The Effect of Extracorporeal Circulation Time and Patient Age on Platelet Retention During Cardiopulmonary Bypass: A Comparison of Roller and Centrifugal Pumps

Beverly G. Parault, RN, CCP and Steven A. Conrad, MD, PhD
Medical Perfusion Department, Schumpert Medical Center and Department of Medicine (Critical Care), Louisiana State University Medical Center, Shreveport, Louisiana

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Abstract

Preservation of platelet count during cardiopulmonary bypass (CPB) was retrospectively studied in 784 consecutive adult patients undergoing cardiac surgery, including high-risk "special case" patients. The extracorporeal circuit included a closed membrane oxygenator system for all patients. A roller pump (Cobe Laboratories or Stockert-Shiley) was used for bypass in one group of 564 patients, while a centrifugal pump (BioPump, Bio-Medicus) was used in a second group of 220 patients. There was no difference between the roller and centrifugal pump groups with respect to age, sex, total bypass time, and pre-bypass platelet count. For purposes of this study, retention refers to the patient's last platelet count on CPB expressed as a fraction of the pre-CPB platelet count. The centrifugal pump group had a higher platelet retention than the roller pump group (.619 vs .595, $p<.05$). Patients with prolonged bypass times (> 120 min) had a lower platelet retention in the roller pump group (.568 vs .610, $p<.05$), but no significant decrease was seen in the centrifugal pump group (.617 vs .621, $p>.05$). Patients over the age of 70 had a lower retention than those under 70 in the roller pump group (.576 vs .604, $p<.05$), but there was no difference in the centrifugal pump group (.600 vs .628, $p>.05$). The special case patients had a lower retention when the roller pump was used (.563 vs .607, $p<.05$), while platelet retention was not affected in the centrifugal pump group (.603 vs .625, $p>.05$), however bypass time was also prolonged in the special case group. The centrifugal pump results in improved platelet retention on cardiopulmonary bypass. This improvement is most notable in prolonged cases (> 120 min), in older patients (> 70 yrs), and in special cases.

Introduction

Platelet preservation during cardiopulmonary bypass (CPB) has long been a goal of both the perfusionist and the cardiac surgeon[1,2]. Hemodilution due to priming of the extracorporeal circuit with crystalloid or colloid solution results in both a lower hematocrit and platelet count during CPB. It is well known that these two factors, plus the activation of platelets within the extracorporeal circuit, can be a cause of coagulopathy during the postoperative period[3-6]. The type of blood pump used for extracorporeal support may influence the preservation of platelets during bypass. The centrifugal pump, employing the constrained forced vortex principle, is felt to be less traumatic to formed blood elements than the conventional roller pump[7]. The effect of the pump on platelet preservation is not well defined. We compared preservation of platelet count between a centrifugal pump and conventional roller pumps.

Address correspondence to:
Beverly Parault, RN, CCP
Director, Medical Perfusion Department
Schumpert Medical Center
P.O. Box 21976
Shreveport, LA 71120-1976

Materials and Methods

As part of the quality assurance program of the Medical Perfusion Department, a database consisting of demographic data, surgical case information, and perfusion data is maintained on all patients undergoing CPB. A quality assurance monitor was established using the quality assurance indicator: "The last platelet count on CPB will be 45% or greater of the patient's pre-bypass platelet count". To perform this monitoring, platelet counts and compliance rates were entered into the database.

Patient Selection

For this study, perfusion records from all adult patients undergoing CPB at Schumpert Medical Center for the two year period beginning April 1989 through March 1991 were retrospectively reviewed. Variables recorded on each patient included age, sex, total CPB time, pre-bypass platelet count, platelet count near the end of CPB, and the fraction of the patient's platelet count retained. A "special case" patient was defined as one having a repeat operation (redo), or on intra-aortic balloon (IABP) support, or one having a failed angioplasty or one having any combination of the above. The "special case" patient represents over thirty-three percent (0.335) of total bypass patients during the time period studied. Therefore, this group of patients could yield valuable information to the cardiac team. Assignment to the roller pump or centrifugal pump group was based solely on surgeon preference.

Extracorporeal Circuit

The extracorporeal setup for all patients included a Medtronic Maxima hollow fiber oxygenator, a Medtronic Intercept cardiotomy reservoir, and a Medtronic custom tubing pack with a Tygon S-50-HL 1/2" - 3/32" segment for the arterial roller pump head[a], Bentley Labs BMR 1900 venous reservoir[b], a Pall model 3840 arterial filter[c], Mallinckrodt model Gem-6 on-line monitoring system[d], Hepcon System 4 and Hepcon ACT[e] for heparin management, Haemonetics Cell Saver Plus[f] and a Sarns heater-cooler[g]. The pump was either a conventional roller pump (Cobe model 043-600-000[h] or Stockert-Shiley model 10-00-00[i]) or Bio-Console 540 centrifugal pump[j]. The roller pump group received a 4:1 mix of blood to crystalloid cardioplegia while the centrifugal pump group received a commercially mixed crystalloid cardioplegia (Plegisol[k]). With this cardioplegia method, the centrifugal group received approximately three times the cardioplegia crystalloid volume as did the roller group (approximately 1200 ml versus 400 ml, respectively). All cardioplegia solution was delivered via a custom tubing pack incorporating a stainless steel coil (Cobe Labs[l]).

Table 1. Procedures performed

Diagnosis	*N*	*Percent*
Aortocoronary bypass ± ventricular aneurysm repair	676	86.2%
Valve procedures ± bypass or other repair	94	12.0%
Ascending aorta repair	4	0.5%
Other	10	1.3%
Total	784	100.0%

Statistical Methods

Analysis was performed using the Statistical Analysis System (SAS) software[m]. Student's t test was used for comparison of two means. Analysis of variance was used to test for differences in more than two means, with Duncan's multiple range test used to compare multiple means. Linear regression was used to evaluate for regression on time and on age. Pearson's product-moment statistic was used for correlation analysis. Frequencies were compared with the Chi-square statistic. Means are expressed as mean ± SEM (standard error of the mean). The level of significance (a error) used was 0.05. To evaluate the effect of CPB time on platelet retention using analysis of variance, cases were divided into short (<90 minutes), mid (90 - 120 minutes), and long (>120 minutes). To evaluate the effect of age on platelet retention using the t test, cases were divided into two groups, patients < 70 years and ≥ 70 years of age. Where appropriate, analyses were repeated after sub-grouping by blood pump type.

Results

The study sample consisted of 784 patients. Eighty six percent (86%) of patients underwent aortocoronary bypass grafting (Table 1). The remaining patients underwent valve procedures, ascending aorta repair or other procedures. Of the 784 total patients, the roller pump group consisted of 564 patients, and the centrifugal pump group consisted of 220. There was no significant difference between the two

a Medtronic Cardiopulmonary, Anaheim, CA 92807
b Baxter-Bentley Laboratories, Irvine, CA 92714
c Pall Biomedical Products Corporation, Glen Cove, NY 11542
d Mallinckrodt Sensor Systems, Ann Arbor, MI 48108
e HemoTec Inc., Engelwood, CO 80112
f Haemonetics Corp., Braintree, MA 02184
g Sarns 3M Health Care, Ann Arbor, MI 48106
h Cobe Laboratories Inc., Arvada, CO 80004
i Shiley Inc., Irvine, CA 92714
j Biomedicus, Eden Prairie, MN 55344
k Abbott Laboratories, North Chicago, IL 60064
l Cobe Laboratories Inc., Arvada, CO 80004
m SAS Institute, Cary, NC 27512

pump groups with respect to patient characteristics, CPB bypass time, and pre-CPB platelet count (Table 2). However, the fraction of platelets retained was significantly lower in the roller pump group than in the centrifugal pump group (.596 ± .006 vs. .619 ± .010, p=.049).

Analysis of variance on bypass time classified into three groups (< 90 min, 90 - 120 min, and > 120 min) revealed a significant reduction in platelet retention with increased bypass time (p < .05). When grouped by pump type, this significant reduction was noted for the roller pump group (p < .05, Figure 1), but in the centrifugal pump group, there was no loss of platelet retention with prolonged bypass times (p > .05, Figure 2). Regression analysis of platelet retention confirmed this significant decrease in retention with increased total CPB time (p = .004). When comparing the effect of time on platelet retention by pump type, the

Table 2. Comparison of patients by pump type

	Roller	*Centrifugal*	*P value*
N	564	220	-
Age	63.1 ± .46	64.6 ± .64	NS
Sex (M/F)	409/155 (74%/26%)	163/57 (73%/27%)	NS
Total CPB time	94.8 ± 1.5	91.6 ± 2.1	NS
Pre-CPB platelet count	240,701 ± 2969	229,690 ± 5489	NS
Post-CPB platelet count	141,157 ± 2021	140,159 ± 3640	NS
Platelet retention	.595 ± .006	.619 ± .010	p = .049

Age is expressed in years, time in minutes, and platelet count in cells/μl. Means are expressed as mean ± SEM.

Figure 1
Platelet retention in the roller pump group for the three groups of total cardiopulmonary bypass time: short (<90 min), mid (90-120 min) and long (>120 min). A statistically significant reduction in platelet retention with longer pump times was noted (p<.05).

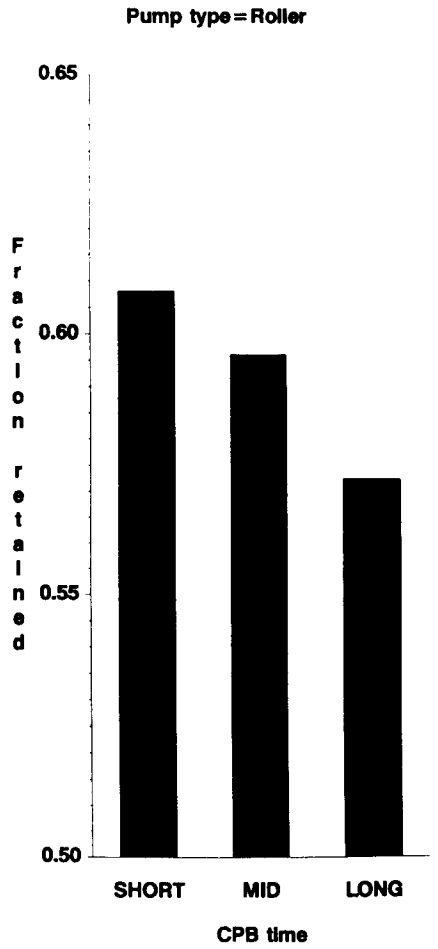

Figure 2
Platelet retention in the centrifugal pump group for the three groups of total cardiopulmonary bypass time: short (<90 min), mid (90-120 min) and long (>120 min). There was no significant reduction in platelet retention with longer pump time.

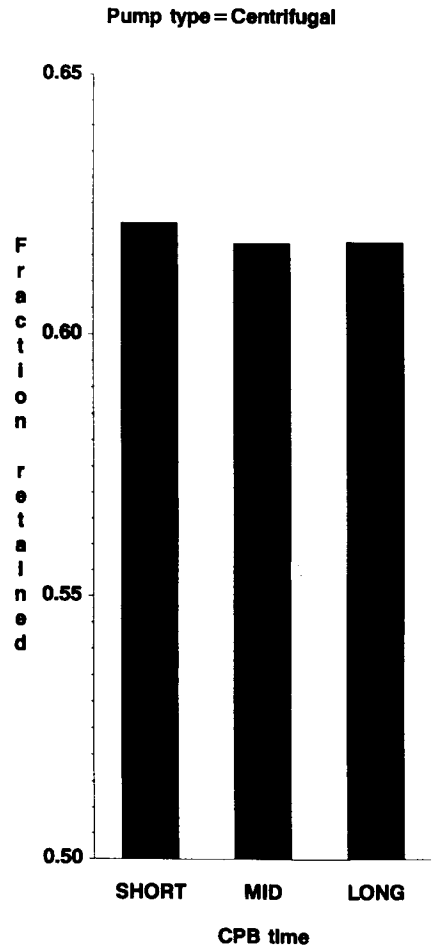

Table 3. Effect of age on platelet retention (all patients)

	Age < 70	*Age ≥ 70*	*P value*
N	542	244	
Age	58.6 ± 0.4	74.3 ± 0.2	
Total CPB time	92.8 ± 1.5	96.4 ± 2.4	NS
Pre-CPB platelet count	240,083 ± 2963	232,147 ± 5361	NS
Post-CPB platelet count	144,040 ± 2012	133,852 ± 3533	p = .008
Platelet retention	.611 ± .006	.584 ± .010	p = .019

Age is expressed in years, time in minutes, and platelet count in cells/μl. Means are expressed as mean ± SEM.

Table 4. Effect of age on platelet retention (centrifugal pump)

	Age < 70	*Age ≥ 70*	*P Value*
N	147	73	
Age	59.9 ± 0.7	74.0 ± 0.4	
Total CPB time	92.7 ± 2.7	89.5 ± 3.2	NS
Pre-CPB platelet count	226,850 ± 4873	235,410 ± 13360	NS
Post-CPB platelet count	140,210 ± 3388	140,054 ± 8635	NS
Platelet retention	.628 ± .011	.600 ± .019	NS

Age is expressed in years, time in minutes, and platelet count in cells/μl. Means are expressed as mean ± SEM.

roller pump cases demonstrated a decrease in retention with increased CPB time (p = .004), the centrifugal pump cases showed no significant reduction (p = .644).

A comparison of patients 70 years of age and older with those under the age of 70 is given in Table 3. Although the two groups did not differ in pre-bypass platelet count or total bypass time, platelet retention rate was lower in the older group. When the analysis was repeated for each pump type, platelet retention was not different between the age groups in the centrifugal pump patients (Table 4). In the roller pump group, those 70 years and older had a lower platelet retention (Table 5). The total CPB time was also greater in this older group, however partial correlation analysis between age and platelet retention with correction for CPB time effect yielded a statistically significant Pearson partial product-moment statistic (rxy.z = -.106, p = .003).

The effect of being a special case on platelet concentration was analyzed. When comparing special case patients (n = 197) to all others (n = 587), the former had a lower pre-bypass platelet count (227,633 ± 4315 vs 241,005 ± 3203, p = .027), a lower retention (.575 ± .011 vs .616 ± .006, p = .003), but also a longer CPB total time (104.0 mins. ± 3.0 vs 90.5 mins. ± 1.2, p = .0001). Comparison of special cases and routine cases was repeated for each pump type. In the centrifugal pump group, there was no difference with respect to age, platelet count, and retention. The roller pump group, however, had a lower retention (.563 ± .011 vs .607 ± .007, p = .003). Special cases had a longer pump time in both centrifugal (102.0 ± 5.1 vs 87.8 ± 2.1 min, p=.002) and roller (104.7 ± 3.7 vs 91.6 ± 1.5 min, p = .001) pump groups.

Table 5. Effect of age on platelet retention (roller pump)

	Age < 70	*Age ≥ 70*	*P Value*
N	395	171	
Age	58.2 ± 0.5	74.4 ± 0.3	
Total CPB time	92.9 ± 1.8	99.3 ± 2.5	p = .046
Pre-CPB platelet count	245,007 ± 3612	230,754 ± 5130	p = .027
Post-CPB platelet count	145,465 ± 2456	131,204 ± 3442	p = .001
Platelet retention	.605 ± .008	.577 ± .011	p = .047

Age is expressed in years, time in minutes, and platelet count in cells/μl. Means are expressed as mean ± SEM.

Discussion

An improved platelet count retention on CPB infers an improved coagulation state post bypass[8, 9]. Decreased platelet concentration and function and platelet activation within the CPB circuit can lead to serious complications including reperfusion injury due to deposition of platelet aggregates within the coronary vasculature[10]. Increased bleeding times post bypass due to loss of platelet fibrinogen receptors may result in increased post-op blood loss[11]. Therefore, methods to improve platelet retention during cardiopulmonary bypass seem warranted.

There have been few studies of the effect of pump type on platelet retention. Takeda et al[12] reported a study comparing roller versus centrifugal pumping in a canine model of cardiopulmonary bypass. Platelet count remained nearly constant in the centrifugal pump group, but dropped to half of pre-bypass levels with the roller pump.

A previous study in humans evaluated a silicone membrane oxygenator in combination with a centrifugal pump

against a polypropylene membrane oxygenator and a roller pump, and found no statistical differences to warrant a change[13]. However, differences due to pump type alone could not be evaluated. In addition, CPB times were relatively short (approximately 65 minutes) in comparison to our group (approximately 94 min), and our current study found similar results in the short CPB times. As time on CPB increases beyond 120 minutes, however, statistical differences between the roller pump and centrifugal pump are evident.

Wheeldon and colleagues[14] reported a prospective randomized human trial of sixteen patients in which the only difference between two groups was the pump type (roller versus centrifugal). Preservation of platelet numbers was significantly better in the centrifugal pump group.

Our study illustrates a statistically significant improvement in platelet count retention utilizing the centrifugal pump in those patients with longer CPB times, in those over the age of 70, and those classified as special cases. Because of a significant correlation between age and total CPB time, however, it is possible that the decreased retention in older patients was due to a longer pump time and not due to the effect of age itself. However, partial correlation with correction for CPB time was still significant, suggesting that age may indeed be an independent factor affecting platelet retention. Special case patients also demonstrated a lower retention. It is likely that this effect was due to the longer CPB time since special cases had significantly longer times.

Although our study was retrospective, it included a large number of (784) patients. It was well controlled in that our two patient groups did not differ, and the only primary difference in cardiopulmonary bypass technique and equipment was the blood pump.

It should be noted that the roller pump cases in our study were conducted with a 4:1 blood:crystalloid cardioplegia, receiving on the average of 400 ml of crystalloid. The centrifugal pump cases were conducted with crystalloid cardioplegia, receiving an average of 1200 ml. In spite of the smaller crystalloid volume in the roller pump group, for which the dilutional effect would be expected to be less significant, platelet retention was lower.

In conclusion, the centrifugal pump is associated with a significantly greater platelet retention than the roller pump. This difference is most pronounced when the length of the pump run is greater than 120 minutes, the age of the patient is 70 and older, and in special case patients. The centrifugal pump should be considered as an alternative to the roller pump when these conditions exist or are anticipated.

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