Original Article

Centrifugal Pumping: The Patient Outcome Benefits Following Coronary Artery Bypass Surgery

William J. DeBois, BS, CCP, Robin Brennan, RN, Elizabeth Wein, RN, O. Wayne Isom, MD, Jeffrey P. Gold, MD

The New York Hospital-Cornell Medical Center, New York, New York

Presented at the AmSECT 31st International Conference, Dallas, TX, February 27, 1993

Keywords: cardiopulmonary bypass, centrifugal pump, roller pump, device comparison

ABSTRACT

The increased use of the centrifugal pump during coronary artery bypass surgery has been based primarily on theoretical data related to patient safety. There is minimal evidence suggesting improved outcome when compared to the traditional roller pump technology. We prospectively randomized 200 patients undergoing elective coronary artery bypass grafting into centrifugal pump (100 patients) and roller pump (100 patients) groups to compare differences in blood product usage, complication rate, length of stay and net hospital financial balance.

Moderate hypothermic bypass was employed on all patients. Cardiopulmonary bypass circuits were similar in both groups with the exception of the arterial pump. Both groups were statistically identical in regard to age, sex, surgeon, complications, total pump time, aortic cross clamp time, prebypass hematocrit and platelet count. The twenty-four hour postoperative hematocrits, platelet counts, red blood cell requirements, blood loss and mortality (2%) were identical in both groups. The centrifugal pump patients had less 24 hour weight gain than their peers in the roller pump group ($p=0.05$) The length of stay and net hospital financial balance were also statistically favored in the centrifugal pump group ($p<0.05$). These latter findings were significant when studied in all payors and coronary artery bypass diagnostic related group classifications. Although the mechanism for improvement in length of stay and net hospital financial balance cannot fully be explained, the ramifications in an increasingly cost conscious environment are obvious.

Address correspondence to:
William J. DeBois, BS, CCP
The New York Hospital-Cornell Medical Center
Division of Cardiothoracic Surgery
New York, NY 10021

INTRODUCTION

Surgery for treatment of coronary disease is one of the most common operations performed in the United States. Approximately 250,000 procedures are done annually. Results for this procedure are quite impressive when considering the physiologic insult incurred during the operative period. Mortality for all coronary artery bypass (CABG) surgery is estimated at 3-5%, and 1-2% for elective procedures (1). According to government data, these results continue to improve (2). Federal expenditure for all health care is approaching the one trillion dollar mark and rising at double digit percentages. With the average open heart procedure costing approximately thirty thousand dollars, financial outlay for this procedure reaches almost ten billion dollars annually. With excellent clinical results which continually improve, we must now consider options that can contain the costs.

The two primary components of the heart lung machine are the oxygenator and the arterial pump. Numerous studies have compared oxygenators, and results indicate that the membrane oxygenators are superior to the bubbler type with regard to safety and patient outcome (3). Now that membrane oxygenation has become more popular, costs of the membrane oxygenators have dropped, and they have been made easier to use. The second part of the system, the arterial pump, has also been studied. Pulsatile flow had shown some advantages, but systems were expensive, had questionable reliability, and required considerable effort to operate (4,5).

Non-occlusive centifugal pumps have been the subject of many comparative studies. Findings indicate that centrifugal systems are less likely to pump gross air, generate considerably less arterial line pressure, have lower particle expulsion rates, reduce complement activation, preserve hematologic integrity, and are less likely to cause coagulation disorders (6,7,8,9). Many studies do not identify, or even investigate, improved patient outcome, decreases in hospital stay and decreases in hospital costs.

Table 1: Patient demographic characteristics and preoperative hematologic values for centrifugal and roller groups

Category	Centrifugal n=100	Roller n=100	P Value
Age	60.9 (9.3)	61.4 (8.8)	NS
Sex	69/31	71/29	NS
Pump time	86.5 (20.9)	82.5 (22.1)	NS
Aortic clamp time	42.9 (13.8)	43.5 (8.8)	NS
Hematocrit (pre-CPB)	39.5 (4.4)	39.2 (4.6)	NS
Platelet count (pre-CPB)	245.8 (79.7)	262.8 (79.2)	NS

Age expressed in years, sex: male/female, pump and aortic cross clamp in minutes, hematocrit in percent, and platelet count in cells/ulX10^3. Values expressed as: mean (standard deviation).

Table 2: Ventilation and hematologic values for centrifugal and roller groups

Category	Centrifugal n=100	Roller n=100	P Value
RBC transfused	2.03 (2.0)	1.93 (2.1)	NS
24 hr hematocrit	28.6 (3.4)	28.1 (3.1)	NS
% change hct.	-27.1 (9.8)	-27.1 (12.1)	NS
24 hr platelet count	139.2 (56.8)	148.5 (48.1)	NS
% change plt.	-42.7 (15.6)	-42.1 (15.1)	NS
24 hr blood loss	865.4 (389.1)	846.3 (368.2)	NS
Ventilator time	20.4 (9.5)	20.8 (13.1)	NS

RBC transfused expressed in units of packed cells throughout hospital stay, 24 hr hematocrit in percent, % change as change from preop value, platelet count in cells/ulX10^3, 24 hr blood loss in mls, and ventilation time in hours. Values expressed as: mean (standard deviation).

MATERIALS AND METHODS

To assess the impact of centifugal pump use on patient outcome during cardiopulmonary bypass (CPB), 200 adult patients undergoing moderate hypothermic CPB for elective coronary artery reconstruction were studied. Patients were randomly assigned to either the centrifugal group (Group CP, n=100) or the roller group (Group RP, n=100).

The bypass circuit consisted of a plate membrane oxygenator with integral cardiotomy reservoir[a], centrifugal[b] or roller pump, a polyvinyl chloride tubing circuit[c] and a screen type arterial filter[d]. Each bypass circuit was primed with 1,600 ml of balanced electrolyte solution, 200 ml of 25% albumin and 200 ml of 20% mannitol. Patients were anticoagulated for CPB with 3 mg/kg of porcine mucosa heparin. Throughout CPB, ACT's were maintained at 480 seconds or higher. Flow rates on CPB were maintained between 1.6 and 2.4 l/min/m^2. Patient hematocrits were maintained above 17%. Arterial blood gas analysis was performed every 20-30 minutes while on CPB. Alpha stat blood gas management was maintained throughout CPB. Myocardial protection was provided by delivery of cold blood cardioplegia (4:1) every 15-20 minutes[e]. Anticoagulation was monitored every 15 minutes utilizing an automated coagulation monitor[f]. Ventilation times were recorded as time to extubation after leaving the operating room. Postoperatively, 24 hour platelet counts, hematocrits, and total mediastinal blood loss values

a Cobe Laboratories Inc., Arvada, CO 80004
b Biomedicus, Eden Prairie, MN 55344
c Baxter-Bentley Laboratories, Anaheim, CA 92807
d Pall Biomedical, Glen Cove NY 11542
e Electromedics, Inc. Englewood, CO 80112
f International Technidyne Corporation, Edison, NJ 08820

were collected. The length of stay (LOS, days) was derived from the day of surgery until the day of discharge. The net financial balance (NFB) was calculated by subtracting total patient costs from total patient revenues. DRG classes as well as financial classes were identified in order to account for differences in reimbursement levels. All mean values were analyzed using the Student's t-test, and frequencies were compared with the Chi-square statistic, with significance assigned at the p=0.05 level.

RESULTS

A total of 200 patients were evaluated during this study. Patients were statistically well matched with respect to age, sex, pump time, aortic cross clamp time, hematologic values and NYHA class (Table 1). Additionally, the distribution of operating surgeon did not differ significantly. Postoperative results revealed no significant differences in red blood cell requirements, 24 hour hematocrits and platelet counts, time on the ventilator or 24 hour mediastinal blood loss (Table 2). There were two deaths in both groups, related to infection and neurologic complications. Table 3 identifies significant group differences ($p<0.05$) involving length of stay, 24 hour postoperative weight gains, and net hospitalization financial balance. In Group CP, patients were observed to have negative 24 hour weight gain. No similar observations were made for Group RP.

DISCUSSION

Cardiopulmonary bypass provides the body with a tremendous physiologic insult which is well tolerated. Continual advances are being made to reduce the insult of bypass, but none have dramatically affected patient outcome. Primary changes in cardiac surgery, leading to decreased hospital stay and improved patient outcome, have been in preoperative and postoperative care (10). With these considerations in mind, we consider the numerous comparative studies concerning the primary arterial pump of the heart lung machine - roller versus centrifugal. Theoretically, the centrifugal pump has been shown to be safer, less hemolytic, to preserve coagulation factors, decrease complement activation and more. This study demonstrates that while the former may be true, there are significant economic benefits and improvements in patient outcome when centrifugal pumping is utilized. In our described patient population we demonstrated that with centrifugal pumping, patients had significantly shorter hospital stays and lower costs. Postoperative weight gain was lower in the centrifugal group and possibly plays a role in these results. Although not studied, improved end organ function as a result of decreased tissue edema could explain these findings. The mechanism of improvements in the length of stay and net financial balance are not fully explained by this study. The relationship to postoperative weight gain is of interest, though, and warrants further investigation.

Table 3: Patient outcome for centrifugal and roller groups

Category	Centrifugal n=100	Roller n=100	P Value
Length of stay	8.9 (2.1)	9.9 (4.0)	p<0.05
24 hr weight gain	1.8 (2.0)	2.5 (1.8)	p<0.05
Net financial balance	11707 (4497)	9644 (4604)	p<0.05

Length of stay expressed as days from surgery until discharge, 24 hr weight gain as kilograms (+/-) and net financial balance in dollars (total revenues minus total costs). Values expressed as: mean (standard deviation).

REFERENCES

1. Gold JP, Eprile T. Well Informed Patient's Guide to Coronary Bypass Surgery. New York: Dell. 1990.

2. Leape LL, HIlborne LH, Park RE, et al. The appropriateness of use of coronary artery bypass graft surgery in New York State. JAMA. 1993; 269(6): 753-760.

3. Van den Dungen J, Karliczek GF, Brenken U, et al. Clinical study of blood trauma during perfusion with membrane and bubble oxygenators. J Thorac Cardiovasc Surg. 1982; 83:108-116.

4. De Bois WJ, Shevde K, Sharon I. Improved circulation during hypothermic cardiopulmonary bypass utilizing a pulsatile device. Anesth Analgesia. 1987; 66:S39.

5 Taylor KM, Bain WH, Davidson WG, Turner MA. Comparative clinical study of pulsatile and non pulsatile perfusion in 350 consecutive patients. Thorax. 1982; 37:324-330.

6 Mandl JP. Comparison of emboli production between a constrained force vortex pump and a roller pump. AmSECT Proc. 1977; 27-31.

7 Wheeldon DR, Bethune DW, Gill RD. Vortex pumping for routine cardiac surgery: a comparative study. Perfusion. 1990; 5:135-43.

8 Salama A, Hugo F, Heinrich D, et al. Deposition of intimal C5b-9 complement complexes on erythrocytes and leukocytes during cardiopulmonary bypass. N Engl J Med. 1988; 318:408-414.

9 Parault BG, Conrad SA. The effect of extracorporeal circulation time and patient age on platelet retention during cardiopulmonary bypass: a comparison of roller and centrifugal pumps. J Extra-Corpor Technol. 1992;

23:34-38.

10 Topol EJ, Burck K, O'Neill WW, et al. A randomized controlled trial of hospital discharge three days after myocardial infarction in the area of reperfusion. N Engl J Med. 1988; 318:1083-1124.