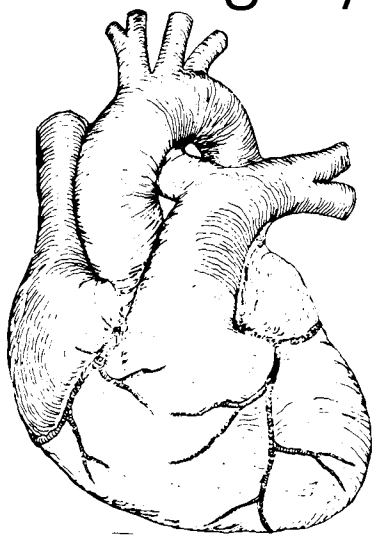
Open-Heart Surgery in Australia



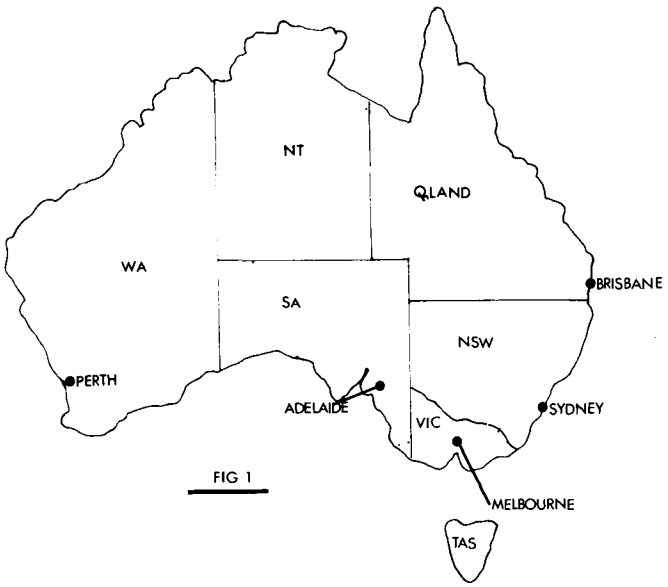


FIG 1

MAURICE ROBERTSON
Perfusionist, Thoracic Surgical Division,
St. Vincent's Hospital, Sydney, Australia

Some aspects of the beginnings and the present position.

INTRODUCTION

Cardiac surgery under hypothermia has been in use in Australia for such cases as pulmonary valvotomy and repair of atrial septal defects for two years when Australia's first cardio-pulmonary bypass was carried out in May 1956 at the Alfred Hospital, Melbourne. The operation was carried out by Sir James Officer-Brown, on a small child with total anomalous venous drainage. The following year, Dr. K. N. Morris, using a sigmamotor finger pump and bubble oxygenator commenced a programme of open-heart surgery on children with congenital defects. Eight of the ten cases operated on in that year survived.

In Sydney, the Royal Prince Alfred Hospital Introduced cardio-pulmonary bypass in 1957. At the Hospital's invitation, this programme was initiated by Dr. H. Bahnson and Dr. F. Spencer, now professors of surgery and chairmen of their respective departments in the Universities of Pittsburg and New York. Surgery was carried out on atrial and ventricular septal defects and pulmonary and aortic stenoses, using a Debakey Roller pump and screen oxygenator.

St. Vincent's Hospital in Sydney also started cardiac surgery under cardio-pulmonary bypass for the correction of congenital defects, the first case being in 1959. A Debakey pump and disc oxygenator of local manufacture were used. This pump-oxygenator, first produced in Sydney in the late 1950's, was jointly designed by the Royal Alexandra Hospital for Children and a commercial company, Ebsray Limited. Known as the Ebsray machine, the pump-oxygenator was widely used throughout Australia until recent years. (An illustration of the Ebsray machine is shown in Figure 10). This introduction of bypass followed considerable experience with hypothermia and ten years' experience in closed cardiac surgery.[1]

The Royal Perth Hospital in Western Australia became actively involved in cardio-pulmonary bypass in the laboratory in 1956. The first clinical case, for the relief of pulmonary stenosis, was undertaken in October 1959. For this operation a bubble oxygenator and a sigmamotor pump were used. The patient is still alive and well. Shortly after, a disc-oxygenator and Debakey pumps were obtained and used until the end of 1962 when the Ebsray pump-oxygenator was introduced.

Today, open-heart surgery in Australia is confined to the capital cities of five of the six states of the Commonwealth. Figure 1 shows the centres of open-heart surgery in Australia.

MELBOURNE - VICTORIA

Melbourne is the capital city of the State of Victoria, and has a population of about 2.25 million. The hospitals practicing open-heart surgery in Melbourne are the Alfred Hospital, The Royal Children's Hospital, and the Open-Heart Surgery Unit of the University of Melbourne Hospitals at St. Vincent's Hospital.

At the Alfred Hospital (Figure 2) the department known as the C. J. Officer-Brown Cardiac Surgery Unit uses a pump oxygenator which was designed and built (1959) in the Hospital. This is the Kinross-Merrie console (Figure 3). More recently disposable oxygenators are being used, the Temptrol having replaced the Rygg oxygenator for routine use. Surgery for aortic stenosis and incompetence began in 1959.

The first valve replacements with a Starr-Edwards mitral prosthesis were carried out in 1962. This department's experience with open-heart surgery now approaches 1200 cases with an average weekly case load of three or four. The present outlook suggest more and more surgery will be devoted to coronary artery vein

Figure 2

grafts, the first of which at the Alfred was carried out early in 1970.

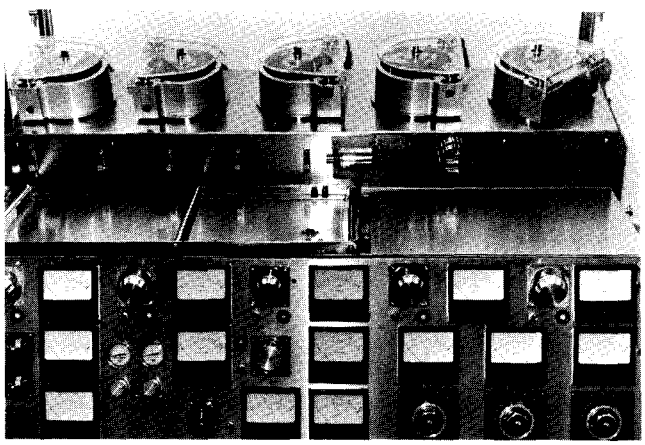
A specialist cardiac unit is situated in the Royal Children's Hospital (Figure 4) where open-heart surgery began in 1959 with the closure of simple atrial and ventricular septal defects. A Kay-Cross disc-oxygenator and a Pemco pump were used. In 1961 the Sydney-made Ebsray pump-oxygenator was introduced. As early as 1962 this unit first used disposable bubble oxygenators, reserving the discs for longer perfusions.

In 1965 the hospital obtained a pump-oxygenator of the Alfred Hospital type (as in Figure 3). During the next few years the same pump was being used at the Royal Melbourne Hospital as well as the Royal Children's and had to be shuttled back and forth between the two institutions. Currently a Sarns pump console and Temptrol oxygenators are used for all cases. As is the general trend in pediatric open-heart surgery, profound hypothermia with partial bypass is being used. In 1970 five such cases in a total of 80 perfusions were undertaken.

St. Vincent's Hospital (Figure 5) was the third of the Melbourne open-heart surgery units to be established and is currently the busiest. The first open-heart operation was the successful closure of an atrial septal defect in 1963. This followed earlier cardiac surgery under profound hypothermia.

The bypass equipment first used consisted of two monopumps combined with a Kay-Cross oxygenator.

Figure 3



This system was replaced by the Alfred Hospital-type machine which has been in continual use ever since. The disc oxygenator has been gradually phased out in favour of firstly the Travenol oxygenator and then the Rygg bag. At present the Temptrol oxygenator is replacing the Rygg bag.

Prior to 1969 the Royal Melbourne Hospital had also been engaged in open-heart surgery, using the same machine as the Royal Children's Hospital. At the recommendation of the Victoria Department of Health the cardiac surgical units of the Royal Melbourne and St. Vincent's Hospital were combined to form the Open-Heart Surgery Unit, University of Melbourne Hospitals. The amalgamation has resulted in a rapid increase in the case load. In the year ending June 1971 160 elective open-heart operations were performed. Currently up to eight bypass procedures have been done weekly. The combined unit is situated at St. Vincent's Hospital and is staffed by the cardiac surgeons of both the Royal Melbourne and St. Vincent's Hospital.

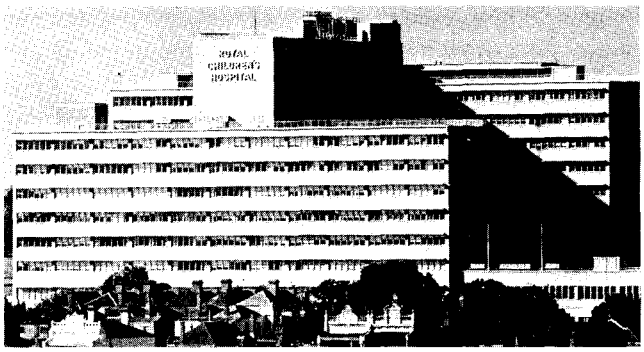


Figure 4

SYDNEY - NEW SOUTH WALES

Hospitals practicing open-heart surgery in New South Wales are the Royal Prince Alfred Hospital, St. Vincent's Hospital, Prince Henry Hospital, the Royal North Shore Hospital, and the Royal Alexandra Hospital for Children, all in the state capital, Sydney.

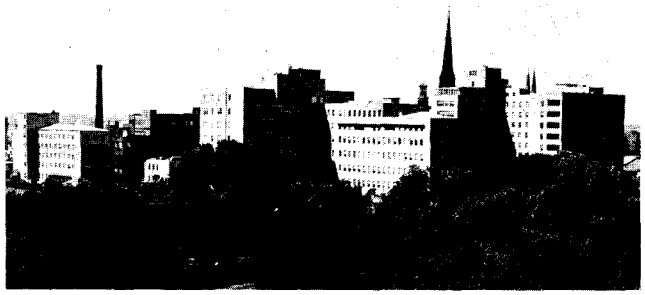


Figure 5

The population of New South Wales is 4.5 million, of which two-thirds are concentrated in the capital. The rest are distributed over an area of 309,000 square miles, served by air-ambulance in cases of emergency, as are the country populations in other states.

The Royal Prince Alfred Hospital is Sydney's largest general hospital and the thoracic surgical unit is one of Sydney's busiest. Up to six cardio-pulmonary bypasses per week is the current case load. Basically the bypass apparatus presently used is an Ebsray disc oxygenator which was introduced into the unit in 1963.

Dr. H. Windsor gives an excellent review of the development of cardiac surgery at St. Vincent's Hospital since its beginnings (see Reference 1). The present case load at this hospital (Figure 6) is three to five elective cardio-pulmonary bypasses a week. St. Vin-

Figure 6

cent's performed Australia's first coronary artery graft in 1970. One hundred and fifty such cases have so far been done.

It was in 1963 that a Kay-Cross disc oxygenator and Debakey pump console were obtained from American Optical. This console was in constant use until 1970. Modified for use with the Temptrol oxygenator the unit is still used in cases where coronary perfusion is necessary.

Otherwise, a modular unit, designed at the Hospital and also using Temptrol oxygenators is used. This unit consists of one Pemco arterial pump (type 6501-P), providing for either pulsatile or constant flows.* Pulsatile flow is used for preference.[2, 3,4,5]. Figure 7 shows a typical blood pressure trace recorded during a pulsatile flow perfusion. Open-heart suction, i.e. a left ventricular vent, hand-held coronary suction plus a sump sucker which doubles as a thumb-tack aortic vent needle, is supplied by the hospital on-wall vacuum.

Figure 8 shows the arrangement of the vacuum suction system. Consisting basically of up to three Temptrol cardiotomy reservoirs, vacuum suction is applied to the cardiotomy reservoirs and is easily regulated by adjustment of the vacuum suction control valve.** (Figure 8a). This use of vacuum suction saves the necessity of providing extra pumps. Only one roller pump (Figure 8b) is therefore needed to empty the cardiotomy reservoirs into the oxygenator.

PERFUSION TECHNIQUE

As the author is the perfusionist at St. Vincent's Hospital, the clinical perfusion technique used can be described in outline. The Temptrol oxygenator is used for all clinical cardio-pulmonary bypasses. In recent times a greater awareness has been shown in respect to micro-emboli[6, 7] and it is now generally believed that all pump oxygenating systems are responsible for the production of microemboli. Microfiltration is provided by the use of the "Pall filter".[8] The filter is used only on the cardiotomy suction side of the circuit, and blood required during the perfusion is transfused through the filter.

Unless contra-indicated by the packed-cell volume-haemoglobin figure, all patients are haemodiluted with Hartmann's or Plasma-Lyte (Travenol) solutions 25-30 ml/kg. body weight. Extra volume as required during the bypass is made up with Plasma-Lyte or whole blood, depending on the packed-cell volume. To the initial priming volume are added a routine 10,000 units of heparin without preservatives, 3 grams ascorbic acid[9], and 100meq. sodium bicarbonate.

If the extracorporeal volume required augmenting at this stage, the volume is made up with A.C.D. blood.

* Pemco Inc., Cleveland, Ohio
** H.I. Clements Ltd., Sydney

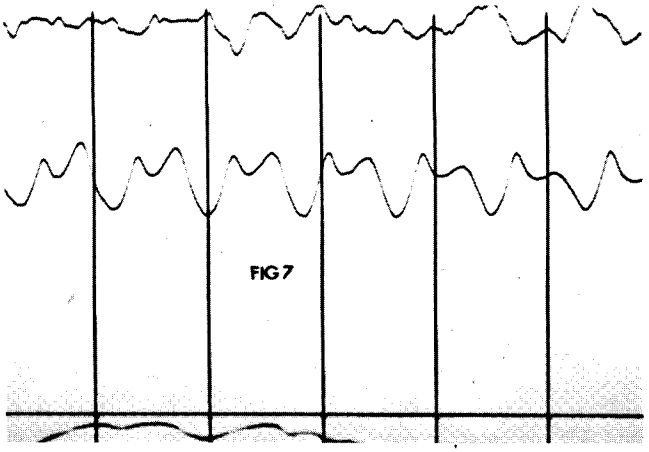


Figure 7

Calcium chloride, 0.5 g. per unit of blood, is added once bypass has been established. Prior to bypass the priming volume is recirculated for at least 10 minutes at 35°C.

The most suitable condition for cardio-pulmonary bypass is provided by aortic cannulation using the largest bore size possible, particularly in conjunction with pulsatile flow. A second advantage at this stage is to find the patient with an elevated right atrial pressure. This helps overcome the initial hypotension associated with the institution of bypass. In the absence of an elevated right atrial pressure bypass is commenced by transfusing the patient from the oxygenator until a right atrial pressure of approximately 5 mm.Hg is obtained.

At this stage venous drainage is opened slowly, the arterial pump flow having already reached its predetermined rate. The venous drainage is finally left unobstructed.

On the establishment of bypass and in the event of a sudden loss of arterial pressure, metaraminol ("Aramine") in 1 mg. aliquots is injected into the oxygenator in order to maintain blood pressure at greater than 40-50 mm.Hg. The author believes that the use of Aramine in this situation is greatly more desirable than the problems associated with the re-establishment of a satisfactory blood pressure during the initial stage of

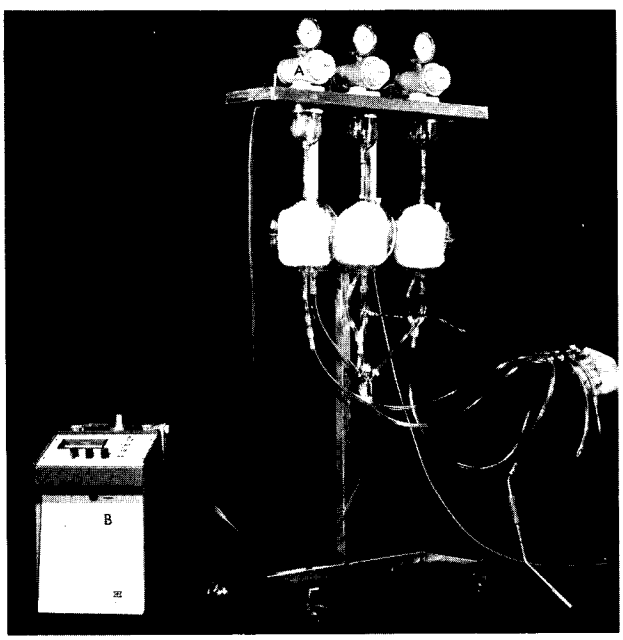


Figure 8

the perfusion. A keen awareness is maintained in relation to blood pressure on bypass and to the post-bypass neurological problems resulting from low-pressure perfusion.[10, 11]

Blood cooling to 30°C is commenced using a Sarns heat exchanger. Many units now have completely discarded mild hypothermia, but it is felt that the occasional time-lag in rewarming is worth it for the safety margin gained in its use. On bypass blood pressure is left to develop above a mean of 80 mm.Hg with a blood flow of usually 2.4 litres per sq. metre. Venous pressure is kept on the positive side, 0-2 mm.Hg.

The occasional hypertension which is unable to be controlled with 0.5% halothane is controlled by the use of a trimetaphan ("Arfonad") drip. Blood gases and haematocrit determinations are done at regular intervals for the duration of the perfusion. All base deficiencies are corrected with sodium bicarbonate, using a solution containing 1 meq. per ml. (8.4%).[12] Serum potassium concentration is measured pre-bypass and during bypass. All electrolytes are measured immediately post-bypass. Potassium chloride is slowly run into the oxygenator throughout the bypass period, usually no more than 20-30 meq. in all.

The volume of urine produced on bypass is measured and Mannitol is given if indicated. Coronary perfusion, when required, is governed by the conditions at the time. There are no pre-calculated flows. The flow rates through the coronary perfusion cannulae are adjusted so that the perfusion pressures, which are continuously monitored at the pump, do not exceed 100 mm.Hg. The coronary perfusion cannulae used are the Mayo type with a range of three sizes. Cannulation is a loose fit so that excess back-pressure will bleed past.

On re-warming, fentanyl (a short acting narcotic analgesic) is injected via the oxygenator. Depending on the ability of the myocardium to produce a satisfactory blood pressure, Aramine is injected into the oxygenator, if necessary, prior to coming off bypass.

PRINCE HENRY HOSPITAL

Although the Prince Henry Hospital (Figure 9) itself is not a new establishment, being built last century as an isolation hospital, its Division of Cardiopulmonary Surgery is the most recently created open-heart unit of the Sydney hospitals. This development was made possible when the Hospital became one of the teaching hospitals associated with the newly-founded Medical School of the University of New South Wales in 1961.

Unlike others in Sydney, this unit was able to start from the beginning with a range of open-heart procedures. The unit has recently extended its interest to paediatric cardiac surgery, including the use of deep hypothermia in 40 such cases to date. The case load has been light, but is now increasing to three or four a week and this, together with liberal funds and equipment made available through the university affiliation has enabled the unit to participate in a variety of research topics bearing on cardiac surgery. The perfusion apparatus consists of the Ebsray pump-oxygenator (Figure 10) although recently a full range of American Optical and Sarns equipment has been introduced.

1961 saw the start of another open-heart unit in Sydney, that at the Royal North Shore Hospital, developing from experience which dated from the establishment of a congenital heart clinic in 1936. Stages in this development included a first closure of a patent ductus arteriosus in 1944 and a first closed mitral valvotomy in 1952.

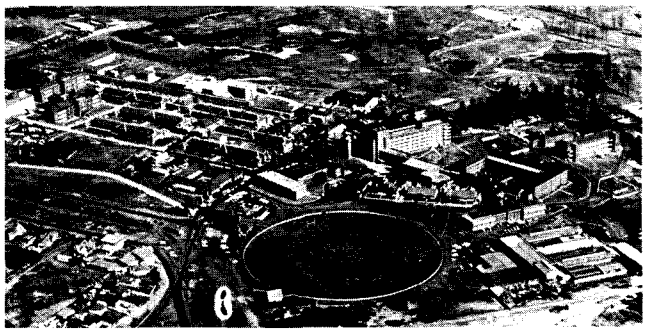


Figure 9

With the introduction of cardio-pulmonary bypass (after a year's experimenting in the laboratory) twelve atrial septal defects were successfully closed using the Ebsray disc-oxygenator and pump. The disc-oxygenator continued to be used until 1968 when Rygg and Travenol oxygenators replaced it. In keeping with the present tendency in Australian open-heart units the Temptrol oxygenator is now used almost exclusively, still with the Ebsray pumping system. Open-heart surgery has always taken its place among general thoracic surgery at the Royal North Shore: the case load was 40 bypasses a year in the early 1960's and 82 a year in 1971.

The Royal Alexandra is the largest children's hospital (550 beds) in Sydney and the vast majority of paediatric cardiopulmonary bypass procedures are undertaken there (Figure 11). The hospital was founded in 1882. The Department of Cardiac Surgery developed from the congenital heart clinic established in 1948. This development followed through until 1957 when atrial septal defects were closed under profound hypothermia.[13]

In 1958 the Adolph Basser Institute of Cardiology Foundation was set up and Dr. Cohen, the present director of the Foundation, visited Drs Gabode and Lillihei. His visits also included the Mayo Clinic and Dr. Gross in Boston.

The following year the Ebsray pump-oxygenator[14] was introduced into the operating room and the first

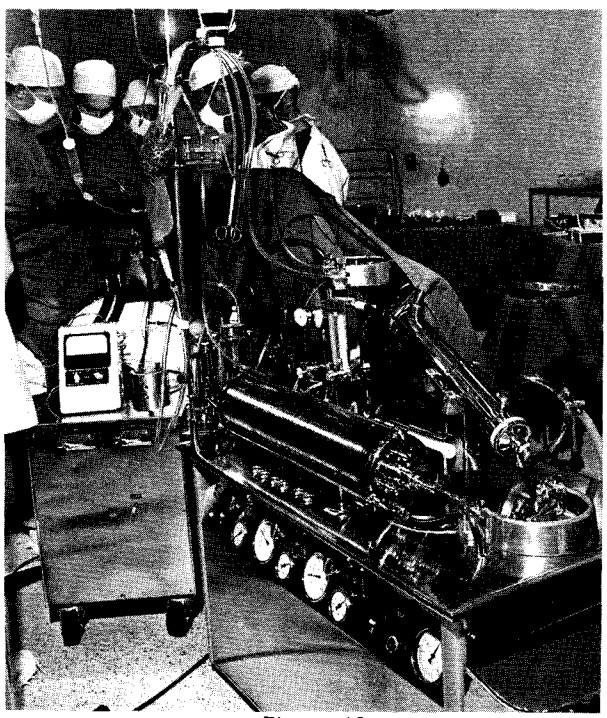


Figure 10

Figure 11

clinical bypass followed with the closure of a ventricular septal defect. The ebsray pump was later used with the Travenol oxygenator.

In 1970 a Sarns console was introduced, but the disc oxygenator was used only for a short period (Figure 12), being followed by the use of the Temptrol oxygenator. This Sarns pump and Temptrol oxygenators are still used routinely. The full range of paediatric cardiac abnormalities are dealt with, the present case load being four or five cardio-pulmonary bypasses a week. For neonates the Kyoto technique of profound hypothermia is increasingly being used with major success. To date a total of 75 such cases have been done.

PERTH - WESTERN AUSTRALIA

Western Australia occupies almost one third of the Australian continent, covering nearly a million square miles. The population is 955,000 most of whom (about 700,000) live in the capital, Perth, where presently open-heart surgery is confined to the Royal Perth Hospital (Figure 13). As has already been described the Royal Perth Hospital was among the earlier Australian hospitals to investigate the use of extracorporeal circulation.

These early bypasses used a sigmamotor pump with a home-made de Wall bubble oxygenator which was soon replaced by a Debakey pump and a Mark disc oxygenator obtained from the Royal Alexandra Hospital in Sydney. About one case a month was continued for 18 months or so with this rather make-shift apparatus until an Ebsray pump-oxygenator was bought in late 1962.

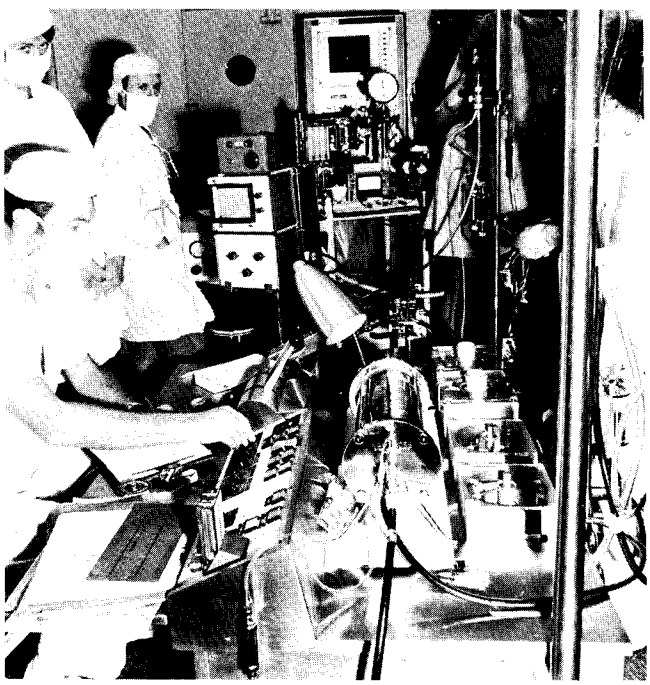


Figure 12

At that time the royal Perth Hospital was concerned with open-heart surgery on only adult patients, children's open-heart operations being done at the Princess Margaret Hospital by the same team using the same bypass equipment. The pump was transferred once a week between the hospitals. In 1967 it was replaced by a pump-oxygenator of the Alfred Hospital design, since modified for use with disposable oxygenators. The total case load at present is about 80 cases a year.

Figure 13

ADELAIDE - SOUTH AUSTRALIA

South Australia ranks among the Australian states third in area and fourth in population. Adelaide, the capital, has a population of 730,000. Following a request by cardiologists, the state government chose the Royal Adelaide Hospital as the site for an open-heart unit in 1960. The staff gained considerable assistance on their initial overseas visits from the Hammersmith Hospital (London) and from the Mayo Clinic. After a short period of experimental work with animals the first clinical case was carried out in late 1960. The English Melrose pump-oxygenator was used.

Since that time the pump has been used continually for a total to date of some 1200 cases and the case load is still approximately three a week. The unit is proud of its statistics, showing a 6% hospital mortality for the series of 1200 cases. Five hundred of these cases have been valve replacements. Of note, the overall mitral valve replacement mortality up to the present time is 5%.

BRISBANE - QUEENSLAND

Queensland occupies the north-east quadrant of the Austrlian continent. It is mostly tropical in climate. The population is 1.5 million. There is only one hospital which undertakes open-heart surgery in the state, the Chermside Hospital in the capital, Brisbane. The hospital is a relatively new one (1959) of a thousand beds. In 1964 the Cardiac Unit was opened. Prior to this time patients were sent to New South Wales for open-heart surgery.

The first bypass apparatus was the Ebsray machine, replaced after two years with a full range of American Optical equipment. The oxygenators prefered by the

See Page 20

unit are the A.O. discs for valve replacements, the Rygg bag for short-term perfusions and the Temptrol for neonates. The perfusion technique briefly is one of mild hypothermia, haemodilution and coronary perfusion when required, with a beating heart.

This unit is the only one in Australia employing homografts in any great number. The aortic valve is routinely replaced with a fresh homograft. The mitral valve is replaced by a fresh homograft or a fascialata valve.

Besides undertaking the full range of surgical procedures on adults, the Chermside Cardiac Unit operates also on children. Fifty total corrections of Fallot's tetralogy on neonates have so far been performed employing the Kyoto technique of profound hypothermia. In the last year a total of 190 cardio-pulmonary bypasses were done. Since its inception the Chermside Cardiac Unit has developed into one of Australia's leading cardiac units.

CONCLUSION

An attempt has been made to present the beginnings and some aspects of the development throughout Australia of cardio-pulmonary bypass, leading to an outline of the present position. No attempt has been made to describe the step-by-step development in detail or to discuss its surgical aspects, in both of which many oustanding names have taken a notable part. A distinctive feature in the development has been the contribution made by the Ebsray pump-oxygenator which, as will have been seen, was used in a large number of Australian open-heart units until very recently.

A report of the National Heart Foundation of Australia for 1970 contains the latest figures available for the 11 open heart units operative in Australia. They document the cardio-pulmonary bypass procedures as follows: the total number of bypass procedures was 1200, of which 340 were done by the three Melbourne units, and 531 by the five Sydney units. Increasing activity in coronary artery surgery is perhaps the most significant feature of recent development.

ACKNOWLEDGMENTS

Grateful thanks are due to Mr. E. Blanche, B.Sc. for his assistance in the preparation of the text.

REFERENCES

1. WINDSOR, H. M. "Cardiac Surgery Past and Present", The Medical Journal of Australia, Vol. 2, No. 16, 1972.
2. SHEPARD, R. and KIRKLIN, John, "Relation of pulsatile flow to oxygen consumption and other variables during cardiopulmonary bypass", J. of Thoracic and Cardiovascular Surg., Vol. 58, No. 5, Nov. 1969.
3. WESOLOWSKI, S. A. Cpt., SAUVAGE, L. R. Cpt., PINC, R. D., "Extra-corporeal circulation: the role of the pulse in maintenance of the systemic circulation during heart lung bypass", Surgery, Vol. 37, No. 4, 1955.
4. TRINKLE, J. K., HELTON, N. E., BRYANT, L. R. and GRIFFEN, W. O. "Pulsatile cardiopulmonary bypass; clinical evaluation," Surgery, Vol. 68, No. 6, 1970.
5. GIRON, F., BIRTWELL, W. C., SOROFF, H. S. and DETERLING, R. A. "Hemodynamic effects of pulsatile and non-pulsatile flow" Arch. Surg. Vol. 93, Nov. 1966.
6. KESSLER, J. and PATTERSON, R. H. Jr. "The production of microemboli by various blood oxygenators", Ann. Thor. Surg., 9, 221-228, 1970.
7. BRENNAN, R. W., PATTERSON, R. H. Jr., and KESSLER, J. "Cerebral blood flow and metabolism during cardiopulmonary bypass: evidence of microembolic encephalopathy", Neurology, 20, 374-375, 1970.
8. PATTERSON, R. H. Jr., and TWICHELL, J. B. "Disposable filter for microemboli", J. Am. Med. Ass. Vol. 215, Jan. 4, 1971.
9. TANAKA, T., BENNETT, L. R., SHERMAN, P. H., BROWN, G. E. and MALONEY, J. V. Jr. "Experimental techniques for the prevention of sludging of erythrocytes in extracorporeal circulation", J. Thoracic and Cardiovascular Surgery, Vol. 49, No. 2, pp. 275-282, Feb. 1965.
10. JAVID, H., TUFO, H. M., NAJAFI, H., DYE, W. S., HUNTER, J. A. AND JULIAN, O. C. "Neurological abnormalities following open-heart surgery" J. Thorac and Cardiovasc. Surg. Vol. 58, No. 4, Oct. 1969.
11. LEE, W. H., Jr., BRADY, M. P., ROWE, J. M. and MILLER, W. C. Jr., "Effects of Extracorporeal Circulation upon Behaviour: Personality and brain function". Ann. Surg. Vol. 173, No. 6, June 1971.
12. ROBERTSON, M. "A Nomogram for the correction of standard bicarbonate" J. Extracorp. Techn. Vol III, No. 4, 1971.
13. COHEN, D. and HERCUS, V. "Controlled hypothermia in infants and children" B.M.J. Vol. 1, pp 1435-1439, June 6, 1959.
14. COHEN, D. "The Royal Alexandra Hospital for Children Heart/Lung Machine" Jed. J. Aust. p.754, Nov. 5, 1960.

Society Clamor

Dr. Galletti Receives Honor

Our congratulations to Dr. Pierre Galletti, of Brown University, who was recently made Vice president for Medical Affairs. Dr. Galletti is a member of AmSECT's Medical Advisory Board.

ASAIO MEETS

The 19th Annual Meeting of the American Society for Artificial Internal Organs will be held at the Statler Hilton Hotel, Boston, April 8, 9, 1973.

A WELCOME CHRISTMAS GIFT

A refund of 2/3 of the current year's membership dues and certificates were mailed to AmSECT members who took the Certification Examination and met all criteria necessary to qualify under the "Grandfather's Clause". Non-members who met the criteria and participated in the tested received their certificates. Congratulations to ALL.