalies of the aortic arch causing difficulty in an infant are double aortic arch, aberrant right subclavian artery, and a right aortic arch with a left ligamentum arteriosum. These may cause obstruction of the trachea or esophagus during the first few weeks of life.

Treatment is directed toward division of the minor arch, the aberrant subclavian vessel or of the ligamentum arteriosum. The operative mortality is low and the results are usually quite satisfactory (Case 2).

Case Report

M.J., a four-week-old male infant, presented with stridor and difficulty in swallowing. A double aortic arch was diagnosed radiographically after instillation of Lipiodol. A retrograde aortogram confirmed the diagnosis. The anterior arch was divided at its junction with the descending thoracic aorta. The vessel immediately retracted a distance of 1.5 cm. The postoperative course was uneventful apart from the fact that the infant experienced some regurgitation of feedings for the first few postoperative days. Six months postoperatively, examination disclosed a healthy infant without feeding or respiratory difficulty.

4. Severe Pulmonary Stenosis

Severe pulmonary stenosis may occasionally cause right heart failure in the neonatal period. The stenosis is invariably severe, and the condition of the patient rapidly deteriorates, owing to the obstructed and failing right ventricle. Operation is urgent; procrastination is mortal! A transventricular pulmonary valvotomy is the treatment of choice, although direct vision valvotomy with inflow occlusion without hypothermia is occasionally warranted. Transventricular valvotomy is effective in quickly relieving the obstruction to the right ventricle. Some pulmonary insufficiency invariably results, but the infant heart bears this lesion well
provided that the stenosis is not associated with other congenital cardiac anomalies. This is the only age group where blind transventricular valvotomy is recommended, because in older children pulmonary valvotomy under direct vision, either with inflow occlusion (hypothermia at 32°C) or with the aid of extracorporeal circulation, is carried out. The operative mortality in either case is under 3%. A higher mortality attends transventricular valvotomy performed on the neonate in failure, largely because of the precarious condition of the infant at this time.

5. Total Anomalous Pulmonary Venous Drainage

Total anomalous pulmonary venous drainage is an urgent surgical problem, as 80% of such patients die before six months of age. The survivors owe their continued existence to a relatively large atrial septal defect. The latter permits escape of blood from the right atrium to the left. There are two main anatomical varieties of total anomalous pulmonary venous drainage.

Type One: In the first variety of anomalous pulmonary drainage the pulmonary veins enter the left innominate vein. This type is best corrected by the Cooley-Ochsner operation. Extracorporeal circulation is utilized. The right atrium is opened and an incision is made in the posterior part of the septum which is hinged anteriorly. An incision is then made through the posterior wall of the left atrium into the common venous channel, and an anastomosis between the common venous channel and the left atrium is accomplished. It is very important to suture the septal flap well into the right atrium so that the resultant left atrial chamber is of adequate size. It is also important to prevent any overloading of the circulation in the postoperative period, as the left side of the heart is often small.

Type Two: In the second variety of anomalous pulmonary venous drainage the pulmonary veins enter the right atrium. The right atrium is opened, the septum is incised anterior to the openings of the anomalous veins and the septum is subsequently sutured to the right atrial wall so that the pulmonary veins open into an enlarged left atrium.4

6. Congenital Aortic Stenosis

This lesion rarely causes heart failure in infancy, but it must be considered a diagnostic possibility. In such cases valvotomy can be carried out by a transventricular or transaortic approach. The latter will require inflow caval occlusion and supplementary arterial transfusion.

B. The palliative group includes those with:
1. Transposition of the great vessels.
2. Ventricular septal defect and atroioventricularis communis (A-V communis).
3. Fallot’s tetralogy.
4. Pulmonary atresia.

Fig. 5.—Transposition of great vessels. Note the presence of pulmonary arterial plethora and an enlarged thymus.

5. Tricuspid atresia.
6. Anomalous left coronary artery.

Aortic atresia and the hypoplastic left heart syndrome are not amenable to relief by surgical procedures in the present state of our knowledge. The occasional patient with a truncus arteriosus with excessive pulmonary flow may be helped by banding the aortic branches to the lungs.

1. Transposition of Great Vessels

Transposition of the great vessels without a significant intracardiac defect, which would allow mixing of the systemic and pulmonary venous

Fig. 6.—Venous angiogram, posteroanterior view. Note opacification of right atrium, right ventricle and aorta.
examination in December 1961 revealed that the child was improved clinically. The cyanosis was still apparent, but less obvious. A corrective procedure (the Senning operation) will be attempted at a later date.

In the occasional patient with transposition of the great vessels, an intracardiac redirection of the systemic venous return to the tricuspid valve (Senning's modification of the Albert operation) may be a suitable form of treatment. Only the occasional patient has survived this rather extensive operative procedure. Baffe's procedure employs an extra-cardiac prosthesis to accomplish partial redirection of venous return. This strictly palliative operation has not been widely accepted, but reasonable results are reported by Baffe in older children. The most recent approach to the problem has been that of Idriss et al. in which great vessel transfer is accomplished together with coronary artery transfer (Fig. 8).

returns, may be benefited by a Blalock-Hanlon operation whereby an atrial septal defect is created. The operative mortality is relatively low, and many patients so treated have improved.

Transposition of the great vessels with marked increase in pulmonary blood flow may also be benefited by banding (stenosing) the pulmonary artery.

**CASE REPORT**

D.M., a deeply cyanosed infant, was admitted to hospital for investigation. Clinical examination revealed a grade III holosystolic murmur that was heard over the entire precordium. The electrocardiogram gave evidence of right ventricular hypertrophy with prominent S-waves in all of the chest leads. Catheter studies of the right and left heart, and right and left-sided angiographic studies, confirmed the diagnosis of transposition of the great vessels with a ventricular septal defect (Figs. 5 to 7). A Baffe operation was scheduled for January 6, 1961. However, at operation, severe bradycardia occurred each time the heart was touched, and it was quite obvious that the infant would not tolerate the procedure. The pulmonary artery was banded in the hope of sparing the lung from the ravages of the large blood flow.

The blood pressure rose from 70 mm. Hg systolic to 105 mm. Hg systolic. Preoperative and postoperative arterial oxygen saturations were not taken, but the clinical impression was that the infant's colour had improved. It was hoped also that the right ventricular (aortic) output would be increased by this procedure.

The postoperative course was stormy. Tracheotomy, nasogastric tube feeding, digitalis, bloodless (tourniquet) phlebotomy, and the orthopneic position were necessary. The patient was discharged from hospital on January 21, 1961, 15 days after the operation. Recent

In the occasional patient with transposition of the great vessels, an intracardiac redirection of the systemic venous return to the tricuspid valve (Senning's modification of the Albert operation) may be a suitable form of treatment. Only the occasional patient has survived this rather extensive operative procedure. Baffe's procedure employs an extracardiac prosthesis to accomplish partial redirection of venous return. This strictly palliative operation has not been widely accepted, but reasonable results are reported by Baffe in older children. The most recent approach to the problem has been that of Idriss et al. in which great vessel transfer is accomplished together with coronary artery transfer (Fig. 8).

**2. Ventricular Septal Defect and A-V Communis**

Controversy still exists as to the efficacy of banding the pulmonary artery (that is, producing pulmonic stenosis) as treatment for infants with large ventricular septal defects. Our experience with this procedure (which will be described in another communication) has been a rewarding one. A small number of seriously ill infants in intractable failure were subjected to banding of the pulmonary artery. The degree of stenosis produced is determined by measuring the pressure in the pulmonary artery proximal and distal to the "band" with two separate No. 18 gauge needles inserted into the pulmonary artery and attached to a Sanborn recording apparatus. A normal pulmonary artery pressure distal to the artificially produced stenosis is desired. There was no operative or hospital mortality. The subsequent course has been uneventful in all but one patient who continues to have occasional respiratory infection. This operation was originally devised by Damann-Muller in 1952, and consider-

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*This does not include cases where banding operations were performed for other than pure ventricular septal defect.*
able experience with it has now been gained in many centres.

It would appear that approximately six years of age is the ideal time at which to carry out complete repair of the ventricular septal defect and the artificial pulmonary valve stenosis (Fig. 9). Continued refinements of extracorporeal circulation, both in regard to apparatus and technique, will undoubtedly increase the indications for complete repair of ventricular septal defects in the infant. At the present time however, in neonates and in young infants, it would appear safer to perform a banding procedure early, and then defer complete repair until six years of age. The ideal patient for a banding operation is one with a low pulmonary vascular resistance and a large left-to-right shunt. Lung biopsy, if taken at this time, will show normal pulmonary arterioles for this age group (Dammann’s hyperkinetic group). Patients with secondary or reactive pulmonary hypertension are also suitable for the banding procedure, provided that the infant is in difficulty clinically. Infants with ventricular septal defects associated with obliteratorive changes in the pulmonary arterioles and a high pulmonary vascular resistance are not candidates for either the banding operation or complete repair.

Case Report

M.W., a 4-month-old male infant, was admitted to War Memorial Children’s Hospital on March 6, 1961, because of breathlessness which was most marked during feeding. Examination revealed a loud Grade IV pulmonary second sound, a Grade III pulmonary systolic murmur, and a pulse rate of 120 per minute. The electrocardiogram showed right and left ventricular hypertrophy. Pulmonary plethora and cardiomegaly were noted on cardiac fluoroscopy (Fig. 10). The right heart catheter study revealed a pressure of 105 mm. Hg in the pulmonary artery and an oxygen “step-up” of two volumes per cent in the right ventricle.

A Dammann-Muller (banding) operation was performed on March 17, 1961. Temporary partial occlusion of the pulmonary artery with a sponge stick was maintained until the pulmonary artery was dissected. The Dacron band (0.5 cm.) was adjusted until the distal pressure in the pulmonary artery was 30 mm. Hg.

The postoperative course was uneventful, apart from transient cyanosis during the first few postoperative days.

The infant left hospital on March 31, 1961, and has remained asymptomatic since that time. Examination on December 15, 1961, revealed an apparently healthy, asymptomatic 14-month-old child. A loud pulmonary systolic murmur was still audible at the base, but was changed in intensity.

3. Tetralogy of Fallot

One-third of patients with the tetralogy of Fallot do not survive beyond the first year of life, and very few survive beyond the age of 20 years. Patients with the tetralogy do not usually develop heart failure in the usual sense of this term. They often die of anoxia, cerebral vein thrombosis or cerebral abscess.
Operation is indicated in infancy if the patient develops severe cyanotic attacks leading to unconsciousness. In this age group, the operation of choice is a shunt procedure (systemic artery to pulmonary artery). The Potts' operation⁹ (aortic to pulmonary shunt) offers the most reasonable opportunity to increase the pulmonary blood flow to relieve the cyanosis, but it has two major disadvantages. It is more difficult to take down at the time of total repair, and care must be taken to avoid making an anastomosis too large, in which case the patient will develop left heart strain.

The Blalock operation¹⁰ (subclavian artery to pulmonary artery anastomosis) is more generally performed (Fig. 11). It may be necessary to make a free graft of the subclavian artery to avoid kinking at its origin. The Brock operation,¹¹ direct pulmonary valvotomy, is not applicable to this age group, but is preferred for the slightly older patient who is not otherwise a candidate for complete repair using cardiopulmonary bypass.

4. Pulmonary Atresia

The minority of patients with pulmonary atresia who have a large right ventricle are quite suitable for surgical treatment, but unfortunately make up less than one-fifth of the total. There is usually an associated communication between the two atria and a patent ductus arteriosus.

Operation is directed at removing the atretic pulmonary valve and division of the patent ductus arteriosus. However, it must be confirmed that the right ventricle possesses an adequate outflow tract before division of the patent ductus arteriosus is undertaken.

The commoner type of pulmonary atresia, that is, one which is accompanied by a small right ventricle, is less suitable for operation.
Fig. 13.—Tricuspid atresia.

Fig. 14.—Right atrium.

Fig. 15.—Right atrium, left atrium and atrial septal defect.

Fig. 16.—Left ventricle opacified.
small foramen ovale defect was identified. This admitted only the tip of the index finger. Pressure in the right ventricle and pulmonary artery at the end of the operative procedure was 30 mm. Hg. The cyanosis immediately disappeared, and on recent follow-up examination (November 1961) the boy was found to be asymptomatic and developing normally.

5. Tricuspid Atresia

The diagnosis of tricuspid atresia carries a very poor prognosis; one-half of these patients die within the first six months of life, and only 10% live to the age of 10 years. There are two main anatomical types of tricuspid atresia, simple and complex; the classification depends upon whether or not there is an associated transposition of the great vessels.

The Glenn operation is preferred to a Blalock procedure in that it removes some of the strain from the right atrium without adding additional strain to the left ventricle.

The results of the Glenn operation are surprisingly good when one considers the precarious condition of these infants before operation.

The anastomosis must be carefully placed to avoid kinking at the suture line. Failure to recognize the importance of this observation will result in early postoperative death.

The operative mortality rate of both the Glenn and the Blalock type of operation is approximately 30%.

Operation should be performed by an extra-pleural approach to avoid the complications of thoracotomy. A Glenn procedure (vena cava to right pulmonary artery anastomosis) is preferred if the right pulmonary artery is at least 50% of the size of the superior vena cava. Should the pulmonary artery be small, the distal cut end should be anastomosed to the side of the ascending aorta. Banding of the pulmonary artery is recommended for the small group (less than 10%) of patients with tricuspid atresia with pulmonary hypertension.

**Case Report**

A.T., a seven-month-old male infant, was admitted to St. Joseph’s Hospital, London, on November 14, 1961, with cyanosis and severe dyspnea. Examination revealed hepatomegaly, and a grade II pulmonary systolic murmur was heard over the entire precordium. Cardiac fluoroscopy showed an upturned apex and pulmonary oligemia (Fig. 13). The electrocardiogram revealed P pulmonale and left axis deviation. A venous angiogram confirmed the diagnosis (Figs. 14 to 18).

A Glenn operation (superior vena cava to right pulmonary artery anastomosis) was carried out December 5, 1961. The postoperative course was uneventful, although edema of the face and neck (which is characteristic of the early postoperative course) was present...
for 72 hours. Since operation, the intense cyanosis that was present preoperatively is now apparent only with straining or crying. The patient was discharged from hospital on December 17, 1961.

The diagnosis of tricuspid atresia should be strongly suspected when left axis deviation is found in the electrocardiogram of a cyanotic infant. Elaborate investigation is not necessary, and indeed may be hazardous. A venous angiogram will confirm the diagnosis and give pertinent information with respect to the sizes of the atrial septal defect and the pulmonary artery.

6. Anomalous Left Coronary Artery

In this condition the left coronary artery takes its origin from the pulmonary artery instead of from the aorta. Two anatomical types are recognized: an infantile type and an adult type. In the infantile type there is very little collateral circulation between the right (aortic) and left (pulmonary) coronary arteries. Ligation of the anomalous left coronary artery at its origin is therefore not indicated. The performance of pericardial poudrage might be considered.

In the adult type, good collateral circulation is present between the right and left coronary artery and a retrograde flow occurs into the left coronary artery. Ligation of the left coronary artery at its origin from the pulmonary artery is indicated and may be life-saving.

An anomalous right coronary artery does not cause difficulty in this age group, but is not a benign lesion. Patients with this anomaly usually succumb in the fourth or fifth decade.

Open-Heart Surgery in the Neonate

The neonate does not tolerate cardiopulmonary bypass well. It is generally agreed that, with occasional exceptions, patients under 20 lb. in weight are not suitable for cardiopulmonary bypass. Difficulties in blood balance, denaturation of plasma protein, trauma to the red blood cells, and technical difficulties in cannulation, are all responsible for this conclusion. The immaturity of the respiratory mechanism, the precarious critical closing area of the bronchial lumen, the small compressible tracheobronchial tree, and the reduced cough reflex are factors which cause additional difficulty. The poikilothermic tendency of the neonate should be mentioned. The severity of the cardiovascular lesion that makes repair necessary at this age also contributes to the high mortality.

The development of a pump oxygenator which can safely be used in the neonate is under way in our laboratory. Similar developments are taking place in other Canadian centres.

Postoperative Care Following Neonatal Cardiac Surgery

Most of the operations in this age group can be carried out with a short period of anesthesia. Corrective procedures for patent ductus arteriosus and banding operations require less than one hour of anesthesia. Operations for uncomplicated coarctation of the aorta, the Glenn procedure for tricuspid atresia, and the Blalock and the Potts' operations for Fallot's tetralogy can usually be carried out successfully in two hours. The duration of the anesthetic and operative trauma are very important considerations in this age group. The incidence of postoperative pulmonary complications directly parallels the duration of the operation. Excessive drying of the bronchial mucosa by poorly humidified anesthetic gas is undoubtedly a major factor in producing postoperative pulmonary complications.

Excessive or inspissated bronchial secretions and atelectasis (lobar or miliary) are of major concern in the postoperative period. Tracheotomy is avoided if possible, but may occasionally be life-saving. In the postoperative period these babies should be kept in a well-humidified environment, but excessive oxygen saturation is avoided because it may have a deleterious effect on the surface-acting lipoproteins which are responsible for maintaining normal surface tension in the alveolus.

Neonates who have been in heart failure before operation are treated in the orthopneic position postoperatively, and are fed by fine polyethylene plastic tube. Morphine is the analgesic of choice.

After anastomotic procedures (Glenn, Potts, Blalock) or operation for patent ductus arteriosus or coarctation of the aorta, patients usually have very little difficulty in the postoperative period, although edema of the head and neck following the Glenn operation may occasionally be troublesome.

Following the banding operation for a high flow ventricular septal defect, many patients will have heart failure and some develop transient cyanosis due to a right-to-left shunt. These infants may require intensive postoperative care. However, most infants are immediately improved following the banding operation.

During the postoperative period, it is extremely important to prevent overhydration, especially in patients with total anomalous pulmonary venous drainage.

The postoperative course of the neonate following cardiac surgery may be uneventful. However, the clinical condition of these infants can change so rapidly that constant attention by experienced personnel is necessary.

Summary

Congestive heart failure in the neonate is associated with a high mortality rate unless intensive medical and surgical therapy is instituted early. The neonate in heart failure presents with dyspnea, with coughing attacks or with cyanotic attacks. Medical treatment consists of nasogastric tube feeding, care in the semi-erect position, and the administration of digitalis and morphine. Over 75% of patients with congenital heart lesions may be suitable for surgical treatment. The result of operations may be curative in cases of patent ductus arteriosus,
coarctation of the aorta, pulmonary valve stenosis, total anomalous pulmonary venous drainage, and anomalies of the aortic arch. The effect of operation may be palliative in infants with transposition, Fallot's tetralogy, pulmonary atresia, tricuspid atresia, ventricular septal defect, A-V communis and anomalous left coronary artery.

The operative mortality has been kept to an acceptable level in most cases, but to achieve this, an accurate diagnosis, expedient yet precise surgery, and intensive postoperative care are essential.

The authors acknowledge the pioneering efforts of Dr. William Mustard and his associates of the Toronto Hospital for Sick Children; Mr. D. J. Waterston of the Hospital for Sick Children, Great Ormond Street, London, England, has written clearly on the subject of cardiac failure in the neonate, and the interested reader is advised to refer to his publications.

REFERENCES