Original Article

Current Perfusion Techniques for Repair of Giant Cerebral Aneurysms using Deep Hypothermia and Circulatory Arrest

Linda B. Mongero, BS, CCP, Joseph J. Sistino, MPA, CCP, James Beck, BS, CCP, Craig R. Smith, MD

Columbia-Presbyterian Medical Center, Milstein Hospital, New York, New York

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ABSTRACT

Intracerebral aneurysms unapproachable with conventional techniques can be clipped during total circulatory arrest under deep hypothermia. In a series of 30 cases, cardiopulmonary bypass techniques were developed which permit efficient core cooling and rewarming with peripheral (femoral-femoral) cannulation. The perfusion circuit was modified to use the centrifugal pump to apply negative pressure to the venous line without sacrificing the ability to rapidly add and subtract volume, and incorporated protection against air embolism by suction entrainment. Protection of the fibrillating heart during hypothermia was facilitated by transesophageal echo monitoring of the ventricular volume to detect distension. Conversion to central cannulation through median sternotomy was required in three patients (10%) because of inadequate venous return in two patients and severe iliac atherosclerosis in one patient. Early in the series there were two deaths (7%) from aortic dissection. The neurosurgical result, in otherwise inoperable patients, was successful in 90% of the cases.

Address correspondence to:
Linda B. Mongero, CCP
Columbia-Presbyterian Medical Center
Milstein Hospital
Building 4-350
New York, NY10032

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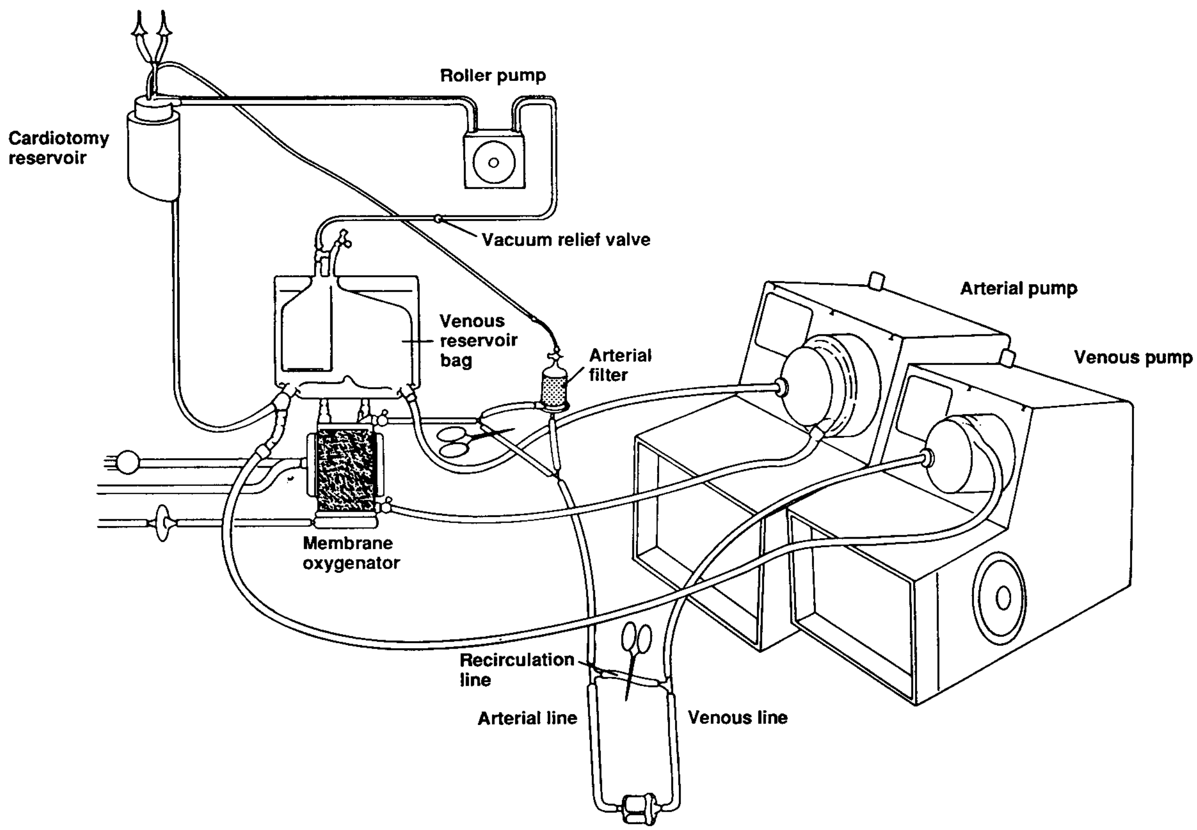
Figure 1
Diagram of perfusion circuit using two centrifugal pumps



INTRODUCTION

Bypass techniques for core cooling and circulatory arrest using peripheral cannulation combined with neurosurgical advances has decreased surgical morbidity and mortality for the repair of giant cerebral aneurysms (1). However, some centers continue to perform these procedures with open-chest cardiopulmonary bypass (2). A series of thirty patients presented at Columbia-Presbyterian Medical Center to undergo clipping of their giant cerebral aneurysms utilizing deep hypothermia and circulatory arrest. We have developed an extracorporeal support system that allows a closed-chest surgical approach for total circulatory arrest under deep hypothermia for an otherwise inoperable neurosurgical lesion. A perfusion system has been designed to facilitate high flows with peripheral cannulation while allowing removal of volume from the patient. This closed loop circuit, with arterial and venous lines driven by centrifugal pumps, permits use of percutaneous cannulas in the femoral artery and vein. The paper reviews the clinical results that have been achieved with this system for patients that have presented for clipping of giant cerebral aneurysms. A retrospective analysis of the results achieved with the double centrifugal pump circuit will be compared to the first 11 cases in this series when other types of perfusion circuits were used.

MATERIALS AND METHODS

Double centrifugal pump system - The femoral vein is cannulated under direct vision using modified Seldinger technique. The venous cannula (19-21 Fr.)[a] has one end-hole, twelve side-holes and is constructed of polyurethane with wire reinforcement which resists collapse under high negative pressures. The 3/8" I.D. venous tubing (3/16" wall) is attached to the venous centrifugal pump[a] that is operated with the outlet in the upward position to facilitate air removal from the venous line (Figure 1). Output from the venous pump enters a 1900 ml collapsible venous reservoir bag[b], which then empties into the inlet of the arterial centrifugal pump[a]. The arterial limb of the circuit also consists of 3/8" tubing and is connected to the outlet of the arterial centrifugal pump. The arterial pump is operated with the outlet in the normal downward position to protect against air embolism. Output from this pump is directed to a low prime (220 ml) adult membrane oxygenator[b] and then to an arterial filter[c] before being returned to the patient. Connected to the top of the reservoir bag is 1/4" tubing passed through a roller pump so that air can be

a Medtronic-Biomedicus, Eden Prairie, MN 55344
b Baxter Laboratories, Irvine CA 92714
c Pall Biomedical, Glen Cove, NY 11542

Figure 2
Distribution of average blood flow rates in the series of 28 patients (mean = 2.15)

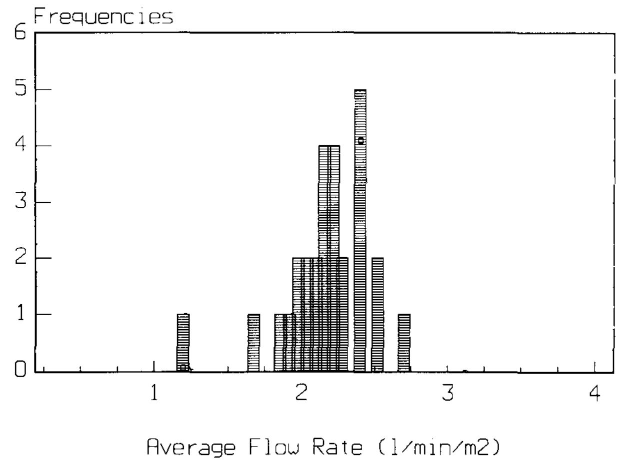


Figure 4
Distribution of warming time in the series of 28 patients (mean = 63.8 minutes)

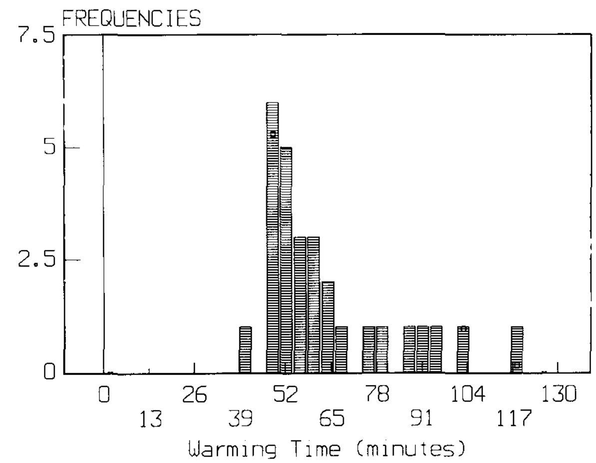


Figure 3
Distribution of cooling time in the series of 28 patients (mean = 30.78 minutes)

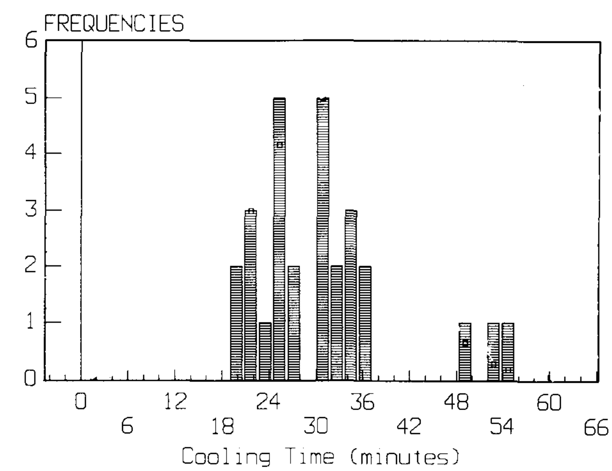
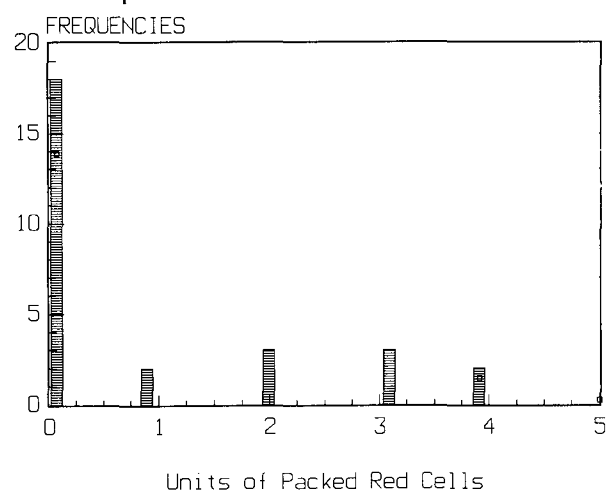


Figure 5
Distribution of blood use (packed red cells) in the series of 28 patients (mean = 0.89)



easily aspirated from the system. The venous reservoir is protected against excessive negative pressure with a pressure relief valve[d]. Volume is returned to the circuit by gravity from the cardiotomy reservoir[b] through the cardiotomy drain line. The circuit is primed with a 1500 ml non-blood prime consisting of 1000 ml 6% Hespan[e] and 500 ml of a balanced electrolyte solution.

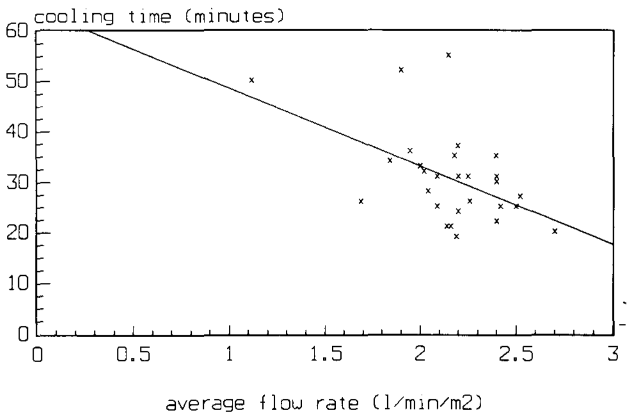
The venous line pressure is monitored with a pressure display box[f] attached to the inlet of the venous pump. Flow is regulated by adjusting the revolutions per minute of the venous pump to maximize venous flow and then increasing the flow of the arterial pump to match the venous return. The venous pump is operated at the lowest revolutions per minute necessary to achieve the desired blood flow rate and limit the venous line pressure to more than -100 mmHg.

A transesophageal echocardiogram is continuously displayed to ensure adequate monitoring of cardiac function and filling. Absence of distention of the ventricles is confirmed by viewing the left ventricular cross-sectional area and comparing it to the prebypass end-diastolic volume. Myocardial protection is ensured with bolus potassium infusion (20-40 mEq) into the CVP catheter during periods of fibrillation.

Neuroanesthesia for these cases is much like anesthesia delivered for routine cardiac cases. Narcotics in conjunction with

d American Omni Medical, Costa Mesa, CA 92826
e Dupont Pharmaceuticals,Wilmington DE 19880
f DLP, Grand Rapids MI 49504

Figure 6
Correlation of cooling time with average blood flow rate (p<.01)



thiopentol infusions are used to reduce cerebral blood flow. In addition, hyperventilation to decrease carbon dioxide tension, allows the neurosurgeon greater visibility. Monitoring of the electroencephalogram is continuous throughout the procedure and it remains flat during deep hypothermia and circulatory arrest.

Temperatures are measured and recorded continuously throughout the procedure. A 30 gauge needle probe is inserted into the temporal lobe to monitor brain temperature. In addition the following temperatures are monitored to ensure adequacy of cooling and rewarming: tympanic membrane, esophageal, axillary, rectal, toe, arterial blood and venous blood. The patient is cooled to a brain temperature of 16-18°C before circulatory arrest.

During circulatory arrest, blood is drained into the venous and cardiotomy reservoirs to shrink the cerebral vessels and aneurysm for direct, bloodless surgical repair under the neurosurgical microscope. Intermittent transfusion from the circuit under the direction of the neurosurgeon, tests the clipped aneurysm for bleeding. Rewarming of the patient begins at full flow once the neurosurgeon determines that bleeding is absent at the aneurysm site.

Blood conservation is maximized with the use of a Plasma Saver and Cell Saver[g]. The Plasma Saver is used to sequester platelet-rich plasma before cardiopulmonary bypass which is transfused back to the patient after protamine administration. The autologous red cells are given back to the patient to maintain the hematocrit above 20% during rewarming. The Cell Saver is used to wash the cells from the perfusion circuit after discontinuation of cardiopulmonary bypass.

A retrospective analysis of the cases using the double circuit (Group 2) and the first 11 cases using other perfusion circuits (Group 1) was performed. The data presented exclude the two aortic dissections since bypass was not completed in these patients. Group 1 includes five patients who were drained by gravity venous return and six patients who were drained with centrifugal pump venous return with 1/2" tubing. A roller pump was used for arterial blood flow in these patients. The next seventeen patients (Group 2) utilized a centrifugal pump in both the arterial and venous lines in the circuit described above. Average flow rates, cooling time, rewarming time and blood use were compared between the two groups using the Student's T-test. A p value of less than 0.05 was considered significant.

RESULTS

Thirty patients underwent clipping of their Giant Cerebral Aneurysms utilizing deep hypothermia and circulatory arrest. Conversion to central cannulation through median sternotomy was required in three patients (10%) because of inadequate venous return in two and severe iliac atherosclerosis in one. Early in the series there were two deaths (7%) from acute aortic dissection. In one patient the aneurysm could not be clipped and the procedure was aborted. Operative results in the remaining twenty seven patients were excellent (90%).

The average flow rate during bypass for the 28 patients was a cardiac index of 2.15 (range 1.12-2.7) l/min/m^2 (Figure 2). Cooling to a brain temperature of 16.0°C averaged 30.7 (range 19-55) minutes (Figure 3) and rewarming 63.8 (range 42-120) minutes (Figure 4). Circulatory arrest time averaged 23.5 (range 6-51) minutes (Figure 5). An average of .89 (range 0-4) units (Figure 5) of exogenous blood was transfused. In 18 of the 28 (64%) patients no blood transfusion was necessary. Cooling time correlated significantly with the average blood flow rate (p<.01) (Figure 6). In 27 of the 28 cases (96%), the electrocardiograms were unchanged post bypass, and no vasopressors or inotropic support were necessary. Fractional shortening was unchanged as measured by the transesophageal echo before and after cardiopulmonary bypass.

Retrospective comparison of cases using the double centrifugal pump system (Group 2) and the other perfusion circuits used in the earlier cases (Group 1) showed a statistically significant difference in average blood flow rate and cooling time. There was no statistically significant difference in blood use or rewarming time (Figure 7).

DISCUSSION

Cardiopulmonary bypass techniques are much improved since the first attempts to clip giant cerebral aneurysms using deep hypothermia and circulatory arrest (3-14). Perfusion of patients with this lesion has been most rewarding at our institution because of the newly designed double pump system and high flow percutaneous cannulas. A controlled bloodless craniotomy for surgical correction was done successfully in 27/30 (90%)

g Haemonetics Inc, Braintree MA 02184

Figure 7
Comparison of average blood flow rates, cooling time, warming time, and blood use for the two types of perfusion circuits

Comparison of Perfusion Circuits for Giant Cerebral Aneurysms					
	Group 1(n=11)		Group 2 (n=17)		
	mean	S.D.	mean	S.D.	
Flow Rate (L/min/m2)	2.00	0.34	2.26	0.23	p<.05
Cooling time (min)	36.00	8.08	27.40	8.35	p<.05
Warming Time (min)	69.20	21.10	60.29	17.94	NS
Blood Usage (units)	1.45	1.75	0.53	0.94	NS

cases with both open-chest and closed-chest techniques. We prefer the closed-chest technique in patients free of peripheral vascular disease. In patients with known or suspected peripheral vascular disease, we are reluctant to use femoral arterial cannulation because of our experience with acute aortic dissection. We have demonstrated sufficient venous return with cannulation of the femoral vein using a double centrifugal pump system without a median sternotomy.

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