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Role of Intra-Aortic Balloon Pump in Off-Pump Coronary Artery Bypass —A Vettath Modification

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Abstract

Objective: Hemodynamic deterioration during positioning of the heart has been the most critical complication of off-pump coronary artery bypass surgery. Pre-operative use of intra-aortic balloon pump has been shown to prevent this complication in high risk patients. The role of balloon pump in high risk patients has been questioned by our group. We modified the role of balloon pump in our patients, thus avoiding the conversion to cardiopulmonary bypass. Methods: 4063 off-pump coronary bypass surgeries were performed by a single surgeon in our center, over thirteen years. 130 intra-aortic balloons used between July 2002 and December 2015 were removed from the theater, once the distal anastomosis was performed. We studied this group of patients for—time and need for insertion, duration of balloon used, local insertion problems and survival. Results: Initially, we inserted intra-aortic balloons in high risk patients. We observed that, patients with low ejection fraction and patients with critical left main coronary artery disease were not the ones who actually needed balloon pump support. It was the patients who had ongoing ischemia, with preserved left ventricular function, and ST depression intra-operatively, who needed balloon pump support to perform complete anatomical revascularization. Conclusions: Intra-aortic balloon pump has helped us to position the heart without hemodynamic instability, thereby avoiding conversion to cardiopulmonary bypass. This enabled us to perform off-pump surgery in virtually all areas of the heart, thus maintaining perfect hemodynamics.

Keywords

Off-Pump Coronary Artery Bypass (OPCAB) Surgery, Intra-Aortic Balloon Pump (IABP)

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1. Introduction

The increase in OPCAB numbers has been aided by technical advances and increased surgical experience but had been limited by the lack of an effective technique for successful grafting of the posterior coronary branches of the left circumflex artery. Use of IABP has been shown to avoid complications in high risk patients, when used preoperatively [1]. To facilitate exposure of these vessels, and to overcome hemodynamic derangement during displacement of the heart, specialized surgical techniques and anesthetic support, such as placement of deep pericardial sutures, patient positioning, pharmacologic manipulation, widely opening the right pleura and sometimes, application of a suction-based cardiac positioning device, have been suggested [2]-[6]. The use of IABP, either preoperative or intraoperative to reduce operative risk and to facilitate posterior vessel grafting, has been well documented [7]. Preoperative IABP counter pulsation has been shown to have better outcomes compared with perioperative or postoperative insertion in critical patients [7]. Also, off-pump surgical procedures have been advocated to reduce mortality in such high-risk patients. In patients with high risk factors, higher mortality and morbidity rates have been demonstrated in spite of massive pharmacologic support combined with postoperative IABP support [7].

IABP therapy results in a more favorable myocardial blood supply, increased stroke volume and cardiac output through augmentation of the diastolic pressure, and after load reduction. Yet intra-operative and postoperative IABP insertion has been disappointing given the associated high mortality rate, as well as the high device-related complication rate [7].

IABP has been indicated in high-risk patients with left main coronary artery disease, intractable resting angina, post infarction angina, left ventricular dysfunction (ejection fraction < 35%), or unstable angina [1]. We previously inserted the IAB in our patients who had any one of these high risk factors. However, we have recently resorted to introduce the IABP only in patients who became hemodynamically unstable during surgery. This was possible, as all our patients had a femoral arterial line *in situ* during induction. The IABP was then used to stabilize the patient during the distal anastomosis alone. After that it was kept on standby mode for the top end anastomosis, and then removed after heparin reversal.

2. Materials and Methods

Between July 2002 and Dec 2015, 4063 patients underwent OPCAB (Dr MPV) (**Table 1**) from our center. Every patient undergoing OPCAB had a femoral arterial line introduced after induction. This was used to monitor arterial pressure as well. We used IABP (Datascope Sensation 7.5 & 8F, 30 & 40 ml balloons; from Datascope Corp, Fairfield, NJ, USA and recently Arrow 7 - 8 F, 30 - 40 ml; Arrow International, Reading, PA, USA) sheathless insertion in all patients. In our earlier experience, when inotropes were being used, IAB was inserted in the OT and surgery was performed and patients were shifted to the ICU with the IAB in place. Eleven patients underwent this routine. They were then removed after 24 - 48 hrs. Those were the days when our conversion rate to CPB was high.

Since 2008 all the patients who had IAB inserted in the theater, had OPCAB performed, and their IAB removed in the OT (**Table 1**). We were initially inclined to introduce IAB in all the patients who fitted into the criteria of being high risk patients. In these patients, after the heparin was given, sheath less IAB was introduced. This was not inflated unless the patient developed hemodynamic compromise, while lifting the heart for grafting of the posterior or lateral wall coronaries. What we noticed was that after grafting the LAD (left anterior descending) artery, most of the patients with critical left main disease and low EF stabilized. Hence it was not necessary to inflate the balloon in the majority of patients (**Table 2**). This table shows that, of the 195 patients who had the IAB inserted, 54 of them did not have the IAB inflated, as they remained hemodynamically stable during the grafting. In fact, these patients had the IAB inserted as they were included in the high risk group as discussed above. As these IAB were not used, they were also removed after the grafting was completed and the heparin reversed. **Table 2** shows that till 2006, 10 patients were shifted to the surgical ICU with the IAB in place. Subsequently, till 2015 we have had only one patient shifted to the surgical ICU with the IAB in place. After 2008, all the patients who had the IAB inserted, has had it removed in OT itself.

In our series, only patients with ongoing ST depression, recent myocardial infarction, tight circumflex stenosis and moderate ischemic mitral regurgitation, developed hemodynamic deterioration had the IAB inflated, and the distal coronary anastomosis performed. Once the heart was placed back in its position, the hemodynamics becomes stable. Then the proximal anastomosis is performed with the IABP on standby mode. Early in our

Table 1. Total No. of off-pump.

From	To	OPCAB	Conversion	IABP removed in OT	Mortality No
01-2003	12-2003	177	12	0	0
01-2004	12-2004	238	6	0	1
01-2005	12-2005	299	0	0	3
01-2006	12-2006	284	0	4	5
01-2007	12-2007	260	1	8	0
01-2008	12-2008	224	0	11	2
01-2009	12-2009	280	0	8	0
01-2010	12-2010	358	0	22	0
01-2011	12-2011	413	0	24	0
01-2012	12-2012	425	0	23	2
01-2013	12-2013	429	0	18	2
01-2014	12-2014	312	0	6	3
01-2015	12-2015	317	0	6	2
Total		4063	19 (0.46%)	130 (3.19%)	20 (0.49%)

Table 2. Statistics of IABP used.

	Total OPCAB	IABP inflated	Inflated removed from OT	Shifted with IABP	Not inflated removed from OT	Total IABP used
07-2002	47	0	0	0	0	0
01-2003	177	1	0	1	0	1
01-2004	238	0	0	0	0	0
01-2005	299	6	0	6	0	6
01-2006	248	7	4	3	3	10
01-2007	260	8	8	0	5	13
01-2008	224	12	11	1	12	24
01-2009	280	8	8	0	5	13
01-2010	358	22	22	0	14	36
01-2011	413	24	24	0	9	33
01-2012	425	23	23	0	2	25
01-2013	429	18	18	0	2	20
01-2014	312	6	6	0	2	8
01-2015	317	6	6	0	0	6
Total	4063	141	130	11	54	195

series, we were inclined to restart the IABP after the proximal anastomosis. But we noticed that all these patients in fact stabilized after the proximal anastomosis was completed. We then introduced another femoral arterial line in the other groin and then removed the IAB, after five minutes of reversing the heparin. This is now our routine. The femoral arterial line was then introduced to the other groin, so as to gain emergency access to femoral artery in case the patient needed it in the surgical ICU.

We used Chi square test only for the association of categorical variables. P value < than 0.05 was considered statistically significant.

3. Results

We have audited all the patients who had the IABP used between July 2002-Dec 2015. In our 4063 OPCAB patients, we have used and removed IAB from OT in 130 patients. Though it was inserted in 195 patients, it was not inflated in 54 patients (**Table 2**). We used IABP in all these patients before starting any inotropes, and that prevented our conversion to CPB. Except in the initial stages of our work, we were able to remove all the IAB's inserted in our patients since 2008, in the OT itself. We were able to remove the IAB in all these patients and shift them to the ICU, without inotropes and without IAB (**Table 2**). Thus far we have not had to re-introduce the IAB in any of these patients.

The duration of the IABP in these patients in the OT are outlined in (**Table 3(a)**). We noticed that the use of IABP was primarily in patients with triple vessel disease (3.5%) and that too in patients with tight circumflex lesion. Though we had inserted IAB in most of the patients with critical left main stenosis, we noticed that, out of the 504 left main patients that were operated on, only 14 (2.7%) patients actually needed IABP to perform their distal anastomosis. Though we had inserted IABP in 46 left main patients with critical stenosis, only 14 were used. This reinforced our belief that it is not the anatomic position of the lesion, but the hemodynamic change that forced us to use the IABP (**Table 3(b)**). That is, only 2.7% of LMCA patients actually needed IABP to perform OPCAB.

Another fact was that, though we had inserted IAB in mostly all patients with low EF (less than 35%), in the initial stages, we had to inflate them only in very few patients. In patients with low EF, only 2.6% of patients had the IAB used and in patients with normal EF, we had 3.4% of patients getting an IAB inserted. That was to infer that, it was not the ventricular function that decided on the use of IAB, but the ischemia that pushed us to use the IAB (**Table 3(c)**).

We have published our results of OPCAB regarding how we were able to avoid conversions to CPB after we had started liberally using the IABP (**Table 1**). It was noticed that in the first three years of our experience, our conversion on to CPB was high. But later on with the liberal use of IABP, our conversion to CPB decreased. Since 2005, we have had only one conversion to CPB till Dec 2015.

We audited our 4063 OPCAB patients by dividing them into two groups. First group was patients operated upto Dec 2006 (1045 patients) and the second group were patients since January 2007 till Dec 2015—3018 patients (**Table 4**). We noticed that our learning curve of OPCAB extended beyond the first 500 patients, where we had not yet standardized our techniques. We were still using inotropes for the first 1045 patients, but once we started using injection Atropine to increase the heart rate, then we noticed that it was easy to stabilize the heart during positioning, or by using the deep pericardial stitch. Earlier, we were using the IABP only after the inotropes were used, which made the patient more ischemic, and the need to continue the IABP postoperatively into the ICU. But when the IABP was used as the first resort to avoid conversion to the pump and the inotropes were not used, we found that patients stabilized very well. We were able to avoid conversions to CPB and also were able to remove the IAB in OT itself. With this modification, we have been able to perform OPCAB in nearly hundred percent of patients who come to our center to undergo CABG. We have been able to decrease our perioperative mortality rate, rate of myocardial infarction, rate of renal dysfunction etc., as shown in the **Table 4**, which shows a significant P value in all the parameters audited, except in Stroke rate and the mortality rate.

In patients with peripheral vascular disease, we have performed antegrade insertion of IAB in two patients, and were able to perform complete arterial revascularization without clamping the aorta. With the technique of sheath less insertion of IABP we were able to avoid the peripheral vascular complication of the use of IABP.

One patient developed loss of pulsation in his dorsalis pedis artery after removal of IAB in the OT itself. His femoral artery was explored and an embolectomy was done and a vein patch was used to close the arteriotomy site.

Table 3. Statistics of IABP inserted and removed from OT from June 2002 to Dec 2015.

(a)

Total No 184	10 - 15 Min	16 - 30 Min	31 - 45 Min	46 - 60 Min	>60 Min	Total
IABP inflated and removed from OT	12	54	46	12	6	130
IABP not inflated & removed from OT	54					

(b)

Role of IABP in OPCAB			
SVD	0	0	130
DVD	5	11 (1.8%)	130
TVD	49	119 (3.5%)	3358
LMCA > 75%	46	14 (2.7%)	504
Total	54	130	4063

(c)

Role of IABP in low EF			
EF	IABP not inflated	IABP inflated	Total OPCABS
<35	36	29 (2.6%)	1103
>35	18	101 (3.4%)	2960
Total	54	130 (3.19%)	4063

Table 4. Role of IABP in OPCAB-audit.

	July 2002-Dec 2006 —1045 Patients	Jan 2007-Dec 2015 —3018 Patients	P-value	
CONVERSION	1.8%	0.03%	<0.001	Significant
INOTROPIC USE	75%	2%	<0.001	Significant
RENAL FAILURE	3%	0.3%	0.001	Significant
PERI OP MI	1%	0.2%	0.002	Significant
STROKE	0.4%	0.2%	0.292	Not Significant
MORTALITY	0.76%	0.36%	0.115	Not Significant
IABP	4 (0.3%)	126 (1.7%)	<0.001	Significant

We have had two patients who had to be taken back for ventricular arrhythmia, in early days, post operatively and had to have IABP inserted and re-opened (**Table 5**). They were not the ones who had IABP inserted before. They had graft occlusion post operatively and had developed post-operative MI (Myocardial infarction).

We followed up all the patients who had IAB inserted during OPCAB, for survival after surgery. **Table 6** shows the cause of death in these patients, the time duration after surgery and the place of death in all these patients.

The other advantage we noticed in this technique is that; in a single surgeon center like ours, where we are able to remove the IAB in the OT itself, then we could still go on with the second surgery, when only one IABP was available as a standby.

Table 5. Last conversion from OFF PUMP to ON PUMP details.

Date	PT name	Age	Diagnosis	Surgery	Remarks
26-07-04	Mr. MK	67/M	CAD/TVD/HTN/DM EF 30%	CABGX 4	Quick primimg/CPB/spontaneous pick up
30-07-07	Mr. AK	55/M	CAD/TVD EF 60%	CABGX 4	Intractable vt/vf patient crashed/IABP supported quick priming-CPB/spontaneous pick up/IABP removed in OT

Table 6. Role of IABP-patients who died after having IABP used during OPCAB surgery.

SLNO	MIMS NO	SEX	AGE	DOS	DOD	Cause	Survival	Remarks	Surgery
1	188159	M	47	06.05.05	20/06/11	Heart Attack	6.5 yrs	Outside	OPCABX01
2	198240	M	59	09.07.05	24/05/10	Cardiac Arrest	5 yrs	Post Op In Hospital Death	OPCABX03
3	12835	M	77	07.03.06	11/03/06	Met Encephalopathy	4 days	In Hospital	REDO OPCABX02
4	172533	F	60	24.07.08	22/09/10	Heart Attack	2 yrs	Outside	OPCABX02
5	529251	M	46	28.06.10	05/02/11	Heart Attack	7 mths	Outside	OPCABX03
6	621391	M	51	23.06.11	07/07/11	Cardiac Arrest	14 days	In Hospital	OPCABX01
7	733639	M	63	08/09/12	28/09/13	Pulmonary Oedema	1 yr 20 days	Post Op In Hospital Death	OPCABX03

4. Discussion

The surgical results of coronary artery bypass grafting (CABG) without cardiopulmonary bypass or OPCAB have demonstrated several advantages by avoiding the potentially detrimental effects of cardiopulmonary bypass and eliminating intraoperative global myocardial ischemia [8]-[11]. In spite of many studies and results, less than fifteen percent of centers in the world are now performing OPCAB routinely. In India, over the last fifteen years, only centers who could deliver good results in terms of patency have continued this technique.

In our pursuit to perform all the coronary bypass surgeries without the use of CPB, we started using IABP early in our experience. This has helped us not only in avoiding CPB, but also in avoiding inotropes in most of our patients.

IABP has been shown to provide a reduction in the ventricular after load, improvement in diastolic coronary perfusion, and enhancement of subendocardial perfusion [12]-[14]. In early days, the indications for preoperative IABP implantation were very restrictive because of the potential detrimental effects associated with the use of the device. The optimal timing for insertion of the IABP pre-operatively was well demonstrated by Christenson *et al.* in the era of on pump CABG. In those days, a 24-hour preoperative period of IABP treatment was found to result in a better postoperative cardiac index than shorter treatment of 1 to 2 hours of preoperative IABP support, with no impact on hospital mortality or postoperative morbidity. But in the present scenario of sicker, older, and patients with co-morbidities, it is important to use the IABP only when absolutely necessary. Postoperative IABP insertion has been disappointing owing to an associated high mortality rate and a high device-related complication rate. Avoiding high inotropic support in these patients could prevent visceral and peripheral malperfusion, which occurs due to peripheral and visceral vasoconstriction. Hemodynamic compromise occurs more often in high-risk patients [15].

We have not used preoperative IABP therapy, except when patient had to be wheeled into OT with an IABP *in situ*. We noticed that the actual high risk patients were the patients with good left ventricular function but, with ongoing ischemia and not the patients with low EF or even with critical left main stenosis. Christenson *et al.* [16] presented a prospective randomized study to evaluate the efficacy and safety of preoperative and perioperative IABP in high-risk OPCAB surgery. They concluded that pre- and perioperative IABP offered efficient he-

modynamic support during high-risk OPCAB and was safe and shortened both intensive care unit and hospital length of stay [16]. Our experience with intraoperative IABP use and its removal after use has been different from theirs.

We did not inflate the IAB in any high risk patients unless they developed hemodynamic compromise. And we did not use inotrope as the first line of support. IABP was the first line of support, when hemodynamic compromise was noticed while the heart was lifted.

Vascular complications associated with use of IABP are not uncommon. Other major complications associated with the use of IABP include aortic dissection, paraplegia, bacteremia, mesenteric infarction, balloon rupture, and balloon entrapment [17] [18].

In our series of OPCAB procedures over the last thirteen years, we were able to prospectively monitor and study each of our patients in detail, so as to avoid the earlier mentioned complications. As a dedicated center for OPCAB surgery we were keen on performing all our CABGs off-pump, and in our drive to attain that goal, we have re-engineered the technique of OPCAB [19]. We have always used sheathless insertion of IABP, and have monitored the lower limb intra- and post-operatively to avoid the vascular complication of the device as well.

Recently, Mannacio *et al.* [20] have shown that two hours of preoperative IABP treatment improved cardiac performance, reduced inotropic requirements, and shortened ICU and hospital length of stay significantly. Preoperative insertion of IABP was safe and not associated with postoperative significant complications regardless of the counter pulsation time. Our technique of shortening the time of use of IABP has helped the patients in this regard.

We have modified the role of IABP in OPCAB to include: using a femoral arterial line in all patients undergoing OPCAB in our center; using IABP when absolutely necessary intra-operatively; being able to remove them after the surgery is over, in all our patients; and finally by redefining the group of high risk patients. Hence, our present approach is to perform surgery with an open mind; given that, any patient could be a potential candidate for an IABP. When hemodynamic compromise occurs during the positioning of the heart, then, instead of starting inotropes, IABP should be used to stabilize the heart during the distal anastomosis. With these modifications, we were able to perform OPCAB safely in all patients who needed CABG, thereby reducing our mortality and postoperative complication rate.

The limitation in this study was that it was more of an audit of our off-pump work which we had been doing for the past thirteen years.

Conflict of Interest

None declared.

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