
Counterpulsation—An Alternate Use for the Pulsatile Bypass Pump

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Abstract

The positive effect of counterpulsation on coronary flow is generally accepted. This report describes an experience with the Pulsatile Bypass Pump (PBP)* as a method of providing not only pulsatile perfusion during cardiopulmonary bypass (CPB), but also counterpulsation before and after CPB. Over 18 months, the PBP was utilized in 200 patients, the majority of whom underwent coronary bypass procedures. Eighteen of these patients who required support of cardiac function before CPB, form the subgroup emphasized. With synchronized counterpulsation via the common femoral artery by cut down, the patient was anesthetized and the operative procedure performed. During CPB, the PBP provided pulsatile flow and after bypass was again used for counterpulsation. All 18 patients were weaned from PBP and survived operation. Diastolic augmentation and systolic unloading were observed by monitoring pressure tracing in the radial artery, while counterpulsating via the femoral artery. In 16 patients cardiac function was preserved

without need for further support. Two patients required the IAB, and both recovered. It is concluded that transfemoral counterpulsation by the PBP provides a safe alternate method of cardiac support in the absence of significant peripheral vascular disease for patients who would otherwise be candidates for the IAB.

Introduction

Assisted circulation in the form of counterpulsation was first described by Clauss¹ in 1961. The following year, Moulopolous² described using a balloon placed on a catheter for diastolic augmentation. In the late 1960's, Kantrowitz³ refined this technique and reported the first large series of patients supported by balloon pumping. The use of balloon pumping increased during the 1970's with major contributions by Bregman⁴ and the group from Massachusetts General Hospital.⁵ As balloon pumping grew as a therapeutic maneuver, the number of patients surviving increased.⁶ Indications for this form of mechanical support included cardiogenic shock, pre-infarction angina and life-threatening arrhythmias. After the initial results with "medical patients," balloon pumping increased in popularity as a mode of treatment in "surgical patients." Most of these were patients with left ventricular power failure following cardiopulmonary bypass. Initial survival reports were poor as onset of balloon pumping was not well defined. As indications for balloon pumping and the timing of onset of treatment became more clearly defined, the survival rate increased.

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Article submitted at AmSECT's 18th Int'l. Conference, Philadelphia, PA 3/19/80, accepted 11/9/81.

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By 1976 it became the practice in many centers to include prophylactic use of the balloon prior to the induction of general anesthesia.^{7,8} With this method, the high risk patient was supported by diastolic augmentation through the induction of general anesthesia, as well as throughout the remainder of the operation. Most of the patients who benefited from this form of support were those with high grade coronary stenosis or compromised ventricular function. Insertion of the intraaortic balloon, however, has been associated with not only morbidity, but also mortality.^{9,10,11}

The concept of pulsatile bypass in a clinical setting was described as early as 1970. However, it was designed to provide pulsatile flow only during the period of cardiopulmonary bypass. There was no capability to support the patient in a synchronized manner before or after the period of bypass. Pappas¹² described the use of the intra-aortic balloon to obtain pulsatile cardiopulmonary bypass. With this method, one could have pulsatile flow during bypass, and the capability for synchronized support before and/or after bypass. However, this again necessitated insertion of the balloon with its attendant possible complications. Bregman¹³ in 1976 reported the use of a pulsatile assist device to deliver pulsatile flow during bypass and counterpulsation before or after bypass. Three commercially available units are in standard use today to allow this option.

Patients and Methods

In the past two years, the Pulsatile Bypass Pump has been employed in 200 patients at Duke University Medical Center. The majority of these patients (87%) underwent coronary artery bypass grafting (CABG). The hospital mortality for this group of CABG patients was 1.15%.

During this same period of time, both the overall use of balloon pumping and the prophylactic use of the intra-aortic balloon have declined, in part due to more appropriate use of controlled anesthetic management including adjustments of pre-load, afterload, and contractility.

Eighteen patients undergoing CABG, however, were felt to be potential candidates for support of cardiac function prior to the induction of anesthesia, and would otherwise be considered for prophylactic intra-aortic balloon support. All patients were NYHA Class III or IV for angina. Operation was considered urgent in 16 of 18 patients (89%). Table 1 describes the indications for using PBP in this group.

TABLE 1
Indications for Use of the PBP

Indications for PBP Support	
Left Main Disease (> 75%)	10 Patients
Pre-infarction Angina	7 Patients
Severe Ventricular Dysfunction	1 Patient

After routine pre-medication, the patients were transported to the operating room and prepared for operation in the standard manner. Prior to induction, after a complete body skin prep and drape was accomplished, under local anesthesia, a cut-down was performed over the common femoral artery. Following isolation of the femoral artery, a standard 50 mg dose of heparin was administered. This is done to increase the activated clotting time (ACT) by the method described by Bull.¹⁴ Next, a femoral arteriotomy is done and a 24 French cannula inserted and secured. The PBP is connected to the cannula as pictured in Figure 1. By using the stopcock connector, any entrapped air can easily be aspirated. The bypass, or shunt line, is clamped at each end as this will not be used in normal operation. The arterial inflow line is clamped just proximal to the PBP to avoid bidirectional flow which would diminish the effectiveness of counterpulsation. Synchronized counterpulsation is achieved using the patient's electrocardiogram. With adequate counterpulsation giving adequate diastolic augmentation and systolic unloading (Fig. 2) by IAB standards, the patient is then anesthetized and the operative procedure begun. The PBP continues to provide support until the cardiopulmonary bypass is instituted. During bypass, when the heartbeat ceases as hypothermic cardioplegic solution is begun, an internal trigger mechanism in the driving console is used to provide pulsatile cardiopulmonary bypass. After release of the aortic cross-clamp,

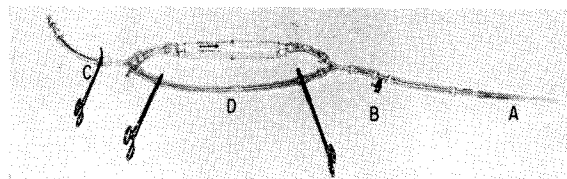


FIGURE 1. Connection of the femoral cannula to the PBP and clamps applied at the appropriate points. A. 24 French cannula introduced into femoral artery, B. stopcock connector for aspirating entrapped air, C. clamp on arterial inflow line to avoid bidirectional flow, D. shunt or bypass line clamped and not used.

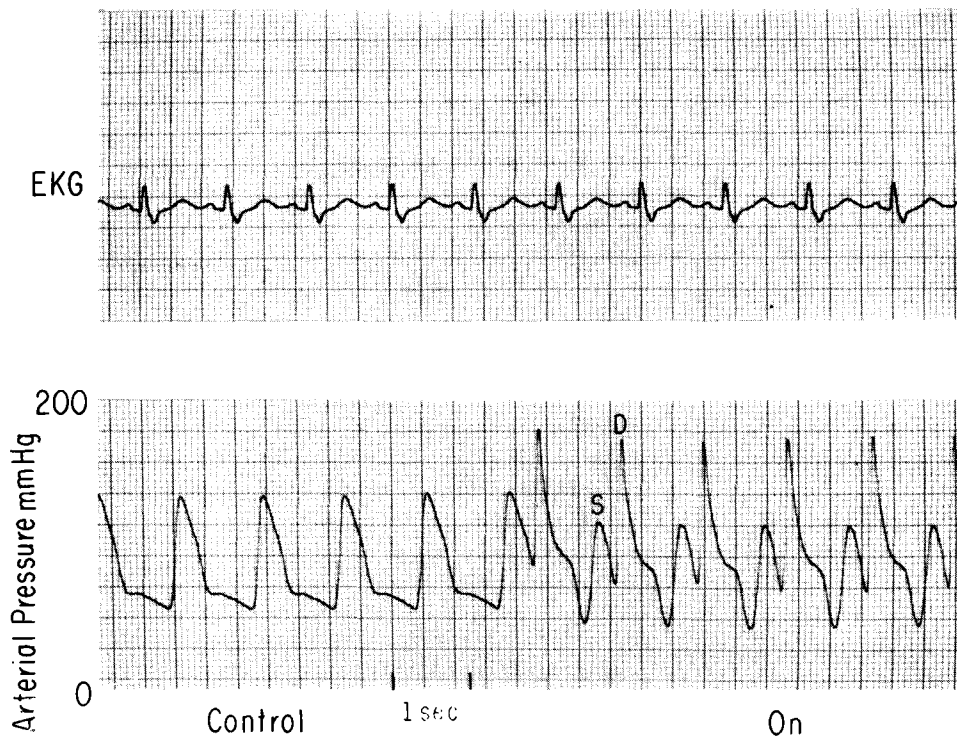


FIGURE 2. Control pressure on left is compared to activation of the PBP showing excellent diastolic augmentation (D) as well as systolic unloading (S).

when the heartbeat is re-established, the PBP is again synchronized with the patient's electrocardiogram and using counterpulsation, the patient is weaned from cardiopulmonary bypass. Off bypass, this synchronized counterpulsation is continued as the patient stabilizes. Using thermodilution cardiac output determinations and pulmonary artery diastolic pressure as guides, the PBP was then discontinued using the weaning mechanism: 1:2 ratio, 1:4, and occasionally 1:8. It should be noted that there were no *set* values, but rather the values were adjusted to each patient's own hemodynamic situation. Only after weaning and discontinuing the PBP was the ACT normalized by Protamine. If prolonged counterpulsation is necessary, the Protamine could be started to aid in generalized hemostasis, but should not bring the ACT back to baseline. As a general rule, enough Protamine is given to bring the ACT to twice the baseline, in this setting.

Results

All 18 patients survived operation. Diastolic augmentation and systolic unloading were observed in all but one patient who had known severe peripheral occlusive disease. In this case, the cannula was changed

to the aorta after opening the chest, and the patient was pulsated with good results and no further problems. One patient with severe aorto-iliac occlusive disease sustained an acute aortic dissection which required simultaneous successful operative repair. Two patients could not be weaned from the PBP and required insertion of the intra-aortic balloon for sustained support. In the remaining 16 patients, cardiac function was preserved without the need for further support. There were no other complications associated with the use of PBP. There was minimal extra operation time associated with the use of the device.

Although no special hematologic studies were included in this series there were no unusual detrimental effects than one would expect from a normal course of CPB or the use of the IAB in terms of decreased platelets, decreased hematocrit, or other values. Further, there was no evidence of micro-embolic phenomenon as evidenced by the lack of an altered mental status or systemic organ dysfunction in any of these patients.

Discussion

The current generation of devices for the creation of pulsatile bypass are safe and easy to use. Although

aortic perfusion is now the preferred method, femoral cannulation still has its place with a low morbidity as discussed here. In properly selected patients, the complication of inserting a cannula into the femoral artery should be less than that of inserting an intra-aortic balloon. The true benefits of pulsatile versus non-pulsatile flow during cardiopulmonary bypass have not been clearly established in spite of enthusiastic reports of its use.¹⁵ It is reported that the use of pulsatile bypass may decrease the need for postoperative balloon support.¹⁶ Other reported benefits of pulsatile flow are: a decrease in postoperative hypertension,¹⁷ improved myocardial function,^{18,19} improved renal function,²⁰ and, in general, improved systemic organ perfusion.²¹ More data is needed to clearly define the merits of pulsatile bypass, but, at the present time, it appears to be a safe device with very few deleterious effects on the patient.²²

Summary

Eighteen out of 200 patients receiving pulsatile bypass were felt to need circulatory assistance before or after the time of cardiopulmonary bypass. This was provided via the femoral artery utilizing the pulsatile bypass pump for counterpulsation. This was successful in 17 of the 18 patients with no operative mortality. Sixteen of 18 patients required no postoperative circulatory support. It is concluded that transfemoral counterpulsation with the pulsatile bypass pump provides a safe alternate method of cardiac support for patients who would otherwise be candidates for intraoperative use of the intra-aortic balloon.

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