and ecological approach to every patient under their care. The factors disclosed may be of significance in aetiology; they are always significant for convalescence, rehabilitation, and the prevention of recurrences.

In a number of medical schools steps have been taken to introduce the undergraduate to the conditions met with in family practice, of which perhaps the most highly developed so far in this country is the General Practice Teaching Unit in Edinburgh under Dr. Richard Scott, and there are many experiments for the same purpose in the medical schools of the United States of America. Doubtless all these have value, but none can replace the example which the undergraduate should be given by all his teachers of how to discover and assess the social and emotional problems of each individual patient. Graduating with this tradition firmly established, every qualified medical practitioner, whether his career is in the hospital, general practice, or local authority services, will know how to make use of the wide range of assistance that local authorities now provide, and how they can help him in his patient-care and remove some of the causes, even if these be only contributory, of the ill-health and unhappiness of those who appeal to him for help and advice. Much has been said and written of the lack of co-operation between the three sections of the National Health Service, a lack due, I am convinced, to ignorance of what each has to offer and what each is competent to provide. There is little doubt that there has been a change during the past 50 years in the help that the individual member of the community seeks from the medical profession, a change that continues still and will require the constant adjustment of medical education and medical practice.

Integration of the Health Services

In his address to the British Medical Association in 1959, from which I have already quoted, Lord Adrian says: "It would be a great mistake to think that there can be a general advance without the support of every doctor who has patients to understand. We have ourselves to understand, too; however healthy and well balanced we may be there may be something to learn by observing our own reactions to difficult situations. At all events we have been trained to the clinical observation of human beings exposed to anxiety and discomfort and we must not belittle our training." Both general practitioners and consultants are able to contribute to this advance and to meet this challenge, and are more likely to do so earlier by co-operation not only with each other but also with the medical officers of the local authority and the social workers. Surely the senior physicians and surgeons of our general hospitals are the persons to take the lead in forming such a partnership, each for its own community.

Regular meetings of representatives of the three divisions of the National Health Service, and perhaps of the clergy also, in the area would soon show how each can best help the others and how the hospital and local authority services can utilize the peculiar experiences of family doctors to supplement their own restricted and specialized training. It seems probable that it was the observation of valves in veins that gave Harvey the clue to the circulation of the blood, and it may well be that some unforeseen observation will provide clues to be followed up by clinicians, physiologists, geneticists, psychiatrists, and social scientists that they may "search and study out the secrets of nature."

In the meantime the ecological study of each patient whom we are called upon to understand and to help must surely contribute to the health and happiness of the communities we have the privilege to serve.

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INITIAL EXPERIENCES WITH EXTRACORPOREAL CIRCULATION IN INTRACARDIAC SURGERY

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The technique of heart-lung by-pass for repair of intracardiac defects was placed on a firm foundation by Kirklin *et al.* (1955) and by Lillehei *et al.* (1956), and good results from these and other groups have established the soundness of the method. The following report concerns the first 25 consecutive such operations to be performed with the aid of a Melrose N.E.P. heart-lung machine (Melrose, 1955) at this hospital. Prior to the first human operation in September, 1958, practice by the complete operating team in the experimental laboratory had resulted in the long-term survival of seven successive sheep after 30 minutes' total heart-lung by-pass during which right ventriculotomy was performed.

Material

This initial series consists of 15 patients with ventricular septal defect (on one of whom two operations were performed), three with partial atrio-ventricular canal, one with atrial septal defect, four with congenital aortic or subaortic stenosis, and one with rheumatic tricuspid stenosis. Pre-operative haemodynamic findings are summarized in the Table in which the cases are grouped according to the major defect present and in which those with ventricular septal defect

are listed in order of decreasing pulmonary-to-systemic-flow ratio.

All 15 patients with ventricular septal defect were limited by dyspnoea. Effort intolerance was relatively slight, and was apparent only on fairly strenuous exertion in five (Cases 3, 7, 13, 14, and 15), but eight were unable to keep up with their companions during ordinary play. The remaining two (Cases 4 and 6) had been in congestive heart failure. None was cyanosed at rest, and, although blueness after effort was reported by the parents of three patients (Cases 8, 11, and 12), this was not apparent on clinical examination, and under conditions of cardiac catheterization the systemic arterial oxygen saturation was not reduced below the normal range.

The clinical features in five patients (Cases 1 to 5) pointed to ventricular septal defect with considerable left-to-right shunt, while the remaining patients (Cases 6 to 15) presented essentially as cases of pulmonary hypertension associated with communication between pulmonary and systemic circulations, the exact nature of which was established only after further investigation. In four (Cases 2, 5, 10, and 15) there was a parasternal early diastolic murmur, attributed, in the context of other features, to pulmonary incompetence. Impressive pulmonary ejection murmurs, accompanied by thrills, were present in four patients (Cases 2, 3, 5, and 15), in whom investigation revealed systolic pressure gradients across the pulmonary valve, and also in one patient (Case 8) where no such gradient was found. Clinical evidence of right ventricular hypertrophy was a constant finding, and this was supported by the electrocardiogram, which also showed a so-called partial right bundle-branch block pattern in all but four cases (Cases 4, 10, 13, and 14). While in the majority both the electrocardiogram and the character of the apex beat pointed to some degree of associated left ventricular hypertrophy there was in four patients

(Cases 6, 11, 12, and 13) neither clinical nor clear electrocardiographic evidence of this (see Fig.).

The listing of these patients with ventricular septal defect in the Table, in order of diminishing pulmonary to systemic flow ratios, serves to group those with large left-to-right shunts without increase in pulmonary vascular resistance (Cases 1 to 5) and those where pulmonary hypertension was in part due to increased flow and in part to elevation of resistance. This elevation of resistance was relatively slight in two patients (Cases 6 and 7), but of at least moderate severity in the remaining eight. The data are, however, inadequate to enable the cases to be placed in the precise order of increasing pulmonary vascular resistance within these groups. In Case 15, for instance, the systolic pressure gradient between the right ventricle and pulmonary artery indicates that there was less increase in resistance than might otherwise be inferred, in the presence of equalization of right and left ventricular pressures, from the flow ratio alone. All other patients with systolic pressure gradients across the right ventricular outflow tract or pulmonary valve fall into the high-flow low-resistance group, and it is of interest that even in Case 3, where the gradient reached 60 mm., this was completely and immediately abolished by closure of the defect.

Pre-operative studies revealed additional anomalies in five patients—small atrial septal defect in Cases 3 and 12; atrial septal defect and persistent ductus arteriosus in Case 6; aneurysmal dilatation of the main pulmonary artery in Case 2; and absence of the left pulmonary artery in Case 7. In this last patient there was aneurysmal dilatation of the right pulmonary artery, and the bronchial blood flow during perfusion reached approximately one litre per minute. In Case 9 it was found at operation that there was complete dextroposition of the aorta, with both great vessels arising entirely from the right ventricle.

Pre-operative Cardiac Catheterization Findings

Case No.	Sex	Age	Wgt. (kg.)	Opn. No.	P.A. Wedge	Pressures† (mm. Hg)				Pulm. Syst. Flow Ratio	Pulm. Vasc. Resistance (R.U.)	Arterial O ₂ Sat. (%)	Remarks	
						P.A.	R.V.	L.V.	Aorta					
Ventricular Septal Defect														
1	M	6	20.5	16	4	36/16	42-2	76/-3	76/42	3.5: 1	—	95	Aneurysmal dilatation L.P.A. Small A.S.D.	
2	M	10	24.1	8	12	35/12	80/0	—	96/76	3: 1	0.9	97		
3	M	12	28.6	22	6	40/12	100/0	112/0	112/96	3: 1	1.1	99		
4	F	6	29.1	6	15	62/26	62/2	—	98/72*	3: 1	1.7	98		
5	F	10	26.4	1	14	76/36	96/2	—	102/68*	3: 1	2.9	100	Small P.D.A. A.S.D.	
6	F	2	22.7	7		92/50	92/4	92/4	—	2.5: 1	—	98		
7	M	12	26.4	17		7	97/46	97/0	—	104/86	2.2: 1	4.1		98
8	M	7	14.1	10		2	76/44	78/2	—	112/74*	2: 1	8.0		96
9	F	2	10.9	4	—	60/34	60/0	—	—	2: 1‡	—	—	Absent L.P.A. Origin both P.A. and Ao. from R.V.	
10	M	5	14.1	5	6	78/50	78/2	—	—	2: 1‡	—	—	A.S.D.	
11	F	6	18.6	15	5	88/60	88/2	88/4	—	2: 1	—	99		
12	F	6	21.4	24	4	84/44	84/0	84/0	84/60*	1.9: 1	—	94		
13	F	5	18.2	19	8	92/46	92/0	—	90/55*	1.9: 1	9.0	95		
14	M	6	22.7	3	19	100/48	100/4	—	—	1.8: 1‡	8.4	—		
15	F	4	15.5	2	5	54/37	72/0	77-2	77/50	1.8: 1	—	97		
Partial Atrio-ventricular Canal														
16	M	8	23.6	12	6	27/6	33/4	104/6	—	2: 1	0.9	95		
17	F	10	26.4	14	4	55/30	55/4	80/4	—	1.5: 1	4.2	92		
18	F	8	30.9	23	1	25/15	25/1	96/1	—	2: 1	—	97		
Atrial Septal Defect														
19	F	8	18.6	18	10	37/12	37/10	80/10	—	2: 1	2.5	95		
Aortic Stenosis														
20	M	15	55.9	9	5	27/8	33/2	224/8	120/82	1: 1	0.6	—	Small V.S.D.	
21	M	24	64.1	11	—	—	—	120/4	74/44	1: 1	—	—		
22	M	16	50.5	13	—	104/60	104/4	230/16	70/56	1.5: 1	9.2§	90		
23	F	45	47.7	21	—	—	—	160/10	94/64	1: 1	—	—		
Tricuspid Stenosis														
24	F	38	58.6	20	—	—	—	—	—	—	—	—	Moderate M.S.	

* Brachial or femoral artery. † Zero level at sternal angle. ‡ Assuming 96% arterial saturation. § Total pulmonary resistance. ¶ Recorded at operation.

In all three patients with *atrio-ventricular canal defects* (Cases 16, 17, and 18) the lesion was of the partial variety with a cleft in the septal leaflet of the mitral valve and an intact ventricular septum. Symptoms were relatively slight in Case 18, but Case 17 was considerably limited by effort dyspnoea and fatigue, and Case 16 was in some degree of congestive heart failure at the time of operation despite intensive medical measures. In this last patient, heart failure with evidence of atrio-ventricular valve incompetence had developed three months previously after an attempt to repair the defect, using the atrial-well technique (Kirklin *et al.*, 1956). The patient had been submitted to operation by this method in the belief that the defect was probably an ostium secundum although minor discrepancies were present.

Electrocardiograms of two patients with ventricular septal defect and severe pulmonary hypertension, both showing at least moderate right ventricular hypertrophy but only equivocal evidence of associated hypertrophy of the left ventricle. Top: Case 11. Closure of the defect did not result in an immediate fall in P.A. pressure. The patient died 36 hours later. Bottom: Case 13. P.A. pressure was immediately halved by closure of the defect. Subsequent progress has been satisfactory.

Case 19, proved to have an ostium secundum type of *atrial septal defect*, was selected for repair by open heart surgery rather than by the atrial-well technique, which would otherwise have been used (Williams and Barratt-Boyes, 1959), because persistent elevation of venous pressure in the context of a relatively small shunt and only slight increase in pulmonary vascular resistance and an atypical electrocardiogram suggested a more complicated anomaly. The explanation of these discrepancies and of the unexpectedly severe episode of congestive failure which followed closure of this simple defect remains uncertain, but, other intracardiac defects and pericarditis having been excluded, an associated cardiomyopathy remains the probability.

Of the three patients with uncomplicated congenital *subvalvular aortic stenosis*, two (Cases 20 and 21) had minor symptoms, and only one (Case 23) was limited by effort dyspnoea during ordinary activities. In all three, however, the electrocardiogram showed changes, including ST depression and T inversion in left ventricular surface leads and their equivalents, indicative of considerable left ventricular hypertrophy. The one patient (Case 22) who had a *valvular aortic stenosis* and also a relatively small ventricular septal defect had deteriorated rapidly and progressively during the nine months prior to admission for surgery, and at the time of operation still showed gross cardiomegaly and incipient congestive heart failure in spite of treatment in hospital on a full medical regime for several months.

The single patient (Case 24) with *rheumatic heart disease* had severe tricuspid stenosis. An associated tight mitral stenosis had been partially relieved by valvotomy seven years previously. When admitted for surgery this patient showed gross systemic venous congestion, which was only partially relieved by preliminary intensive medical treatment. Open heart surgery was decided upon because of the danger of producing tricuspid incompetence by blind valvotomy.

Method

The details of the extracorporeal circuit and of the technique of perfusion are to be published elsewhere (Barratt-Boyes and Yarrow, 1961). Premedication was with promethazine, pethidine and hyocine according to body weight. Anaesthesia was induced with cyclopropane and oxygen, and was continued with these agents while cannulae for recording inferior vena caval and aortic pressures were inserted via the left femoral vein and artery (the latter by a Seldinger needle). Anaesthesia was then maintained by 75% nitrous oxide and 25% oxygen supplemented by thiopentone. For relaxation D-tubocurarine was used. During perfusion the lungs were kept gently inflated with pure oxygen.

The operative technique was essentially that described by Harshbarger *et al.* (1958) except that a median sternal split was employed in all but one patient, and the right common femoral artery was used for arterial inflow. Heparin dosage to the patient, initially 2.5 mg./kg. body weight, was later increased to 3 mg./kg. and the machine was primed with fresh warmed blood containing 18 mg. of heparin per pint (32 mg./litre). Potassium citrate arrest (Melrose *et al.*, 1955) was employed in all cases of ventricular septal defect and aortic stenosis, but the heart was not arrested for repair of partial atrio-ventricular canal and atrial septal defect, or for tricuspid valvotomy. During all operations the

inferior vena caval and aortic pressures, the mid-oesophageal temperature (by thermistor), and electrocardiogram were monitored, but continuous display of the electroencephalogram and arterial oxygen saturation (by ear oximetry) was undertaken only in the earlier cases. Multiple blood samples were taken for estimation of arterial pH, venous and arterial oxygen saturation, blood and serum haemoglobin, and serum electrolytes, and for culture. As an aid to blood balance the patient was weighed before and after perfusion, and timely replacement of post-operative blood loss was facilitated by continuous suction of chest drainage into graduated cylinders. The pressure cannulae were left in position for the first 8 to 12 hours to assist in the early post-operative management. In the immediate post-operative period fluid requirement was calculated on a basis of 800 ml. of 4.2% dextrose in N/5 saline per square metre of body surface area per day.

Perfusion Data

The length of by-pass varied from 7 to 57 minutes. Perfusion had to be stopped in Case 24 after seven minutes because the venous cannulae, which were not rigid enough, became kinked within the right atrium when they were retracted to give exposure of the tricuspid valve. Although sufficient time was available for an adequate tricuspid valvotomy the proposed direct-vision approach to the mitral valve was abandoned; and instead, after coming off heart-lung by-pass, a blind finger-fracture mitral valvotomy was performed using the right-sided approach of Bailey and Morse (1957).

The average flow rate during perfusion ranged from 36 to 89 ml./kg./min., with a mean of 67 ml./kg./min. for the 25 perfusions. Expressed as litres per minute, the pump output varied between 0.5 and 4.2. Although a high flow perfusion of 2.4 l./sq.m. of body surface per minute was aimed at it was not always attained. In addition to avoiding kinking of the venous lines, the most important factors in achieving a high venous return were the selection of venous cannulae which approximated as nearly as possible to the diameter of the superior and inferior cavae, and proper positioning of the metal tips of these cannulae just beyond the caval occlusion tapes. That technique improved with experience is suggested by the fact that the mean flow rate for the last 15 perfusions in this series was 72 ml./kg./min., an improvement of 12 ml./kg./min., on that obtained in the first 10. In all except Case 22, where the average arterial oxygen saturation was 82% at a flow rate of 4.2 l./min., oxygenation can be considered adequate, though it varied between 88 and 100%.

Levels for serum haemoglobin in blood taken from the machine at the end of perfusion ranged from 10 to 65 mg./100 ml., while the average rise during the perfusion was 11 mg./100 ml. Readings of arterial blood pH were taken immediately before, during, and after perfusion and were continued at intervals of two to three hours for a further six to ten hours. These usually showed a mild alkalaemia prior to perfusion, the patients being moderately hyperventilated in the early stages of the operation and, with the exception of Case 22, either a mild acidemia or alkalaemia in the immediate post-operative period. Blood in the machine was not warmed during perfusion, and the maximum temperature fall during operation ranged from 0.8 to 4.2° C. (average 2.3° C.).

Results

These operations were performed between September, 1958, and June, 1959, and while it is as yet too early to assess the final result the 21 surviving patients have shown progressive improvement with, in those who had congenital communications, reduction in heart size and often gain in body weight. There must be some misgivings, however, as to the future outlook of two patients (Cases 6 and 18) who have remained in complete heart-block, and of one patient (Case 5) who has significant aortic incompetence. The remote prognosis of patients with marked increase in pulmonary vascular resistance is also uncertain, though there is reason to anticipate that it will be favourable. The patients with subaortic stenosis should have an excellent prognosis, as excision of the obstructing diaphragm completely abolished the systolic pressure gradient in all three cases.

Details of the three deaths among the 24 patients are as follows:

Case 9.—In this 2-year-old infant both great vessels arose from the outflow tract of the right ventricle. The perfusion and surgical repair were both considered satisfactory. When the heart beat returned a 2:1 atrio-ventricular block was present which, apart from transient restoration of normal rhythm by isoprenaline on two occasions, persisted until four hours post-operatively, when complete block suddenly appeared and death followed a few minutes later. Necropsy confirmed that the semi-compressed "ivalon" sponge used for repair had completely corrected the defect. The ventricles were of equal thickness (7 mm.). Only 45 ml. of free fluid was found in the thorax. The lungs were free from significant oedema and from intra-alveolar haemorrhage. The medium-sized pulmonary arteries showed muscular thickening and intimal hyperplasia, these changes corresponding to early grade 2 changes of Heath and Edwards (1958). The brain and other systems showed no abnormality. Although the heart-block was probably sufficient cause for death this infant may also have been slightly hypovolaemic.

Case 11.—The ventricular septal defect in this child was 11 mm. in diameter and lay beneath the septal leaflet of the tricuspid valve (type 3 defect of Becu *et al.*, 1956). It was closed with a pledget of semi-compressed ivalon sponge. The perfusion was satisfactory in all respects, but two disturbing features were noted during operation. Firstly, there was greater hypertrophy of the wall of the right ventricle than in any other ventricular septal defect in the series; and, secondly, the pulmonary arterial and central aortic pressures remained identical after closure of the defect. The initial post-operative course was, however, quite uneventful. In the afternoon of the day after surgery the patient was a little restless and less alert, but there was no other evidence to suggest deterioration. That evening she suddenly vomited, had a convulsion, and lost consciousness. The heart was found to be in arrest, and cardiac massage was begun immediately but to no avail. At necropsy, accurate closure of the ventricular septal defect was confirmed. The right ventricle measured 11 mm. in thickness and the left 9 mm. There was no free blood in the chest. The lungs showed moderate acute oedema without intra-alveolar haemorrhage. The small and medium-sized pulmonary vessels showed marked pulmonary hypertensive changes with advanced fibrotic obliterative thickening, plexiform lesions, and some dilatation of arterial branches—early grade 4 changes of Heath and Edwards (1958). The brain and other systems were normal.

Comment.—Death at this juncture was unexpected and the precise mechanism of events leading to it remains uncertain. While proof that it was due to acute right heart failure is lacking, both the failure of pulmonary arterial pressure to fall after closure of the defect and the necropsy findings seriously question

whether pulmonary vascular resistance was not already too high to permit successful surgery; and this in spite of pre-operative data suggesting that pulmonary resistance was no higher than in some others in the series, and that pulmonary flow was approximately double the systemic flow. It is perhaps significant that in the two patients with similar pre-operative haemodynamic findings, in whom pulmonary artery and aortic pressures were measured after closure of the defect (Cases 12 and 13), the pulmonary artery pressure had fallen to approximately half the systemic level.

Case 22.—Because of the degree of cardiomegaly (C.T.R.=70%), the electrocardiographic evidence of gross left ventricular hypertrophy, and the persistence of mild congestive heart failure in spite of intensive medical treatment, this patient with congenital valvular aortic stenosis and small ventricular septal defect was clearly a poor surgical risk. At operation the ventricular septal defect was readily closed and the aortic valve gradient completely abolished. Ventricular fibrillation occurred, however, on attempting to restart the heart and proved most difficult to convert to normal rhythm. It recurred six hours post-operatively. A severe acidemia (pH 7.16) also developed but responded to intravenous sodium lactate. Death occurred 20 hours post-operatively, the patient having failed to recover consciousness.

Comment.—Although this patient was a poor operative risk, death must be attributed to inadequate perfusion, for at a perfusion rate of 4.2 litres a minute (74 ml./kg./min.) the oxygen saturation of blood returning from the machine fell progressively during the 45 minutes of perfusion to a lower limit of 80%.

Post-operative Complications

There have been few serious post-operative complications in the survivors. However, as already noted, in Case 5 a second operation was required because of complete breakdown of the direct suture repair of ventricular septal defect on approximately the sixth post-operative day. After the second repair there is evidence of moderate aortic incompetence.

Post-operative bleeding has not been a problem after any of these 25 operations despite the fact that two patients (Cases 5 and 16) had had a thoracotomy within the preceding three months; and in only two patients did the total chest drainage exceed one litre. In three patients there have been minor complications from the left groin incision used for insertion of pressure cannulae into the femoral artery and vein. Post-operative sepsis elsewhere has not been encountered except possibly in Case 21, in which severe heart failure developed, associated with fever, elevation of sedimentation rate, and anaemia some 10 days after surgery, and which received intensive antibiotic treatment for presumed infective endocarditis, although confirmation from embolic phenomena or positive blood culture was not obtained. On the other hand, several patients, especially those whose heart failure was particularly severe, had low-grade pyrexia, lasting several weeks, which subsided spontaneously without any cause having been found.

Atrio-ventricular block of varying degree occurred in seven patients. In Case 9 the heart-block at least contributed to death; this has already been discussed. In four other patients (Cases 8, 10, 14, and 16) the block was of short duration and did not influence recovery in any way. In Cases 6 and 17, however, complete heart-block has persisted up to the time of writing, two and four months respectively after operation. In Case 17

direct stimulation of the myocardium by an artificial pace-maker via a wire electrode sewn into the right ventricular myocardium was required for approximately seven days. Both these patients have been given ephedrine and small doses of thyroid hormone (including initially L-triiodothyronine), but whether the subsequent gradual increase in pulse rate in both to between 55 and 65 is related to this treatment is uncertain.

Heart failure with systemic venous congestion, usually readily controlled and of short duration, has been a prominent feature during the post-operative course. In Cases 16 and 24 failure was already present pre-operatively, and in Case 5 it was associated with breakdown of the initial repair of the defect, but all the remaining survivors, except Case 20, also showed some evidence of failure in the immediate post-operative period. The degree of failure varied from very slight to very severe, necessitating continuance of a full decongestive regime for two months or more post-operatively. It has tended to be greatest in those cases having a marked increase in pulmonary vascular resistance. The duration of hospital convalescence, which varied from 22 to 114 days, although influenced by other factors such as rhythm change (Cases 6 and 17) and post-operative infectious mononucleosis (Case 3), was fairly closely related to the severity of heart failure. All patients have, however, shown progressive improvement in the degree of failure, and although at the time of discharge the temporary continuance of digitalis has usually been advised, this has been merely a precautionary measure to prevent recurrence of congestion during further convalescence and resumption of more normal activity.

Discussion

While no conclusions of statistical value can be drawn from this report of our initial experiences with extracorporeal circulation in intracardiac surgery, some general comments would seem to be justified.

The importance of the preliminary trials in the animal experimental laboratory, when the team as a whole became familiar with the technique, is emphasized by the fact that these first 25 human perfusions were adequate in all but one case. In this patient the arterial oxygen saturation fell to unsatisfactory levels for between 10 and 15 minutes. It appears from our data that the Melrose oxygenator, as used in these perfusions, seldom gave 100% oxygen saturation of the blood, even when the flow rate was as low as 0.8 l./min., and that when the flow rate rose to more than 2.5 l./min., the oxygen saturation tended to fall. The results in this small series suggest, however, that an arterial oxygen saturation in the region of 90% is not detrimental to the patient, at least for perfusions of moderate duration. More recently, by enlarging the filming plates of the oxygenator, the total surface area for filming has been increased by approximately two-thirds. While the upper limit of performance of the oxygenator, modified in this way, has not as yet been firmly established it has proved capable of raising the blood oxygen saturation from a venous level of 73% to 90% or more at sustained flow rates of 4.25 l./min. Another modification yet to be undertaken is provision for temperature control of the blood in the machine.

In this initial series the problem of case selection has related almost entirely to patients with ventricular septal defect as the principal lesion, for, once the adequacy of the method was established, it was applied as the

technique of choice for relief of congenital aortic or subaortic stenosis and tricuspid stenosis, and for repair in cases where there was reason to suspect an atrio-ventricular canal rather than an ostium secundum type of atrial septal defect. Patients with ventricular septal defect as the principal lesion have been accepted for operation not because they appeared to be good-risk cases but rather because either a large left-to-right shunt or a marked increase in pulmonary vascular resistance argued for correction without delay. In the former group the anticipation that successful surgery would result in restoration of the circulation to normal is not in question, and it appears that even in those with considerable cardiomegaly and incipient failure the risks of operation are quite acceptable. On the other hand, it is widely recognized that the immediate operative risk increases greatly with progressive elevation of pulmonary vascular resistance, and that repair is almost certainly contraindicated when peripheral resistances in the two circulations are approximately equal with only slight residual left-to-right shunting. Moreover, it has yet to be shown that closure of the defect in patients with considerable elevation of pulmonary vascular resistance will necessarily lead to progressive restoration of the circulation to normal and improvement in the long-term prognosis.

To date the criteria which separate, even from the point of view of immediate risk, the operable from the inoperable among patients with moderate to considerable increase in pulmonary vascular resistance have not been finally established, and in this series the difficulty of selection is emphasized by experience with the one patient with anatomically uncomplicated ventricular septal defect who died. In this patient the clinical and pre-operative haemodynamic features did not differ significantly from those in others who responded favourably with an immediate fall in pulmonary arterial pressure to closure of the defect, yet repair of the defect in this case did not result in any fall in pulmonary arterial pressure, and at necropsy gross obstructive lesions were found in the pulmonary arterial tree. Our present policy is not to recommend closure of ventricular septal defects if the pulmonary to systemic flow ratio is less than 1.75:1 or the pulmonary vascular resistance is known to be greater than 10 resistance units; but this attitude may well require modification in the light of further knowledge and experience.

One of the cases of ventricular septal defect was complicated by both great vessels taking origin from the right ventricle, a fact not appreciated before operation. In this case there was no history or clinical suggestion of cyanosis and no polycythaemia, and at catheterization, already performed when surgery was not immediately in prospect, a sizable left-to-right shunt had been found. An arterial sample had not been obtained, and it is possible that measurement of arterial oxygen saturation, which would now be undertaken routinely, might have led to the diagnosis. On the other hand, patients with an apparently similar abnormality of the aortic origin but without reduction of arterial oxygen saturation below the normal range have since been studied, and it appears that selective angiocardiology may be necessary to exclude this complication with certainty.

Summary

An initial series of 25 consecutive heart-lung by-pass operations performed with a Melrose N.E.P. pump oxygenator is described.

In 15 cases ventricular septal defect was the principal lesion, and eight of these had at least a moderate increase in pulmonary vascular resistance. The principal lesion in the other nine cases was partial atrio-ventricular canal in three, atrial septal defect in one, congenital aortic stenosis in four, and rheumatic tricuspid stenosis in one.

Perfusion was regarded as adequate in all but one case in which the oxygen saturation of blood from the machine fell progressively, at a flow rate of 4.2 l./min. to 80%. By modification the oxygenating capacity has been improved.

There were three hospital deaths. The first of these occurred in a 2-year-old child, included in the ventricular septal defect group but in whom both the pulmonary artery and the aorta arose entirely from the right ventricle. The second death, attributed to the perfusion, occurred in an adolescent with severe congenital aortic stenosis associated with a small ventricular septal defect. The third occurred in a child with ventricular septal defect associated with a considerable increase in pulmonary vascular resistance.

Complete heart-block has persisted since surgery in one case of ventricular septal defect and one case of partial atrioventricular canal.

The technique of operation and problems of case selection are briefly discussed.

ADDENDUM.—Since submission of this paper a further 85 perfusions have been performed, bringing the total to 110. In the most recent 25 cases there have been four hospital deaths—namely, one case with corrected transposition with single ventricle; one with corrected transposition, pulmonary stenosis, and ventricular septal defect; one with tetralogy of Fallot; and one with congenital mitral valvular disease in which it was technically impossible to correct the mitral incompetence. Included amongst the 21 survivors are four cases of complete correction of tetralogy of Fallot.

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"The mayor of the little commune of Aromas, near Dijon, has protested to his local prefect, claiming that his authority is being undermined by madmen. It appears that the 148 sane members of the village are outnumbered by the inmates of a local lunatic asylum, who in France are entitled to vote, and recently have been voting as a block for the opposition. The mayor's protests, however, seem to be based not on any inherent lack of judgment in the voters but on the fact that, coming from all parts of France, they should not be allowed to control the affairs of Aromas." (*The Times*, November 10.)