Portable Bypass for the Procurement of Organs Used in Heart and Lung Transplants

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Abstract

In July 1985, a method of organ procurement was devised using a portable cardiopulmonary bypass machine. Up to July 1985 all donors were transferred to Harefield Hospital for organ removal. Only 7 were performed by this method. Upon the introduction of the portable device, 25 more organs were transplanted, a significant increase in organ availability. To date, 114 organ procurements have been performed not only in Great Britain and Northern Ireland, but also in Europe with the longest ischemic time being 4 hours and 45 minutes.

The following is a detailed description of what was used to develop the portable machine. We utilized a bubble oxygenator cardiotomy reservoir, and a cooling system, which allows the user to cool down the donor to a temperature of 6 degrees opesophageal and approximately 8 degrees nasopharyngeal. It is believed that this method could help with the procurement of other organs, such as liver and kidneys, because of the total body cooling. This device has also been used on two occasions for the treatment of pulmonary embolism, where the operation was carried out at a non-cardiac hospital, and the transfer of such a patient would have led to the patient's demise.

Introduction

We evaluated our existing cardiopulmonary bypass machine to see how it could be condensed, yet still provide effective perfusion. Our present cooling system was effective, providing temperatures of 10 degrees centigrade or less; but the system was not portable. The following is a description of the development of our system and the reasons why it was chosen. This system had to be developed from scratch.

Methods and Materials

The arterial pump we chose to use was our existing pump, the Cobe Stockert roller pump.[a]

The base for this pump was designed around an attache case[b] made from aluminum. This had been converted to take four castor wheels, thereby making it movable. The base of this case had been strengthened to take the weight of the aterial pump. It could also be used to carry small items including the castor wheels.

The two support stansions to hold the flowmeter, the oxygenator, the cardiotomy reservoir, and the heat exchanger were made from aluminum pipping (3/8 inch in diameter) and fixed to the base using the specially designed feet of the case for this purpose.

The oxygenator chosen was the D700s[c] bubble oxygenator. A bubble oxygenator, rather than a membrane oxygenator, was chosen because of the short bypass times required, a maximum of thirty minutes. This unit was also chosen because it could be utilized on all size patients, from a neonate to a geriatric patient. By adjusting the ports on the top of the oxygenator, the priming volume can be reduced, if necessary. The holder for this oxygenator was a g-clamp, supplied by the manufacturer.

The suction to the cardiotomy reservoir was initially achieved by wall suction, regulated to a maximum vacuum of 200 mmHg. This has since been changed to a portable suction device supplied by the donor hospital.

Due to the occurrance of implosion, an American Bentley cardiotomy reservoir has been replaced by the

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a Cobe Laboratories, Lakewood, CO
b R & S Supplies, Ltd.,
c Dideco, Ltd.

Shirley[d] Card-F cardiotomy reservoir. This complication has not been observed since the change.

A second heat exchanger is used to get twice the cooling capacity, thus reducing the bypass time. Currently, we are using the D720[c] for this purpose.

The tubing sets[e] utilized are based on our standard open heart packs. The lengths of tubing were shortened considerably, reducing priming volume as well as packaging requirements.

The flowmeter[f] consisted of an oxygen flowmeter rated from 0.5 liters per minute to 6 liters per minute, with a shrider connection. This was attached to an oxygen line which had a "Y" piece connection on one end to which was fitted a male and female strider connector. This allowed us to break into and share the oxygen line utlized by anesthesia, if only one oxygen source was present in the donor hospital. We carry seven different types of oxygen probes to accommodate the variety of equipment in the various donor hospitals we cover. We also carry a European electrical adaptor for oxygen procurements performed abroad.

The cooling source proved to be the most difficult aspect of this circuit. Cryogenic gasses, liquid oxygen and liquid nitrogen were evaluated and discarded due to the vast quantities required and the inability to regulate temperature. Freon gas, used mainly in refrigeration systems, was also evaluated. This idea was also discarded because of the carcinogenicity of the gas.

The next cooling agent we looked at was ice. It is safe and readily available.

We took the pump from an old Churchill heater cooler and placed it into a small portable container with inlet and outlet Hansen connectors. Because the pump had to be gravity filled, the ice had to be higher than the inlet. A plastic container, normally utilized to transport eggs, was filled with water and frozen. A two inch piece of polystyrene was placed into the base of the original box to prevent the ice from occluding the outlet to the water pump.

A circuit was made to go from the ice block to the water pump, to a separate heat exchanger, to the heat exchanger in the oxygenator and finally back to the ice block.

An attempt was made to melt the ice as evenly as possible by the returning water. To accomplish this, the return water was forced to go through a "spray" system over the ice block. The water temperatures remained a constant 3 degrees centigrade during the initial cooling phase of bypass, dropping to as low as 1 degree centigrade near the final phase of bypass.

Through our experience, we have found that an 8 kg. block of ice (approximately 8 liters of water), is required to satisfy our cooling needs.

An overflow pipe has been added 1½ inch above the water outlet to prevent the water level from rising above one inch and ½ in the base.

The ice block is transported in an insulated box used to transport blood. This box also serves as a base unit for the ice block container to attain the proper height for gravity priming.

Two suitcases were obtained to carry holders, electrical cords, oxygen lines, pressure gauges, tubing clamps, water lines, arterial and venous cannulae, extra connectors, priming fluids, temperature probes and perfusion records.

The bypass circuit takes about 6 minutes to set up and prime. Upon arrival at the donor hospital, we determine the type of electrical connections that are required, as well as the availability of oxygen. The specific oxygen probe is also determined. Requests for a portable suction unit and an IV probe for priming fluids are also made.

Once this has been done, we set about assembling the bypass machine. We place casters on the base of the suitcase, then attach two stansion poles. The arterial pump is placed onto the base, leaving approximately a 2 inch gap for the right hand side of the base. Next to this pump, we place the water pump and connect the electrical leads. From there we place the oxygenator holder onto the right hand stansion, then place the oxygenator onto this. The heat exchanger holder is attached next. The heat exchanger is placed into this holder. Finally, the cardiotomy reservoir holder is fixed into position, followed by the placement of the cardiotomy reservoir into this holder.

The machine set is opened. The arterial line, consisting of a ⅜ inch piece of PVC tubing connected to a ½ inch silicone boot, is attached to the oxygenator outlet. The silicone boot is placed into the roller pump. For a child or neonate, we would use a ⅜ inch silicone boot. A small piece of ⅜ inch PVC tubing leads from the boot to the heat exchanger. From the heat exchanger, a ⅜ inch tubing is attached at the other end of this piece of tubing. There is a ⅜ × ¼ leur lock y piece to which is added an 8 inch piece of ⅜ inch PVC tubing and a ¼ inch PVC tubing. The ⅜ inch PVC tubing is attached to the arterial line from the table, and the ¼ inch is attached to the top of the oxygenator.

This acts as our recirculation line for priming. The oxygen line is connected to the flowmeter, which is placed on the left hand stansion. The only other task is to place the venous line into position (Figure 1).

d Shiley
e Polystan UK, Ltd.
f D & G, Ltd.

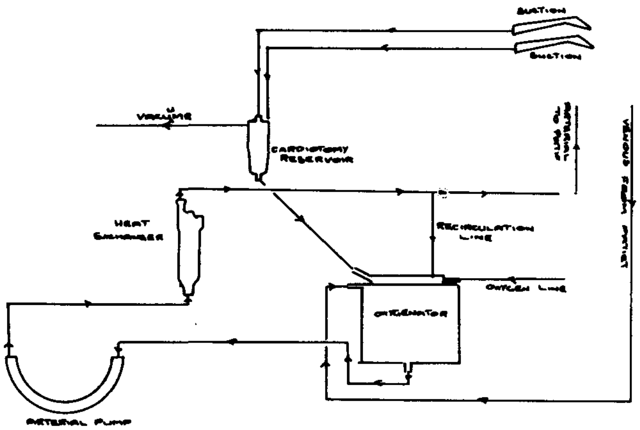

Figure 1.

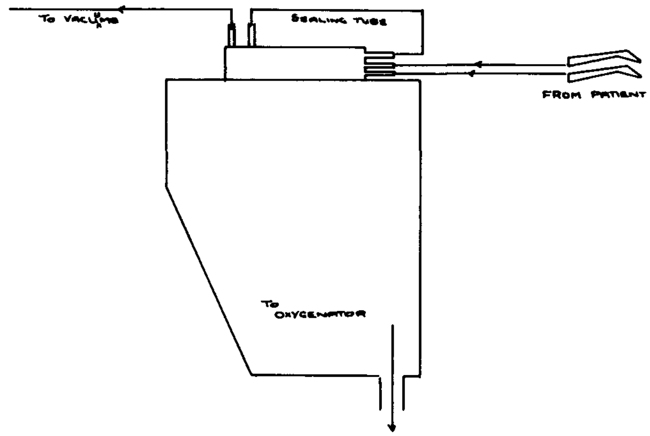

Figure 2.

The cardiotomy has two suckers attached to remove blood from the operating site. The third sucker connection is used to seal the cardiotomy reservoir, ready for vacuum to commence (Figure 2).

The bypass machine is then placed into position in the operating theatre. The ice-box is removed from its box, the box is turned onto its side and the ice-block is placed on top of it. The water leads are connected, and water is placed into the top of the ice-block. About 600 mls is required initially to allow the water to circulate in a continuous loop when the water pump is turned on (Figure 3). The bypass machine is now ready to be primed.

The priming fluids that are used consist of 500 mls of dextran 70 (MACADROX), and two units (400 ml each) of Haemaccell. If the patient's hemoglobin is below 11 grams, the two units of blood are cross matched, if there is time, and added to the prime and used in the bypass machine. The bypass machine is now ready.

The lines from the table are connected to the bypass machine in the normal manner. The arterial cannula (adult) is a 28fg PVC with a 3/8-inch conncetor[g]. Children and neonates range from 10fg, 12fg, 14fg blue line angled[h], to 20fg, 22fg PVC cannula[g]. The venous cannula is a single stage wire reinforced type[i] with sizes ranging from 20fg, 24fg, 44fg, 50fg, depending on the size of the patient.

The arterial cannula is placed in the ascending aorta in the normal manner. The venous line is placed into the right atrial appendage, again in the normal method. Once these have been connected to the bypass machine, then bypass is begun. While the surgeon is dissecting out the organ, the patient is being cooled. A nasopharyngeal probe as well as oesophageal probe is inserted into the patient's nose and mouth. As an added precaution, a myocardial temperature probe is also given to the surgeon.

By the time the surgeon is ready to remove the organs, the temperature of the donor is 6 degrees oesophageal, 8 degrees nasophageal and 6 degrees myocardial.

By request of the surgeon, bypass is discontinued. The aorta is clamped and the patient is exsanguinated. The organs are removed. The blood that is left in the oxygenator is put into a plastic bag, later used for organ storage. The bag is then sealed and placed into an ice box, ready for transportation back to Harefield Hospital.

The bypass machine is stripped down. Disposables are placed into a waste bag, sealed and left for the donor hospital to dispose of in the usual fashion. The bypass hardware is replaced into their respective suitcases, ready to return to Harefield Hospital.

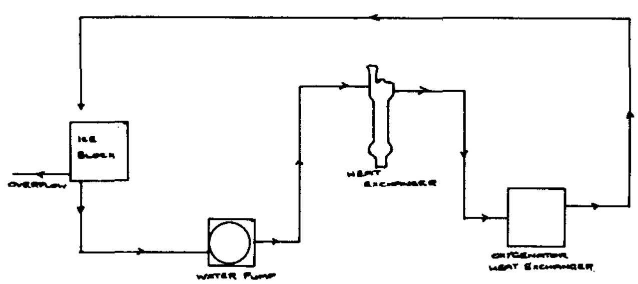

Figure 3.

g Wessex Medical
h Sherwood Medical
i Shiley, Ltd.

Results

The total weight of the portable bypass machine is only 70 kg.; therefore, it can be placed in either a car, plane or helicopter. This makes it very convenient for transport.

Positive feedback that has been provided by the organ procurement teams has included the superiority of organ cooling achieved by this method.

Discussion

We firmly believe that this method has proved to be a very reliable system to use, and that other procurment teams can benefit when this system is employed. It can be adapted for use on emergency cardiac operations where the patient is not actually at a specific cardiac center, and the moving of the patient to a specific center could lead to his/her demise.

The second generation of this portable device is already nearing completion, and with the use of new light weight material and a completely new cooling system requiring no ice. The weight for this device has been calculated to 45 kg. Because of its compact size, it will even fit into the smallest boot of a car, making transport of such a device available at a short notice.