OPEN HEART SURGERY IN SINGAPORE — A REVIEW

By N. C. Tan
(Thoracic Surgeon, T.T.S.H., Singapore)*

This paper reviews the work of the Open Heart Team at the Thoracic Surgical Unit at the Tan Tock Seng Hospital, Singapore. This Unit was established in December 1966 and the first open heart case was done on the 23rd of February 1967.

Prof. Kenneth N. Morris with an open heart team from Melbourne helped us with our initial 15 cases. Since then, altogether 93 open heart cases have been done and this paper reviews 90 of them.

THE MONITORS

We are at present monitoring the following parameters:-

1. Pressure monitors:
   (a) Central Venous Pressure (S.V.C. and I.V.C.)
   (b) Arterial Pressure (Descending Aorta)
2. Electrocardiogram
3. Temperature—Nasopharyngeal
4. Urine Output
5. Blood Gases—Before, during and after the By-pass
6. Electrolytes—Serum Electrolytes and Urinary Potassium

We have found the above monitors adequate to keep tract of the response and physiological state of the patient throughout the operation.

THE HEART-LUNG MACHINE

We are at present using the Rygg-Kysgaard Heart-Lung Machine from Denmark. This is a disposable pump oxygenator of very simple design. It is very robust and meets all our requirements. It oxygenates the blood and removes the carbon dioxide efficiently and can function satisfactorily for 5 hours before the defoaming chamber is exhausted.

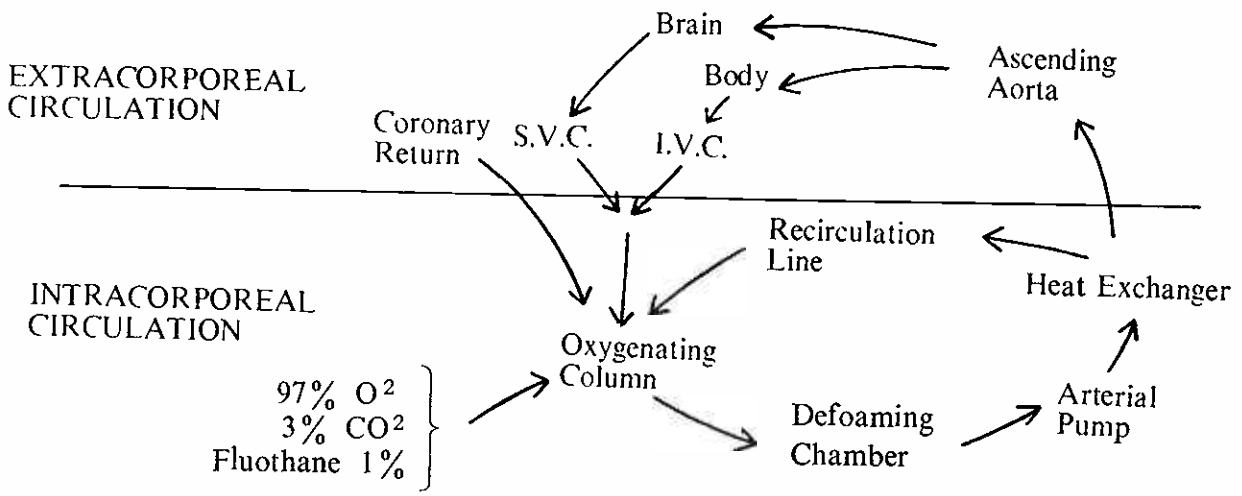
Trauma to the blood is minimal.

The coronary suction system is very gentle on the blood and it takes some time to get used to the characteristics of this system. Our studies have shown that haemolysis is of a very low order during our perfusions.

THE EXTRACORPOREAL CIRCUIT

Blood leaves the body and enters the oxygenating column from the bottom where it is joined by a gas mixture of 97% oxygen and 3% carbon dioxide which is passed through a fluotec to give 1% fluothane in the gas (Fig. 1).

The blood then rises up the column and enters the defoaming chamber and next the



Circuit Diagram of the Disposable Pump Oxygenator.

Fig. 1.

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settling chamber where there are fine-meshed filters to filter out any fibrin threads. The blood is then pumped through a heat exchanger back into the patient via the ascending aorta.

THE BLOOD REQUIREMENT

Fresh A.C.D. blood collected within 24 hours of the operation is used. To each 500 c.c. of blood is added:-

25 mg. of heparin (2,500 I.U.)
6.0 c.c. Calcium Gluconate 10%, and
10 mEq. Sodium Bicarbonate 8.4%

Realising the relative shortage of blood in our community, we have been making efforts to reduce the blood requirements for our open heart operations and it is interesting at this stage to review the blood usage right from the beginning.

For this purpose, we have divided our cases into 3 groups:-

Group I — 1st 25 cases when we were starting and relatively inexperienced.

Group II — 2nd 25 cases when certain modifications were made to the haemodilution and surgical techniques.

Group III — Last 40 cases after further modifications were made following a study tour of Australia and New Zealand.

An analysis showed that the amount of blood required during the operations had fallen to one-third of the original requirements— from round about 4.5 litres in the 1st group to an average of 1.3 litres (Table I).

This was reflected in the overall average for all the operations in each of the groups. The latest blood requirements for each operation averaged 1.3 litres or slightly more than 2 large units of blood.

TOTAL BLOOD USAGE

This usage is inclusive of the blood required for replacing blood lost during the post-operative period through oozing and also for correcting anaemia from accelerated haemolysis as a result of trauma to the blood in its passage through the heart-lung machine. This requirement extended to about 7 days after operation.

After the first week, further transfusion is rarely required (Table II).

The total blood usage closely follows the pattern that was seen in the previous table. Initially, the average amount of blood required was 6.1 litres. The latest average requirement was 2.0 litres or less than 4 units altogether.

CLINICAL MATERIAL

Sex Distribution

In those patients with atrial septal defects, the females were three times as many as the males (Table III). In the other groups, the sex distribution was about equal.

The Age Distribution

Only the patients with atrial septal defects and ventricular septal defects were analysed (Fig. 2). The other groups of patients were too small for significant analysis.

The youngest patient was 2 years old and she had an ostium primum defect with recurrent heart failure. The oldest patient was also one with an atrial septal defect aged 42 years.

The majority of patients were below 25 years. All those with ventricular septal defects were below 25 years of age. These patients had

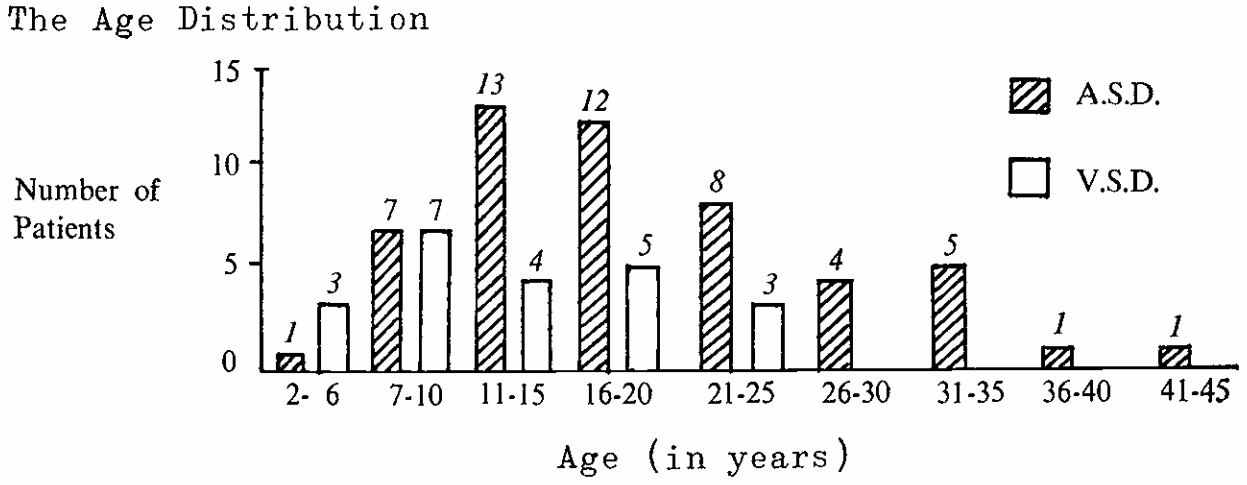

Fig. 2.

TABLE I

BLOOD USAGE DURING OPERATION

No. of Cases: 90 Blood Usage (In Litres)

Lesion	Group I(25)	Group II(25)	Group III(40)
	(23.2.67-12.7.67)	(19.7.67-11.4.68)	(5.6.68-28.11.68)
A.S.D. (52)	4.5 (3.4—6.8)	2.1 (0.8—3.8)	1.3 (0.5—2.0)
V.S.D. (23)	4.9 (2.4—7.6)	2.5 (1.9—3.1)	1.5 (1.1—2.0)
P.S. (9)	1.9 (0—3.5)	—	1.3 (1.0—1.5)
Fallot's (5)	2.7 (2.1—3.3)	—	0.4 (0—1.2)
Others (2)	—	1.4	1.0
AVERAGE	3.7	2.1	1.3

TABLE II

TOTAL BLOOD USAGE

No. of Cases: 90 Total Blood Usage (In Litres)

(Including Operation)

Lesion	Group I(25)	Group II(25)	Group III(40)
A.S.D. (52)	6.8 (4.0—9.9)	3.4 (1.3—4.8)	1.8 (0.9—4.1)
V.S.D. (23)	9.1 (4.3—13.4)	4.9 (3.2—8.0)	2.4 (1.7—3.3)
P.S. (9)	2.9 (0—8.5)	—	2.5 (2.1—2.8)
Fallot's (5)	7.3 (6.0—8.7)	—	1.4 (0.4—2.4)
Others (2)	—	3.2	1.0
AVERAGE	6.1	3.6	2.0

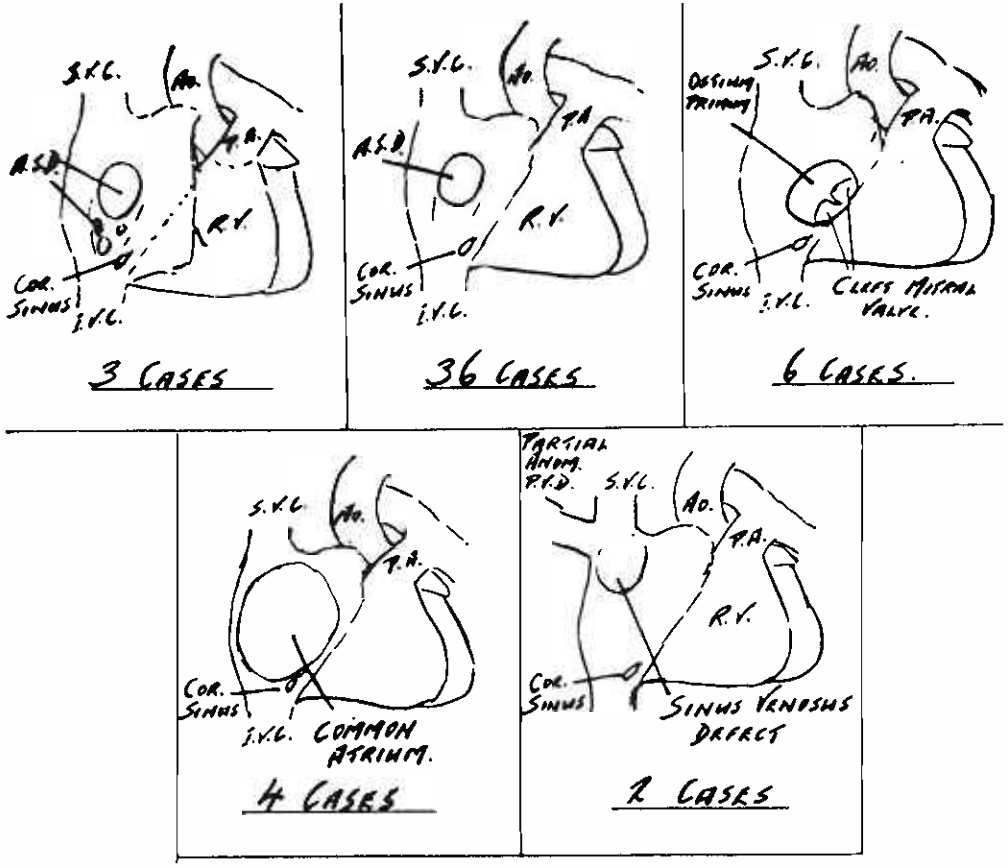

Fig. 3. Outline drawing of the varities of A.S.D. encountered at operation.

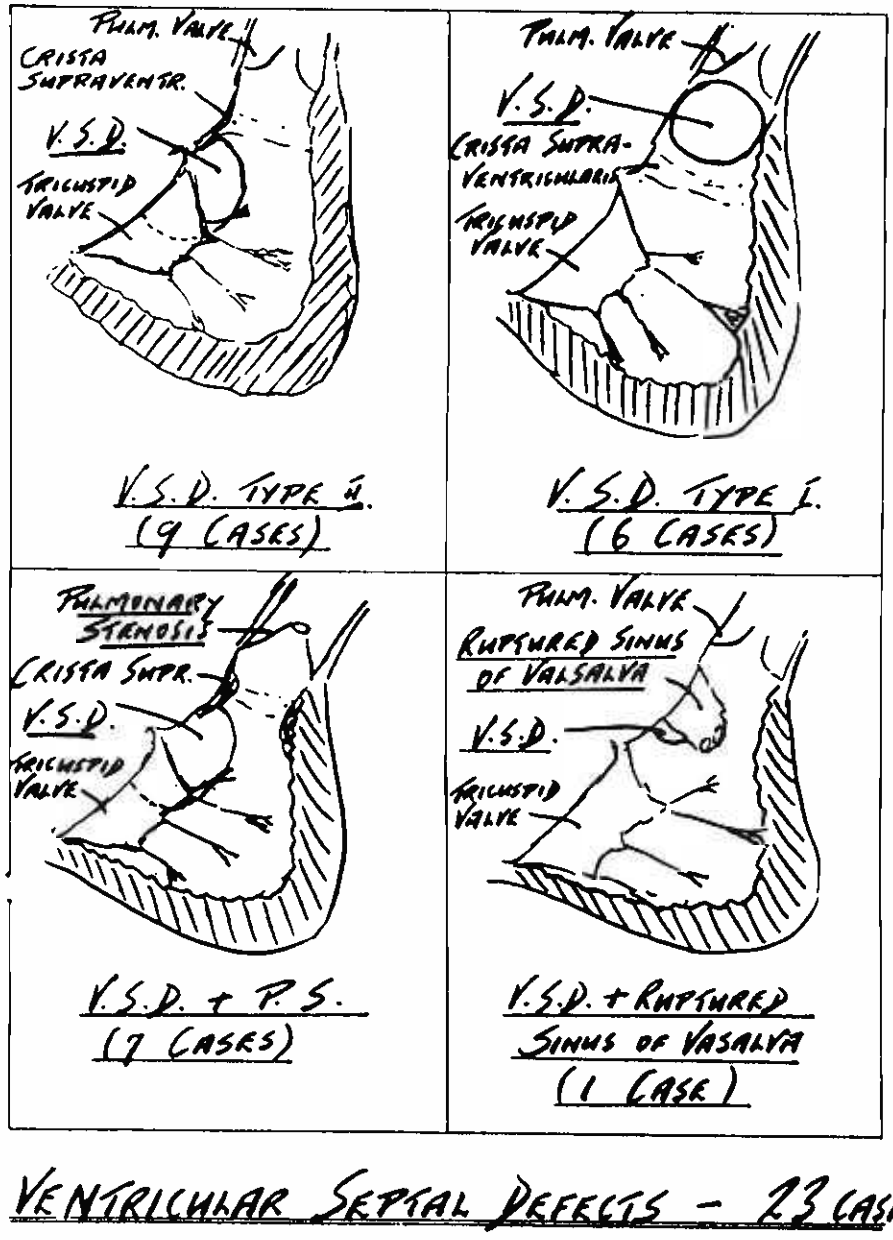

Fig. 4. Outline drawing of the types of V.S.D. encountered at operation.

TABLE III

THE CLINICAL MATERIAL

Sex Distribution

Lesion	Male	Female
Atrial septal defect	13	39
Ventricular septal defect	13	10
Pulmonary stenosis	4	5
Fallot's Tetralogy	2	3
Coronary arteriovenous fistula	1	0
TOTAL	33	57

TABLE IV

INDICATIONS FOR OPERATION

Symptoms	A.S.D.	V.S.D.	P.S.	Fallot's	Total
Asymptomatic	21	1	5	0	27
Failure to thrive	4	2	0	0	6
Palpitations	9	4	0	0	13
Recurrent chest infections	10	13	0	0	23
Effort Dyspnoea					
Grade I	4	3	2	0	9
Grade IIA	6	2	1	1	10
Grade IIB	6	4	0	4	14
Cardiac failure	5	7	0	0	12
Cyanosis on exertion	0	2	2	3	7
Cyanosis at rest	0	0	2	2	4
Syncope	0	0	1	0	1

very large shunts and were in trouble. Over half of these patients had very considerably pulmonary hypertension.

THE INDICATIONS FOR OPERATION

Patients with Atrial Septal Defects. In this group of patients, 40% were asymptomatic but had shunts of 2.5 times or more through their lungs as compared to the circulation through the body. 40% had effort dyspnoea. 20% had recurrent chest infections and 25% had palpitations or failure to thrive. 10% of these had recurrent cardiac failure (Table IV).

Patients with Ventricular Septal Defects. Only one patient in this group is asymptomatic. The others had palpitations, recurrent chest infections and cardiac failure, and effort dyspnoea.

Many of these patients have severe pulmonary hypertension.

Patients with Pulmonary Stenosis. Fifty percent of these patients were asymptomatic. But they had gradients across the pulmonary valve or right ventricular outflow tract of over 100 mm. Hg. The other fifty percent had effort dyspnoea, cyanosis on exertion due to reverse shunt through a foramen ovale, cyanosis at rest or syncope.

Patients with Fallot's Tetralogy. All these patients had effort dyspnoea. Cyanosis of varying degree was present.

THE CLINICAL TYPES

Clinically, the following types were picked up.

(a) *Atrial Septal Defects*

1. 39 patients were diagnosed as having classical ostium secundum defects.
2. 6 patients had the features of an ostium primum defect.
3. 3 patients had pulmonary stenosis in association with the atrial septal defect.
4. 2 patients had evidence of partial anomalous pulmonary venous drainage in association with the atrial septal defect.
5. 2 patients presented as uncomplicated atrial septal defects with large shunts but were found to have other combinations at operation.

(b) *Ventricular Septal Defects*

1. 13 patients had ventricular septal defects with varying degree of pulmonary hypertension.
2. 7 patients had pulmonary stenosis in association with the ventricular septal defect.
3. 1 patient had aortic incompetence of a mild degree which was diagnosed only at operation.
4. 1 patient had ruptured sinus of Valsalva presenting as the main lesion.
5. 1 patient had mitral incompetence of severe degree recognised at operation.

(c) *Pulmonary Stenosis*

These patients all had obstruction at the valvular level.

Varying degrees of infundibular obstruction was present. Altogether there were 9 patients in this group.

(d) *Fallot's Tetralogy*

5 patients presented the classical features of Fallot's Tetralogy.

FINDINGS AT OPERATION

At operation, the findings in the group of atrial septal defects and ventricular septal defects were as follows:-

(a) In the atrial septal defects (Fig. 3):

i. 3 patients had multiple holes in the atrial septum.
ii. 36 patients had the classical ostium secundum defect.
iii. 6 patients had the low anterior defect of the ostium primum variety in association with the cleft anterior mitral valve cusp.
iv. 4 patients had such a large defect that there was practically no septum at all, and
v. 2 patients had a high sinus venosus defect in association with partial anomalous pulmonary venous drainage.

(b) In the ventricular septal defects (Fig. 4):

i. 9 patients had a large low posterior Type II defect hidden by the septal cusp of the tricuspid valve.
ii. 6 patients had anterior defects just below the pulmonary valve cusps.
iii. 7 patients had septal defects associated with pulmonary valvular and often infundibular stenosis, and
iv. 1 patient had a small Type II ventricular septal defect in association with a ruptured sinus of Valsalva.

No attempt is made to analyse the other patients as their numbers are too small

TABLE V

POST-OPERATIVE COMPLICATIONS

Complications	Gr. I(25)	Gr. II(25)	Gr. III(40)	Total
No Complications	12	12	23	47
Haemorrhage				
Persistent Bleeding	2	2	1	5
Cardiac Tamponade	1	0	0	1
Haemopericardium	0	0	1	1
Haemolytic Jaundice	1	0	0	1
Cardiogenic				
Cardiac Failure	3	3	5	11
Left Heart Failure	0	2	1	3
Nodal Rhythm	0	3	2	5
Supraventricular Tachycardia	0	3	1	4
Ventricular Extrasystole	0	2	0	2
Renal Shutdown	1	1	0	2
Respiratory				
Tracheo-bronchitis	2	0	0	2
Bilateral Bronchopneumonia	1	1	0	2
Pleural Effusion	2	0	1	3
Post-Perfusion Lung	1	0	0	1
Others				
Poor Wound Union	2	0	0	2
Psychoneurosis	2	0	0	2
Air Embolism	1	0	0	1
? Residual Shunt	0	0	1	1
Oedema Glottis	0	1	0	1

TABLE VI

MORTALITY

A. **Operative Mortality**

		Nos.	Mortality
Atrial Septal Defects		52	2
A.S.D. Secundum	39		
A.S.D. Ostium Primum	6		
A.S.D. + P.S.	1		
Common Atrium + P.S.	2		
Common Atrium	1		
Common Atrium + Mitral Atresia	1		
Sinus Venosus Defect + Partial Anomalous Pulm. Venous Drainage	2		
Ventricular Septal Defects		23	1
V.S.D.	13		
V.S.D. + P.S.	7		
V.S.D. + A.I.	1		
V.S.D. + M.I.	1		
V.S.D. + Ruptured Sinus of Valsalva	1		
Pulmonary Stenosis		9	1
Fallot's Tetralogy		5	1
Coronary Arteriovenous Fistula		1	0
TOTAL		90	5(5.5%)

COMPLICATIONS

Over 50% of our patients had a smooth uneventful post-operative course.

1. *Haemorrhage.* Seven patients were troubled with bleeding in various forms. Four of these occurred in the first group. Six of them were explored in the post-operative period for persistent haemorrhage. One patient had a large haemopericardium and was tapped repeatedly. All patients survived.

   One patient had haemolytic jaundice.

2. *Cardiogenic Complications.* Fifteen percent of our patients had varying degrees of cardiac failure. Except for one patient, the others responded favourably to standard therapy.

   Six patients had arrhythmias.

3. *Respiratory Problems.* Most of our respiratory problems occurred in the first group of cases. Since then, respiratory problems have been insignificant.

4. *Miscellaneous.* In this category, the most serious was air embolism which occurred at the time of the operation in the first case in this series. Again, most of these cases in the first group of patients.

5. *Delayed Complication.* A case of tracheal stricture occurred in one of our patients in the first group who had persistent tracheobronchitis. This occurred three months after operation (Table VI).

MORTALITY

Our overall mortality for this group of patients is 5.5%.

In presenting the subsequent tables of comparative mortality, it must be emphasised that they are being used as a rough yardstick of our performance (Table VII).

To make a relevant and significant comparison, one has to break down the figures further and do it in relation to the severity of the lesion and other patho-physiological changes that were present at the time of the operation.

At the moment, our series is too small for such a comparison.

The first death in our group of atrial septal defects was in our very first patient in this group. She had congested lungs following operation. This was complicated by bilateral broncho-pneumonia which caused her death 11 days after operation.

The second death was a child of 2 years who had a large ostium primum defect. Following a successful repair, he developed a marked supraventricular tachycardia on the 3rd day at 5.00 a.m. and succumbed.

The death in the group of ventricular septal defects was a young man who also had pulmonary stenosis. He had persistent insomnia after operation. Otherwise his progress was uneventful. On the 8th day, he went into left ventricular failure with acute pulmonary oedema. This was followed by cardiac arrest. His cardiac function was established by external cardiac massage and other resuscitative measures but he had a renal shutdown. Peritoneal dialysis was started 12 hours later but he died 24 hours later.

The only death in the group with pulmonary stenosis was due to air embolism. This was the very first case in this series.

The patient with Fallot's Tetralogy who died succumbed from a post-perfusion lung. His lungs were very stiff following operation. Ventilation was difficult. He died 20 hours after operation.

DELAYED MORTALITY

One patient died 6 months after operation after surviving 3 months in a decerebrate state. Three months following operation she was found to have a diaphragmatic obstruction in her upper trachea. Following a tracheostomy, she was transferred to another department for the management of this complication.

She improved with tracheal dilatation and the tracheostomy tube was removed prior to transfer. She developed another episode of respiratory obstruction during which she had cerebral damage.

FUTURE DEVELOPMENTS

To date, we have confined our activities to the field of congenital heart disease.

We are now working towards acquiring facilities and developing the capacity to handle cases with:-

(a) Acquired heart disease who require valve replacement.

(b) Ischaemic heart disease, and in the more distant future.

(c) Cardiac transplants when it is put on a more practical basis.

To achieve this, we are planning to acquire a new 5-pump heart-lung machine with facilities for coronary perfusion and a more positive and effective coronary suction.

TABLE VII

B. Comparative Mortality

Source	No. of Patients	Deaths	Mortality
Atrial Septal Defects			
Cooley *et al* (1960) Texas Medical Centre, U.S.A.	194	12	6.2%
McGoon *et al* (1959) Mayo Clinic, U.S.A.	32	2	6.3%
Prabchuabmoh *et al* (1967) Siriraj Hospital, Bangkok	69	10	14.5%
Tan, N.C. (1968) Tan Tock Seng Hospital, Singapore	52	2	3.8%
Ventricular Septal Defects			
Cartmill *et al* (1961-1966) Mayo Clinic, U.S.A.	447	31	7.0%
Cooley, D.A. (1956-1965) Texas Medical Centre, U.S.A.	592	55	9.3%
Prabchuabmoh *et al* (1960-1967) Siriraj Hospital, Bangkok	75	10	13.3%
Tan, N.C. (1967-1968) Tan Tock Seng Hospital, Singapore	23	1	4.3%
Pulmonary Stenosis			
Shumacker *et al* (1961) Indiana Univ. Medical Centre, U.S.A.	72	2	2.8%
Dilley *et al* (1963) Univ. of California Medical Centre	60	3	5.0%
Slade, P.R. (1963) Brompton Hospital, London	13	3	23.0%
Prabchuabmoh *et al* (1967) Siriraj Hospital, Bangkok	18	3	16.6%
Tan, N.C. (1968) Tan Tock Seng Hospital, Singapore	9	1	11.1%
Tetralogy of Fallot			
Starr. A. (1968) Portland, Oregon, U.S.A.	160	19	12.0%
Sutherland, D.A. (1968) Royal Adelaide Hospital, Adelaide	60	6	10.0%
Kirklin *et al* (1960) Mayo Clinic, U.S.A.	110	18	17.0%
Prabchuabmoh *et al* (1967) Siriraj Hospital, Bangkok	38	16	42.1%
Tan, N.C. (1968) Tan Tock Seng Hospital, Singapore	5	1	20.0%

With this machine and the increasing experience and skill of the open heart team, we should be able, in time, to cope with all the problems in this field of endeavour.

ADDENDUM

The three patients who have not been included in this presentation are:-

(a) 2 cases of atrial septal defects, and

(b) 1 case of common atrium with mitral atresia which was diagnosed preoperatively as having a large A.S.D. with a large shunt.

One patient is recuperating now. Two of them have mild cardiac failure which is responding satisfactorily to therapy.

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