

New Zealand's First Open Heart Operation

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In 1954, I was extremely fortunate to be appointed to Green Lane Hospital to provide technical assistance to an emergent cardiac surgical unit, the first such appointment in New Zealand. My background was in electronics and instead of servicing radar equipment, I found myself involved in a far more interesting and fascinating field.

At that time, a small team headed by surgeon D. Robb (later Sir Douglas) performed closed cardiac operations on the beating heart using digital valvular dilation or with the aid of various knives, etc. Additionally, closure of patent ductus arteriosus and resection of coarctation of the aorta were carried out. The ability to carry out a surgical repair within the exposed dry heart was, for us, a dream for the future, but our sights were set to achieve that.

EARLY EXPERIMENTS

In 1956, D. Robb visited Minnesota and noted that surgeon C.W. Lillehei was repairing intracardiac defects in infants using a cross-circulation technique, whereby the patient's vascular system was joined via a pump to that of a compatible donor, usually a relative. Robb thought that we should experiment with that technique and so we obtained the required ("Sigmamotor"®) dual pump. This operated by massaging blood within a rubber tube by external mechanically driven fingers.

We never got off the ground with cross circulation as events overtook us. Lillehei abandoned his system in favor of a simple bubbler oxygenator devised by one of his team named DeWall. The concept was that of "low flow" or "azygos vein," as Lillehei had shown that in animals' venous inflow stasis with only the azygos vein draining into the right atrium for a period of time resulted in survival. This was in contrast to the preceding work of John Gibbon, which used the precept of much higher blood flows.

I duly built a DeWall oxygenator (Figure 1), and we embarked on animal experiments using our Sigmamotor pump and using sheep as subjects, as those animals are plentiful in New Zealand, outnumbering humans by a ratio of about 15 to one. We got as far as being able to routinely institute total cardiopulmonary bypass but for reasons, which at that time were not clear to us, the animals' hearts soon failed and could not be restarted. We

know now that it was due to a profound irreversible metabolic acidosis induced by the low flows and the use of old blood to prime the circuit.

In 1957, a young unknown surgeon, B.G. Barratt-Boyes ("BB", later Sir Brian) was appointed to the unit and Robb (very generously, in my view) handed over further development to him. BB had worked in the Mayo Clinic followed by a year in Bristol, England, working on the Melrose heart/lung machine. He was a believer in higher blood flows and asked for a Melrose machine to be purchased from England at a cost of £3,000. With Robb's support the Hospital Board agreed, and it arrived late in 1957. When I unpacked it, it was clear that it could certainly not be used as delivered but would require considerable modification and the manufacture of parts not provided. Fortunately, we had the assistance of a Government scientific department who were prepared to manufacture such parts for us. Of course no details were provided with the machine, in fact at that time in the absence of any literature on cardiopulmonary bypass all problems had to be solved by the individual units.

THE MELROSE MACHINE

Two separately controlled pumps were provided plus a rotating disc oxygenator. The design of the pumps was clearly based on the human heart, except that to vary pump output stroke volume rather than rate was adjustable. Each pump comprised a length of wide bore tubing lying within a channel, compressed rhythmically by a reciprocating bar at a rate of about 70/minute. This was the ventricle; flow was varied by control of the position of the channel holding the tubing. At each end of the tubing a pinch valve moved up and down occluding then releasing the tubing lumen. All this was performed by cams driven by the motors.

The oxygenator consisted of a rotating cylinder of Plexiglass® comprising about 250 thin discs with thicker spacers arranged in groups of 5 pairs (Figure 2). The cylinder was inclined from the horizontal and blood pumped in from the venous pump at the upper end traveled down to pool at the lower end from which it was sucked into the inlet of the arterial pump and thence returned to the pa-

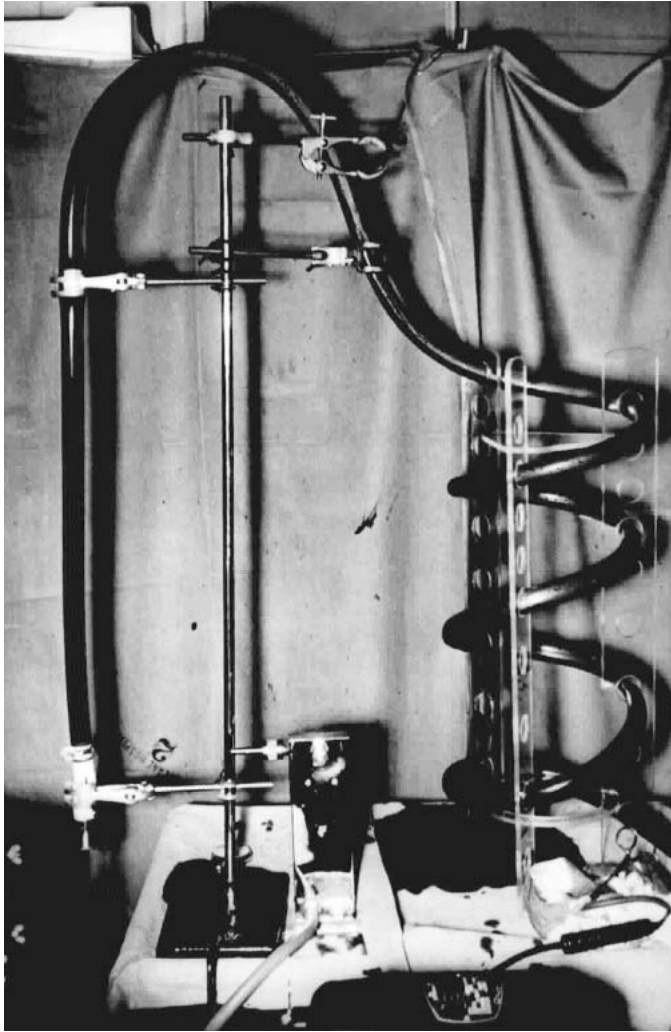


Figure 1. The DeWall oxygenator built by the author.

tient. The theory was that films of blood were formed on the protruding surfaces of the discs; the cylinder was infused with oxygen and so oxygenated the blood.

MODIFICATIONS TO THE MACHINE

We had to carry out major changes to achieve a workable system. The operation of the compression bar and the pinch valves produced violent pressure and resultant flow pulsations, whereas a steady gentle flow was required into the upper end of the oxygenator. We felt also that such pulsations would reflect adversely at the site of venous cannulation. Our solutions were to add a “depulsator” at the oxygenator inlet and a venous reservoir to feed the venous pump inlet. The depulsator consisted of a length of very thin rubber tubing, which distended with the pulsations and thus smoothed them out. Our venous reservoir was mounted on a vertical shaft and could be adjusted in height to control blood inflow (1). The reservoir also in-

corporated a defoaming chamber for the return of spilt open-heart blood to the circuit. The facility provided with the Melrose machine for pumping such open heart return was unworkable so we made use of our Sigmamotor pump for that purpose (Figure 3).

In an effort to improve the limited efficiency of the oxygenator, we had designed new discs that offered a larger surface area on which the blood could film, and we also added an arterial filter using a fine stainless steel mesh.

OTHER PROBLEMS

During *in vitro* trials I soon discovered that a very real problem was residual foaming of the blood collecting at the lower end of the oxygenator. Silicone antifoam seemed to be the answer, but I was not prepared to use that on the surface of the oxygenating discs; after all if blood filming was necessary for oxygenation it would be counterproductive to use an agent (Silicone) known to be nonwetting. My solution, albeit tedious, was to preassemble the oxygenator without the blood filming discs and rinse the interior with diluted Antifoam A® (Dow Corn-

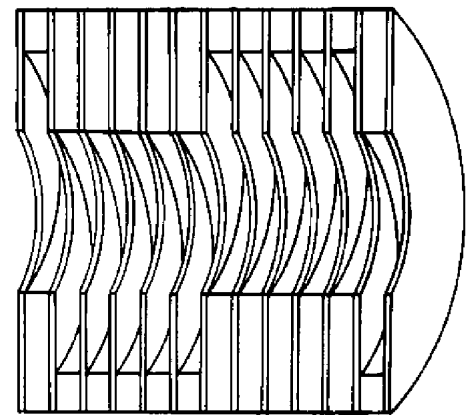
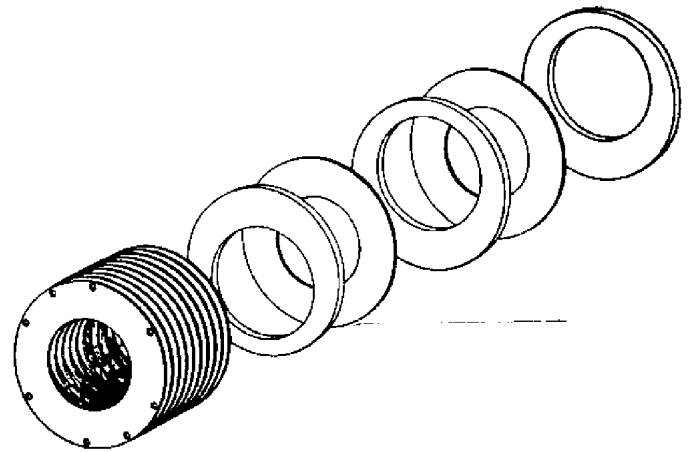


Figure 2. Diagram of disc arrangements for the Melrose machine.

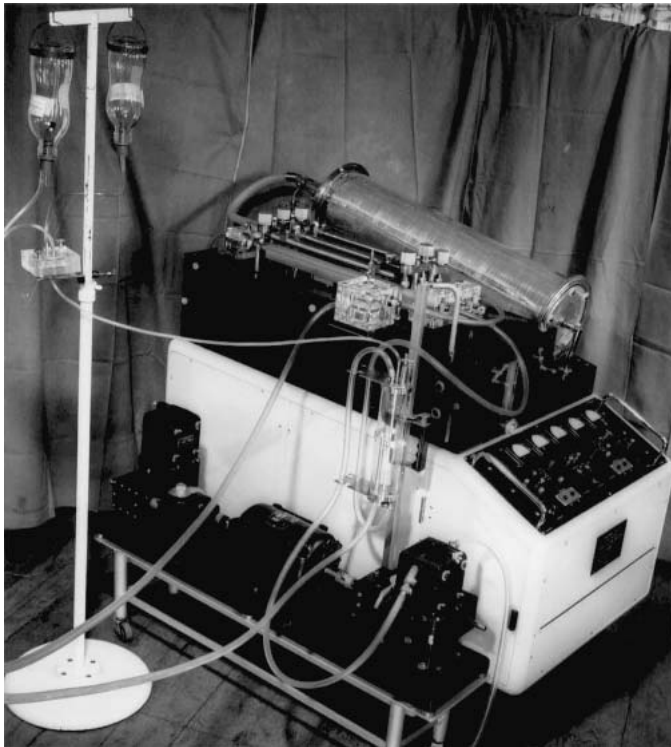


Figure 3. The modified Melrose machine with the sigmamotor pump for open heart return.

ing Corporation Inc., Midland, MI), thus leaving within a thin film of the compound. The oxygenator was then carefully disassembled then again reassembled to include the filming discs, which were free of the silicone compound.

One problem that I had to solve very early was to ensure that the oxygenator could rotate. Because it consisted of a stack of discs held together by tie rods, I soon found that it would not run unless it was assembled true so that the axis of rotation was perpendicular to the plane of the discs. I therefore had made a mounting base that could be leveled by spirit levels. The discs were assembled, layer upon layer on this plate. Before tightening the tie rods, a plumb line was dropped from the uppermost to the lowest end plate and the stack adjusted until it hung centrally. That ensured alignment and the cylinder would then rotate freely.

Of course, everything in those days was reusable. I therefore had to ensure that (a) blood proteins were removed and (b) silicone material was removed after each use. Stainless steel parts were therefore boiled in a solution of sodium hydroxide and the thermoplastic Plexiglass components were soaked in a stronger cool solution of the same. The discs were then washed with Petroleum Ether to remove any Silicone residue, as my literature research indicated that the plastic was impervious to both substances.

Of course, in those days we had no blood heat ex-

changer; however, because the period of total perfusion was anticipated to be comparatively brief, I was able to combat the otherwise inevitable body cooling by preheating the circuit in the following way: I had made a stainless steel enclosed container in which was mounted an electric heating element controlled by a thermostat. By priming the circuit with crystalloid solution and circulating the same using the container as a dummy patient the fluid preheated the components to counter the heat loss which would occur during total body by-pass. The warming solution was drained before priming with blood.

STERILIZATION

We understood that the Melrose originators had filled the oxygenator with formalin solution, but I was not prepared to use such a deleterious fluid. We had heard of ethylene oxide as a sterilant and acquired a few canisters of that material. I found an old circular steam autoclave and we modified that with mild heating and a vacuum pump for air removal. (Vacuum pumps were readily available in New Zealand for milking machines, this being a pastoral industry country) Everything was manually operated, but we found through biological testing that our homemade system was effective and safe, that being the first time that ethylene oxide (ETO) as a sterilant had been used in New Zealand.

EXPERIMENTAL WORK UP

In between our clinical commitments we embarked on weekly sessions in our experimental laboratory, again using sheep. Blood was collected using heparin as an anticoagulant by a visit to the local abattoir on the morning of our experiment and that whole blood was used as a prime. BB decreed that when we were able to place 6 successive animals on total bypass for 30 minutes, with 100% survival rate, we would then perform our first human operation.

We made many mistakes and learned from them. On one memorable occasion, the line from the arterial pump became disconnected from the cannula during the bypass period. The violent spurts of blood from the arterial pump caused the line to wave furiously about and the surgeon could not catch it. For the few seconds before the pump could be stopped the walls, ceiling, and staff were covered in blood. Our hospital cartoonist duly recorded the scene for posterity.

One day BB called me into his office to point out that when he commenced VSD closures, sooner or later surgically induced heart block would occur and we would need a pacemaker. Therefore, he said, "You had better get on and build one." (That was how he got things done but none of the team minded and all of us, himself included, were working very hard to a common goal, BB perhaps

most of all.) So in my spare time (!) I designed and built a pacemaker and some polyethylene insulated stainless steel wires as electrodes, the first destined to be used in New Zealand and the only one we had for a year or so.

THE FIRST HUMAN CASE

We had by now completed the series of successful experiments so the date of September 3, 1958 was set as the day when we would do our first case, when an 11-year-old girl had a VSD closed by direct suture. The circuit was primed with whole, fresh blood collected with heparin as an anticoagulant the same morning, whole blood being our standard for many years, as it was then believed that significant haemodilution would result in pulmonary

edema. Later on I was rostered to give such blood and more than once my donation was part of the prime, notwithstanding uncomplimentary remarks from the other team members!

They were tremendously exciting and rewarding times, and it has been said that the ability to isolate the heart and work on it using extracorporeal circulation was one of the most giant steps in medicine. I am fortunate to have been a part of that in New Zealand.

REFERENCES

1. Barratt-Boyes BG and Yarrow S. A Combined Venous Reservoir and Defoaming Chamber for use in a Heart-Lung By-Pass Circuit. *Australian and New Zealand J Surg.* 1961;30:4.