
A Proposed Method for Weaning from IABP Assist Following Sequential Hemodynamic Assessment Utilizing a Microcomputer

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Abstract

Before consideration is given for discontinuing an assist device (IABP) a set protocol should be developed by the cardiac assist team through which the necessary steps can be taken for proper management and control of the patient's status. Such a protocol is described in this preliminary report. At our institution the feasibility of weaning is established via sequential clinical and hemodynamic assessments which are made prior to the initiation of the assist device and continue throughout the assist and weaning period. In the patient who is a candidate for cardiac surgery, an initial hemodynamic assessment is accomplished prior to surgery which serves as a baseline for future cardiopulmonary profiles and aids in the initial evaluation of the patient. The profile consists of various hemodynamic variables that are entered into the TRS-80 system which provides a printout of cardiac parameters used during trend analysis of the patient status. Counterpulsation is initiated as indicated by a compromised post-bypass profile or obvious left ventricular failure. Sequential hemodynamic and clinical reassessments are performed every 2 to 4 hours to aid the operator in making decisions as to the effectiveness of the assist as well as inotropic and/or vasopressor therapy. Typically 12–24

hours of assist are carried out prior to reassessment for discontinuation. Once optimal hemodynamic status is obtained the process of weaning begins consisting of 4 hours for each 24 hours of assist. The first phase of our weaning technique consists of 5cc reductions to 50% of total balloon volume. In this way diastolic augmentation and afterload reduction are gradually tapered, thus minimizing significant increases in cardiac workload and acute strain. The second phase consists of an assist ratio reduction from every beat to every fourth beat which accounts for one-fourth the total wean time. Hemodynamic assessments of the patient's condition are made before and shortly after each change in wean condition. Complete weaning and balloon catheter removal occurs only after sequential clinical and hemodynamic assessments have indicated maximum possible improvement in cardiac performance and its persistence after a period of trial with minimal assist.

Introduction

The use of the intra-aortic balloon pump (IABP) as an adjunct for treating compromised left ventricular performance and refractory hypotension following cardiopulmonary bypass is well established.^{1,2,3,4} Attempts have been made to define patients at risk who may require mechanical support prior to surgery as well as hemodynamic criteria for the use of IABP.^{1,2,3,4,10}

This report describes a cardiac assist profile (CAP)

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developed by our group to aid in the evaluation of patients being supported on and weaned from IABP assist. The profile consists of microcomputer generated assessments of hemodynamic data. An analysis of two groups of patients requiring IABP support is presented.

Materials and Methods

From May 1978 through January 1981, 18 patients required IABP assist and were followed using the CAP. There were 16 males and 2 females ranging in age from 14 to 72 years (mean age 57.5). This represented 1.8% of 1,004 patients undergoing open cardiac surgery during this period. The SMEC* IABP was used exclusively during this period. Two groups of patients were identified based on survival: Group I (13 patients, 72%) were successfully weaned from IABP assist and discharged home. Group II (5 patients, 28%) did not survive long enough to be weaned from IABP or died after successful weaning from IABP.

The CAP consisted of the following parameters (Figure 1):

Thermodilution Cardiac Output

Systemic Arterial Pressure

Systolic (SP)

Diastolic (DP)

Mean (MAP)

Mean Pulmonary Artery Pressure

Pulmonary Capillary Wedge Pressure (PCWP) or

Left Atrial Pressure (LAP)

Heart Rate (HR)

Mixed Venous Oxygen Saturation (MVO₂S)

Weight

Body Surface Area (BSA)

This information was entered into a TRS-80, Model I, Level II microcomputer disk operated system** with a Centronics line printer*** (Figure 2). The computer was programmed in Disk Basic to calculate and print the following:

Stroke Volume

Cardiac Index (C.I.)

Stroke Index

Right Ventricular Stroke Work

Left Ventricular Stroke Work

Systemic Vascular Resistance

THE DEPARTMENT OF CIRCULATION TECHNOLOGY CARDIAC ASSIST PROFILE

THIS IS PATIENT PROFILE NO.: 6

PATIENT INFORMATION

NAME: SMITH JOHN

HOSPITAL NO.: 1233211

LOCATION: SICU 3

PHYSICIAN: WILSON

CARDIAC ASSIST INFORMATION

ASSIST CONDITION: FULL

BALLOON SIZE: 40

TIMING: 1/1

BALLOON VOLUME: 40

	CARDIAC VARIABLES		CARDIAC CALCULATIONS
1 DATE	11280	14 STROKE VOLUME (45-65ML)	47.06
2 TIME	1630	15 CARDIAC INDEX (2.5-4L/MIN/ MSQ)	2.51
3 CARDIAC OUTPUT (L/MIN)	4.8	16 STROKE INDEX (30-35ML/ MSQ)	24.64
4 SYSTOLIC PRESSURE (MMHG)	112	17 RVSW (5- 15GM-M)	6.4
5 DIASTOLIC PRESSURE (MMHG)	56	18 LVSW (60- 80GM-M)	36.48
6 MEAN ARTERIAL PRESSURE (80- 90MMHG)	75	19 SYS VASC RESIS (1200ARU/S)	1033.33
7 HEART RATE (BEATS/ MIN)	102	20 PUL VASC RESIS (200ARU/S)	83.33
8 MEAN PA PRESSURE (10-25MMHG)	23	21 PUMP FAILURE CORR (>150)	189.78
9 WEDGE/LAP MEAN (2-12MMHG)	18	22 MYOCARDIAL O2 CONS CORR	114.24
10 CVP (2-12MMHG)	13		
11 VENOUS SATURATION (65-80)	61		
12 WEIGHT (KG)	90		
13 BODY SURFACE AREA (MSQ)	1.91		

PATIENT INOTROPIC DRUG INFORMATION

DOSAGE OF DOPAMINE IS 583.33 MCG/MIN (6.48 MCG/KG/MIN)

DOSAGE OF NITROPRUSSIDE IS 50 MCG/MIN (.56 MCG/KG/MIN)

ASSIST EVALUATION

C.I. IS WNL

* LAP/WEDGE IS WITHIN ACCEPTABLE LEVELS *

PUMP FAILURE CORRELATE IS ABOVE MINIMAL ACCEPTABLE LIMIT

* SMEC, Inc., Rt. 7, Cookeville, Tn. 38501

** Tandy Corporation, Fort Worth, Tx. 76102

*** Centronics

FIGURE 1. The Cardiac Assist Profile



FIGURE 2. The TRS-80 Microcomputer

Pulmonary Vascular Resistance

Two useful correlates of myocardial function were generated. The first is known as the myocardial oxygen consumption correlate¹² and is expressed as:

$$MVO_2C = \frac{SP \times HR}{100}$$

The myocardial oxygen consumption correlate, though not a direct measure of oxygen consumption by the heart, does correlate with changes in myocardial work and O₂ consumption although no limits have been established. The final parameter is the pump failure correlate (PFC) developed by Verdouw, et al¹¹ and is an indication of overall ventricular status:

$$PFC = \frac{DP \times MVO_2S}{PCWP} \times 100$$

Cardiac assist profiles were obtained prior to bypass, prior to initiating IABP, and after weaning from IABP. The indications for initiating IABP are shown in Figure 3. In the post-operative period, evaluation of the efficacy of assist was carried out by clinical and hemodynamic assessment. The clinical assessment of augmentation included the patient's overall sense of well being, absence of cold clammy skin and diaphoresis, and the absence of angina. Frequent physical exams were performed to determine the extent of pulmonary congestion and changes in cardiac auscultatory findings. The electrocardiogram, pulse rate and urinary output were noted and an assessment of peripheral blood flow was made (especially distal to the balloon catheter site).

The CAP was obtained every 2 to 4 hours. Pharmacologic support was discontinued or significantly reduced prior to consideration for weaning from IABP.

FIGURE 3. Indications for Initiating IABP.

If patient was on high dose inotropic support and any three of 1 to 4 existed IABP was initiated.

- 1.) Cardiac Index $< 2.0L/min/m^2$
- 2.) Mean Arterial Pressure $< 60mmHg$ and Falling
- 3.) Pulmonary Capillary Wedge Pressure $> 20mmHg$
- 4.) Pump Failure Correlate < 150
- 5.) Patient on High Dose Inotropic Support

FIGURE 3. Indications for Initiating IABP

In general, the patient remained on balloon assist 12 to 24 hours before initiating the weaning process which was indicated by improvement of the cardiac assist profile above the stated minimal, acceptable limits (Figure 3).

Weaning from Intra-Aortic Balloon Assist

Once the decision to wean from circulatory assist had been made based on clinical assessment and evaluation by assist profiles, a weaning schedule was generated by the microcomputer and reviewed by the perfusionist

THE DEPARTMENT OF CIRCULATION TECHNOLOGY CARDIAC ASSIST PROFILE

CARDIAC ASSIST WEAN SCHEDULE

NAME: SMITH JOHN HOSPITAL NO.: 1233211
TOTAL WEAN TIME (HOURS): 6
BALLOON VOLUME REDUCTION TIME: 4.0 HOURS
BALLOON ASSIST RATIO REDUCTION TIME: 2.0 HOURS

VOLUME REDUCTIONS

BALLOON VOLUME	INITIATION TIME
35	1200
30	1300
25	1400
20	1500

ASSIST RATIO REDUCTION

RATIO REDUCTION	INITIATION TIME
1/1	1500
1/2	1600
1/4	1700

FIGURE 4. Cardiac Assist Wean Schedule

TABLE 1
IABP insertion in 24 patients. Group I are survivors and Group II are non-survivors.

Procedure	No. of Patients	Group I (Survivors)		Group II (Non-Survivors)	
		No.	Percent	No.	Percent
CABG	7	6	86	1	14
MVR (±)	3	2	67	1	33
AVR (±)	5	3	60	2	40
LVA (±)	1	1	100	0	0
VSD (±)	2	1	50	1	50
Total	18	13	72%	5	28%

IABP = intraaortic balloon pump, CABG = coronary artery bypass graft, MVR = mitral valve replacement, AVR = aortic valve replacement, LVR = left ventricular aneurysm, VSD = ventricular septal defect, (±) = with or without additional cardiac operation.

and surgeon (Figure 4). This schedule was prepared by entering the patient identification, balloon volume, total assist time, and desired wean initiation time into the computer. The wean duration was 4 hours of wean for every 24 hours of assist and was divided into two major phases. The first phase was a reduction in balloon volume which accounted for 75% of the total wean time (.75Tw). During this period the balloon volume was decreased in increments of 5cc's to 50% of the original volume (.5BV/5). This reduced diastolic augmentation. Afterload reduction was gradually tapered, thus minimizing significant increases in cardiac workload and avoiding acute myocardial strain. By the time 50% of the original balloon volume was reached, augmentation and afterload reduction were minimal, yet the balloon was still partially inflated. This was done to prevent thrombus formation in the static folds of the balloon. It follows that the rate of volume reductions or the time between reductions was proportional to the total wean time (.75Tw) and inversely related to the size of the balloon used (.5BV/5).

$$\begin{aligned} \text{Rate of Volume Reduction} &= \frac{\text{Time}}{\text{Reduction}} \\ &= \frac{\text{Volume Reduction Time}}{\text{No. of Reductions}} = \frac{.75Tw}{.5BV/5} \end{aligned}$$

During the second phase, successive assist ratio reductions in balloon timing were made from every beat, to every other beat, and finally every fourth beat. This phase was directly related to the total assist time and accounts for one quarter of the total wean time.

Before either volume or timing reductions were made, a CAP was obtained and a second profile was obtained 15 to 30 minutes after a change in wean condition. If, by the described parameters, the patient's

cardiac profile indicated the need for continued assist we returned to the previous wean condition and re-evaluated the patient's status. If during minimal assist the hemodynamic state declined below acceptable limits the patient was considered balloon dependent and diastolic augmentation (full assist) was continued for a longer period. Other therapeutic measures were initiated as indicated.

Weaning was considered complete when clinical and hemodynamic assessments indicated maximum improvement in cardiac performance. The balloon catheter was removed after persistence of adequate hemodynamic stability for a trial period with minimal assist. Time of minimal assist was directly related to the period required for full circulatory support.

Results

The types of cardiac operation for the two groups in which IABP was used are shown in Table 1. Seven patients had coronary artery bypass grafting (mean = 4.1 grafts/patient), with 86% survival.

Among 3 patients with mitral valve replacement, 2 had additional cardiac procedures (CABG) and 2 survived (67%). There were 5 aortic valve replacements, all with additional cardiac procedures (4 with CABG and 1 with resection of aneurysm of the ascending aorta), and there were 3 survivors (60%). One patient had left ventricular aneurysmectomy with CABGx3 and survived. One patient had closure of post-infarction ventricular septal defect (VSD) and did not survive. One patient had closure of a post-traumatic VSD and survived. The overall survival rate was 72%.

There was no significant difference ($p > .05$) between time of insertion of IABP and survival between the two

TABLE 2
Time of Insertion of IABP

Time of Insertion	No. of Patients	Group I (Survivors)		Group II (Non-Survivors)	
		No.	Percent	No.	Percent
Pre-Operative	3	2	67%	1	33%
To Terminate CPB	11	8	73%	3	27%
Post-Operative	4	3	75%	1	25%

IABP—intraaortic balloon pump, CPB = cardiopulmonary bypass

groups (Table 2). Three patients were placed on IABP pre-operatively and 2 survived (67%). The majority of the patients (11 of 18, 61%) were placed on the IABP to terminate cardiopulmonary bypass with 8 survivors (73%). Four patients were placed on IABP post-operatively after arrival in the surgical intensive care unit and 3 patients survived (74%).

The duration of IABP for Group I was not significant compared to Group II ($p > .05$) and ranged from 21 to 118 hours (mean $\pm$ 1 SD = 51 ± 31.4 hours). The duration for Group II ranged from 13 to 102 hours (mean $\pm$ 1 SD = 65.8 ± 35.3 hours). In Group II, 4 patients died on IABP and one died after being weaned from IABP.

Demographic data of Group I and Group II for age, crossclamp time and bypass time was analyzed (Table 3). There was no significant difference ($p > .05$) between the two groups for age, crossclamp time or bypass time.

TABLE 3
Patient Demographic Comparisons for Group I and Group II. (Mean $\pm$ 1 S.D.)

Group	Age (Years)	Crossclamp Time (min)	Bypass Time (min)
I	54.7	90.5	175.7
n = 13	± 14.0	± 38.8	± 52.3
II	62.6	118.4	201.6
n = 5	± 8.0	± 22.6	± 88.6
p > .05	N.S.	N.S.	N.S.

Comparison of the cardiac index, mean arterial pressure, pulmonary capillary wedge pressure and pump failure correlate both prior to cardiopulmonary bypass (Table 4) and prior to IABP initiation (Table 5) for Groups I and II showed no significant difference ($p > .05$).

There were no significant differences between the on-IABP cardiac index, mean arterial pressure and pulmonary capillary wedge pressure ($p > .05$) (Table 6). There was a significant difference between Groups I (Survivors) and II (Non-survivors) for the pump failure correlate on IABP at $p = .0001$ (Table 6).

The post-IABP cardiac index, mean arterial pressure, pulmonary capillary wedge pressure and pump failure correlate for Group I is shown in Table 7. A comparison of Group I pre-IABP and on-IABP cardiac index, mean arterial pressure and pump failure correlate revealed a significant increase ($p < .05$) between the pre-IABP and on-IABP values. The decrease in pulmonary wedge pressure was significant at ($p < .05$). The pre-IABP and on-IABP cardiac index, mean arterial pressure, pump failure correlate and pulmonary wedge pressure for Group II was not significant.

Discussion

The initial results of the cardiac assist profile (CAP) as an aid in evaluating and weaning patients on IABP have been encouraging. The hospital survival of 86% in our patients requiring IABP after coronary revascularization is higher than that reported by some

TABLE 4
Prebypass Cardiac index, mean arterial pressure, wedge pressure and pump failure correlate in Groups I and II. (Mean $\pm$ 1 S.D.)

Group	C.I. (L/min/m ²)	MAP (mmHg)	PCWP (mmHg)	PFC
I	2.24	77	16	170
	$\pm .48$	± 15	± 5	± 61
II	1.97	74	17	194
	$\pm .51$	± 14	± 5	± 79
p > .05	N.S.	N.S.	N.S.	N.S.

TABLE 5
Pre-IABP Cardiac index, mean arterial pressure, wedge pressure and pump failure correlate in Groups I and II. (Mean $\pm$ 1 S.D.)

Group	C.I. (L/min/m ²)	MAP (mmHg)	PCWP (mmHg)	PFC
I	1.85 $\pm$.35	75 $\pm$ 10	20 $\pm$ 4	109 $\pm$ 37
II	1.86 $\pm$.32	72 $\pm$ 6	19 $\pm$ 4	101 $\pm$ 21
p > .05	N.S.	N.S.	N.S.	N.S.

TABLE 6
On-IABP cardiac index, mean arterial pressure, wedge pressure and pump failure correlate in Groups I and II. (Mean $\pm$ 1 S.D.)

Group	C.I. (L/min/m ²)	MAP (mmHg)	PCWP (mmHg)	PFC
I	2.63 $\pm$.43	83 $\pm$ 3	17 $\pm$ 4	247 $\pm$ 65
II	2.21 $\pm$.49	73 $\pm$ 12	19 $\pm$ 4	95 $\pm$ 21
p > .05	N.S.	N.S.	N.S.	Significant at p = .0001

TABLE 7
Post-IABP cardiac index, mean arterial pressure, wedge pressure and pump failure correlate in Group I. (Mean $\pm$ 1 S.D.)

Group	C.I. (L/min/m ²)	MAP (mmHg)	PCWP (mmHg)	PFC
I	2.81 $\pm$.46	85 $\pm$ 5	14 $\pm$ 4	278 $\pm$ 75

groups.^{1,2,3,4,5,6,8,10} The survival rates for patients requiring IABP support after valve replacement have been more variable.^{1,2,3,5,7,8} Our results compare well with the higher survival rates as reported by others.^{1,2,3}

The use of the CAP for weaning patients from IABP has proven successful. We were able to wean 14 of the 18 patients (78%) in which the CAP was employed. The one patient who survived weaning from IABP and was included in Group II died several days after weaning with multiple organ system failure. The other 4 patients in Group II could not be weaned from IABP and died on IABP. In this group the use of IABP and drug therapy did not significantly effect cardiac index, mean arterial, pulmonary wedge pressure or the pump failure correlate. The pump failure (PFC) proved to be a valuable indicator of long-term survival in this series. We have found that a PFC of less than 150 is not associated with long-term survival. This was verified by the significant increase in the PFC for Group I after initiation of IABP versus the unchanged values for

Group II. It would be interesting to compare the PFC with the endocardial viability ratio (EVR) developed by Philips and Associates⁹ as a criteria for early utilization of IABP and for predicting long-term survival. In conclusion, we feel that the use of the CAP provides accurate, qualitative evaluation of the therapeutic efficacy of IABP assist as well as decision making regarding the weaning of patients from IABP.

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