INTRACARDIAC SURGERY USING PROFOUND HYPOTHERMIA

By Mark F. O'Brien

The improved standards and comparative safety of corrective surgery for children with congenital cardiac diseases and the realisation that palliative procedures have considerable limitations have provided the logical sequence for the development of one stage correction at the neonate and infant stage. In principle, structural abnormalities in the ventricles and in the pulmonary vasculature are reversed with this early haemodynamic correction before permanent and sometimes irreversible changes develop.

Reports from the Kyoto[1] and New Zealand[2] groups have shown the feasibility of successful repair utilising for neonates and infants a combination technique of surface-induced deep hypothermia, circulatory arrest and bypass assistance to rewarm. With minor variations in technique, many units throughout the world are confirming the experiences of the above pioneering groups.

At Chermside Hospital, 54 infants have had total correction of a variety of cardiac lesions. Forty-four infants have survived. The experiences to date indicate that the combination technique has many advantages and may represent one of the most outstanding advances in cardiac surgery over the last decade.

OPERATIVE PROCEDURE

After anaesthetic induction, surface hypothermia is instituted by a cooling blanket and ice bags. Central venous (IVC via saphenous vein or SVC via internal jugular vein) and occasionally a percutaneous radial artery catheter are inserted for pressure measurements and blood gas analysis. At 29°C. naso-pharyngeal, the median sternotomy incision is performed. During this stage a further temperature drop to 26°C. occurs and with cardio pulmonary bypass (Infant Temptrol Oxygenator with blood prime, single right atrial catheter, aortic cannulation) the central temperature is dropped to 20°C. naso-pharyngeal. The period of bypass is about ten minutes and during this time the cavae and ascending aorta are taped and the external anatomy of the heart carefully examined. At 20°C., the aorta is clamped proximal to the cannula, bypass ceased and the cavae snared immediately, leaving a blood volume in the infant. The lungs are inflated to empty most of the blood into the heart and with the venous line open to gravity drainage, the heart is emptied to provide a bloodless atonic organ. The heart is opened and examination for a patent ductus is made with the arterial pump being turned on for several seconds. By leaving blood in the body and not draining it into the oxygenator, it is considered that some further oxygen exchange is possible, possibly providing further safety during the period of circulatory arrest. After completion of the intracardiac repair (20-69 minutes), bypass is recommenced and the temperature elevated to 35°C. At the beginning of this phase, air is evacuated from the heart by needle aspiration, the head lowered and the aortic clamp removed to restore coronary perfusion. Spontaneous sinus rhythm or a temporary period of atrio-ventricular dissociation is present. Occasionally defibrillation is necessary. At the end of the operation in most instances and possibly more for prophylatic reasons, the naso-tracheal tube is inserted and the baby respired for one to several days depending on the extent of the preoperative pulmonary vascular changes.

CLINICAL RESULTS

The results with 54 babies are summarised in Table 1 according to age and lesion. The commonest anomalies have been V.S.D. (27), Transposition (10) and Tetralogy (8). The youngest infant was three weeks of age and the weights ranged from 2·9 kilos to 10·8 kilos.

All infants with V.S.D. were in some cardiac decompensation, failing to thrive in spite of anti-failure therapy. Of the deaths, one eight week old child had experienced two preoperative cardio-respiratory arrests and was anuric at the time of operation, dying on the third postoperative day; another child developed a postoperative urinary tract infection during the second week and fulminating bacterial endocarditis on the Dacron V.S.D. patch caused death; the third infant had a large V.S.D. and P.D.A. and developed fibrinolysis postoperatively. The clinical state of the 24 surviving infants having closure of V.S.D. ± P.D.A. has improved remarkably. The defect appears clinically closed in all but one in whom a small residual shunt is probably present.

The group with uncomplicated transposition has provided the most gratifying results. All survived atrial-pericardial baffle repair with very satisfactory haemodynamic results. Of the complex transpositions, two infants aged ten weeks and six months did not survive. In the younger infant, there was an intact atrial septum, small V.S.D. and P.D.A. After excision of the septum the trans-atrial pathways of the caval tunnels were inadequate. In the second case, pulmonary vascular hypertensive changes were exceptionally marked and in spite of an excellent repair, confirmed at autopsy, respiratory failure and death occurred on the tenth postoperative day. Both infants should have had palliative procedures in the form of open atrial septectomy and pulmonary artery banding with total correction later but preferably still within the first 1 to 1½ years of life. This policy has been successful in the other patient with complex transposition at 16 months.

The small pulmonary valve ring has presented the problem with the tetralogy group. Eight patients have had correction under profound hypothermia with two infants (9 and 11 months) dying because of this problem. The third death was due to a consumptive coagulation defect. The 5 infants, in whom satisfactory outflow tract channels were obtained, progressed without any complication. The policy is now to shunt any infant with a pulmonary valve ring less than one third of the size of the ascending aorta.

A variety of lesions have been corrected in the remaining 9 patients. These have included severe pulmonary valve stenosis and reversed shunt through an atrial septal defect (2 infants), aorto-pulmonary window[1], anomalous pulmonary venous drainage[1], aortic valve stenosis[2], one infant not surviving with associated fibroelastosis), double outlet right ventricle with severe pulmonary hypertensive changes[1], and one infant of four weeks who failed to survive repair of a complete atrio-ventricular canal defect.

TABLE I

	Age in Months <1 Month	1 - 6	7 - 12	13 - 24	>24
V.S.D. ± P.D.A.	1	11 (2)	8 (1)	4	3
T.G.A. Simple		2		5	
T.G.A. Complex		2 (2)		1	
Fallot		1	4 (2)	2	(1) 1
P.V.S. ± A.S.D. (Reversed)		1	1		
A-P Window		1	1		
A.P.V.D.		1			
Ao. V. Stenosis		1 (1)		1	
Double Outlet R.V.		1			
A-V Canal (complete)	1 (1)				

( ) = Deaths

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Twenty-one infants have therefore had cyanotic lesions with 16 survivors.

POSTOPERATIVE COURSE

Providing the technical repair of the lesion has been carefully and fully corrected, the cardiac function has been most satisfactory. Metabolic acidosis has not been a problem. In order to carry out a uniform pattern and policy of nursing care, most infants have been respired via a naso-tracheal tube (nonreactive Portex Z. 79) and Bird respirator. By standardising this management, the nursing care is vastly simplified although still demanding a meticulous standard. In 2 patients, severe pulmonary hypertension has presented the need for prolonged intubation. The four month old infant with double outlet right ventricle was ventilated for six days and progressed satisfactorily but the six month complex transposition child mentioned above succumbed from marked pulmonary arteriolar obstruction. It is considered that in both children operation at an earlier stage would have been preferable but late referral dictated the timing of operation.

Two of the patients have died of coagulation disorders for unknown reasons particularly as no problem has been seen with any of the other infants.

Close observation of cerebral function at a clinical level has naturally taken place because of the unknown effects of hypothermic circulatory arrest. No deaths have been associated with or caused by a cerebral lesion. Pathological examination of the brain of non-survivors has not revealed any abnormal features. With one patient the temperature recording apparatus was reading incorrectly and hypothermia was probably continued to as low as 15°C. naso-pharyngeal and rewarming to as high as 44°C. This child has suffered some cerebral dysfunction. This complication is considered the result of a failure to execute the technique correctly rather than due to the method of profound hypothermia per se. Two other infants had fits of short duration in relationship to high temperatures postoperatively. Both progressed very well in all respects without apparent abnormality.

DISCUSSION

The advantages of the principles of one stage repair in the neonate and infant before gross structural changes occur in the lungs and myocardium have been reflected in the higher immediate survival rate. Particularly is this so when the results are compared to the combined operative mortalities of stage procedures and the wastage rate of infants who do not survive for the final stage correction.

The technique of hypothermia, arrest and bypass assistance has a promising application although the long term observations of the normality of physical and mental development and of the permanency of correction and satisfactory cardiac function have still to be ascertained over the ensuing years.

In the neonate and infant group, surgery for complex lesions with conventional cardio-pulmonary bypass is technically difficult and carries for these lesions a high mortality and morbidity. With the profound hypothermia technique, the bloodless motionless heart permits safe and accurate repair which unquestionably is one of the most important aims to achieve. In addition providing myocardial function is adequate, postoperative complications are minimal. Satisfactory pulmonary function, unless extreme pulmonary hypertension has been present, is not difficult to maintain.

Some surgical units prefer core cooling with bypass to achieve profound hypothermia prior to circulatory arrest. No advantages with this modification are discernable but theoretically an uneven central organ temperature drop with the non-pulsatile flow would appear more likely. For the very complex lesions requiring up to more than sixty minutes of circulatory arrest, the evenly distributed hypothermia of surface-induced methods should give a safer organ protection.

Some limitations to the universal application of one-stage surgery and profound hypothermia exist. They are related to the complexity of the cardiac lesion. Two specific instances may still require staged operations.

The tetralogy lesion with the very small pulmonary valve ring in the infant requires outflow-tract patch reconstruction. The late effects of pulmonary valve insufficiency or even stenosis of the reconstructive patch are still to be determined. Therefore it is not known which of two methods, namely initial shunt followed at a later age by homograft reconstruction (if necessary) or a one-stage correction and patch reconstruction, will give the superior long-term results.[3]

For complex transpositions, an initial palliative procedure may be advisable. When the associated lesion is a ventricular septal defect with intact atrial septum (and failed balloon septostomy), in the first months of life, neither the Mustard nor the Rastelli procedures is ideal; the first because of difficulty with the size of caval tunnels and the second because the V.S.D. may not be of adequate size, the Rastelli operation being then unsuitable. In this type of defect, open atrial septectomy and banding of the pulmonary artery is performed and within 12 to 18 months, the Mustard repair, Dacron patch closure of the V.S.D. and debanding indicated. It is not known whether it may even be wiser, if the V.S.D. is large, to wait for some years to perform the Rastelli procedure thereby restoring the ventricles to their rightful function. In addition some reports have suggested that it may be possible to increase the size of the ventricular septal defect enabling a wider application of the Rastelli technique.

In this series, the ventricular septal defect is the commonest surgical lesion. All the babies would have been candidates for pulmonary artery banding if total correction had not been performed. Spontaneous closure without surgery is known to occur but one could not have justifiably withheld operation. Some of the deaths could have been avoided with a wiser selection of patients; firstly by shunting the tetralogy group with the small pulmonary valve ring (two infants) and secondly by initial temporising palliative surgery instead of one stage correction for the complex transpositions (two infants).

SUMMARY

Profound combined surface and limited bypass hypothermia (20°C.), circulatory arrest (20 to 69 minutes) and bypass rewarming has been the technique for correction of cardiac defects in 54 babies, (three weeks to 28 months, 2·9 kilos to 10·8 kilos). Thirty-seven infants have been aged 12 months or under with 23 infants six months or under.

The lesions corrected have included V.S.D.27, transposition of the great arteries10, tetralogy of Fallot8, P.V.S. and reversed A.S.D.2, aorto-pulmonary window2, anomalous pulmonary venous drainage1, aortic valve stenosis2, double outlet right ventricle1 and atrio-ventricular canal1.

Forty-four infants have survived and the results have justified the technique which has provided ideal operating conditions for accurate safe intracardiac repair.

For most lesions, the principle of correction before the development of extensive cardiac and pulmonary structural changes appears valid. The earlier the referral of the infant to a cardiac unit, the better should be the overall results with operation.

There is still a sound place for palliative procedures for Fallot's tetralogy with a small pulmonary valve ring and for the complex transposition group. For the latter lesion, complete anatomical correction is still preferable some months after palliation.

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