MEDWIN PUBLISHERS
Committed to create value for Researchers

Open Access Journal of Cardiology
ISSN: 2578-4633

Intra-Aortic Balloon Counterpulsation after Primary and Redo Mitral and/or Aortic Valve Replacements in Rheumatic Heart Disease: Results and Guidelines for Candidate Selection

Chowdhury UK [1]*, George N[1], Sankhyan LK[1], Malik V[2], Chauhan A[1], Gudala V[1], Hasija S[2] and Kalaivani M[3]

[1]Departments of Cardiothoracic and Vascular Surgery, All India Institute of Medical Sciences, India

[2]Cardiac Anaesthesia, All India Institute of Medical Sciences, India

[3]Biostatistics, All India Institute of Medical Sciences, India

Research Article

Volume 3 Issue 1

Received Date: April 09, 2019

Published Date: May 22, 2019

DOI: 10.23880/oajc-16000140

***Corresponding author:** Ujjwal Kumar Chowdhury, M.Ch, Diplomate NB, Professor, Department of Cardio-thoracic and Vascular Surgery, All India Institute of Medical Sciences, New Delhi-110029, India, Tel: 91-11-26588700; Email: ujjwalchow@rediffmail.com

Abstract

Objective: The relationship between the timing of intra-aortic balloon counterpulsation (IABC) and surgical outcome in high-risk patients undergoing valve replacements remain debatable. Perioperative IABC is commenced either prophylactically or after increasing inotropic support has proved inadequate. This study evaluates the effect timings of IABC support on the in-hospital mortality in patients undergoing valve replacements.

Methods: One hundred and twenty high-risk patients aged between 22-72 years (mean±SD: 49.68±22.6) undergoing mitral and/or aortic valve replacements requiring IABC between 1998 and 2018 were studied. Thirty-five (29.1%) patients were hemodynamically compromised and required preoperative IAB support (group I), 48 (40%) patients required intraoperative IAB support (group II), and 37 (30.8%) patients required postoperative IAB support. The independent predictors of operative mortality were determined by means of stepwise logistic regression analysis.

Results: The overall operative mortality was 19.1%. Mortality was 5.7% in group I, 18.7% in group II and 32.4% in group III. The independent predictors of operative mortality were (odds ratio in parentheses) urgency of operation (4.66), low body mass index (4.15), New York Heart Association (NYHA) class IV (2.82), renal failure requiring dialysis (3.44), preoperative ventilation (3.68), left ventricular ejection fraction <30% (3.15), previous cardiac surgery (3.83) and postoperative institution of IABC (5.88).

Conclusion: Patients who warrant IABC in the postoperative setting have a significantly increased operative mortality when compared to any other group. Therefore, earlier IAB support in patients with advanced functional class (NYHA-IV), requiring increasing inotropes on ventilator with metabolic/lactic acidosis, in acute pulmonary edema and oliguria/anuria as part of surgical strategy may help to improve outcome.

Keywords: Rheumatic Heart Disease; Intra-aortic Balloon Counterpulsation; Operative Mortality; Low Cardiac Output Syndrome; Mitral Valve Replacement; Aortic Valve Replacement

Abbreviations: IABC: Intra-Aortic Balloon Counterpulsation; CABG: Coronary Artery Bypass Grafting; LCOS: Low Cardiac Output Syndrome; LVEF: Left Ventricular Ejection Fraction; CTR: Cardiothoracic Ratio; NYHA: New York Heart Association; CPB: Cardiopulmonary Bypass; PT: Prothrombin Time; INR: International Normalized Ratio; 2D: Two-Dimensional; CCF: Congestive Cardiac Failure; PAH: Pulmonary Arterial Hypertension; BMI: Body Mass Index.

Introduction

"Published literature has confirmed the therapeutic efficacy of intra-aortic balloon counterpulsation (IABC) after coronary artery bypass grafting (CABG) in certain subset of patients, but the conclusive proof of therapeutic benefit in patients after valve replacement has not been demonstrated. IABC may not be as helpful as is currently believed in patients undergoing valve replacement, and its use in this context should be further assessed"-so wrote Craig Miller and colleagues, the Stanford group in 1986 in a classic treatise that promulgated the concept of IABC in postoperative valve replacements [1].

Despite aggressive preoperative medical management, advances in cardiac anaesthesia, perioperative critical care, hemodynamic monitoring, chordal preservation strategies and improved protocol of myocardial preservation, the immediate and long-term results of a subset of patients undergoing mitral and/or aortic valve replacement are disappointing because of refractory low cardiac output syndrome (LCOS) following surgery [1-11].

The risk factors of LCOS in CABG patients (such as incomplete revascularization) may not be relevant in patients undergoing primary or redo mitral and/or aortic valve replacements. Left ventricular hypertrophy and/or dilatation, pulmonary hypertension induced right ventricular hypertrophy and/or dilatation may have important deleterious effect on postoperative myocardial function. Additionally, the impact of poor preoperative left ventricular function may be more pronounced in patients with mitral and aortic regurgitant lesions than those of stenotic lesions [12-19].

Although the therapeutic efficacy of balloon counterpulsation after CABG and ventricular aneurysmectomy has been confirmed, the conclusive proof of therapeutic benefit in patients after valve replacement has not been demonstrated. Furthermore, controversy exists as to the optimal timing of intra-aortic balloon insertion, with difficulty in predicting patients who will require an IABC and who can be managed without one [12-19].

From these observations, it has been hypothesized that prophylactic preoperative institution of IABC prior to escalating the dose of inotropes, might be beneficial in these high-risk patients undergoing primary or redo valvular heart surgeries. To investigate this hypothesis, this study aimed first to compare the outcome of preoperative IABC use in high-risk patients undergoing valve replacements with patients receiving intraoperative or postoperative IABCs, second to analyse the short- and long-term outcome of patients who received an IABC in the pre, intra- and postoperative period and third to determine the possible prognostic factors for early and late death.

Central Message

Preoperative institution of IABC in high-risk patients undergoing mitral and/or aortic valve replacements provides hemodynamic stability during induction on bypass provides pulsatile flow and minimizes inotropic requirement to maintain viability of end-organs.

Perspective Statement

The prohibitively high mortality in the postoperative group requiring IABC suggests revision of our selection criteria in the pre- or intraoperative period in high-risk patients requiring valve replacements.

Patients and Methods

Criteria for Decision-Making and Selection of Patients

This single-centre retrospective cohort study evaluated outcomes after institution of IABC in a consecutive series of high-risk patients undergoing either primary or redo mitral and/or aortic valve replacements with or without tricuspid valve reconstructive surgery. In the initial study period, the decision for IABC insertion was made in patients undergoing valve replacement(s) who are hemodynamically compromised despite therapeutic inotropic support either to get weaned from CPB or in the postoperative period for intractable low cardiac output syndrome (LCOS). Subsequently, we extended its usage prophylactically in the preoperative period in patients with borderline hemodynamics, on inotropic support and/or on ventilator with a high estimated preoperative risk i.e. poor left ventricular ejection fraction (LVEF) <0.30 and a large cardiothoracic ratio (CTR) >0.7.

Patient Characteristics, Operations Performed and Indications for Intra-Aortic Balloon Counterpulsation

To test our postulates, we embarked on a program of institution of intra-aortic balloon counterpulsation in selected high-risk patients undergoing primary or redo mitral and/or aortic valve replacements in our institution. This study conforms to the principles outlined in the declaration of Helsinki. Between January 1998 and June 2018, 120 consecutive patients (70 males), aged 22-72 years (mean= 49.68+22.6 years) underwent primary or redo mitral and/or aortic valvular replacements using the surgical techniques described after obtaining informed consent and institutional ethics committee approval. All operations were performed by a single surgeon (corresponding author), which ensured uniformity in the surgical protocol.

The decision to place an IABC pre, intra-or postoperatively was at the discretion of the operating surgeon. Common indications were inability or difficulty to separate from bypass and intractable low cardiac output syndrome despite optimal inotropic support.

Data for 120 consecutive high-risk patients undergoing primary or redo mitral and/or aortic valvular replacements between January 1998 and June 2018 at All India Institute of Medical Sciences, New Delhi, India, requiring a short-term IABC support perioperatively were identified retrospectively and grouped into one of the three categories as follows:

Group I: Preoperative IABC for emergent, high-risk urgent or elective cases (n=35). High-risk was defined as patients in NYHA class IV/V, having a cardiothoracic ratio >0.75 with severe left/biventricular dysfunction in low cardiac output syndrome (LCOS) in the preoperative period requiring increasing inotropes, on ventilator, with metabolic/lactic acidosis, in acute pulmonary edema, oliguria/anuria (<0.5ml/kg/hr >2 hr consecutively). The preoperative group included patients who had an IABC placed before surgical skin incision (n=35). Preoperative IABCs were usually placed in the pre-theatre settings (cardiac cath lab, in hospital transfer or intensive care). The emergency cases requiring IABC was defined as operation within 12 hours of referral to avoid death from cardiogenic shock and are included in this group.

Group II: The intraoperative group included patients in whom IABC was placed after skin incision but before leaving the operating room either due to CPB weaning problems or other intraoperative issues, like:
a) Low resistance state,
b) Left ventricular dysfunction,
c) Right ventricular dysfunction,
d) Electrocardiographic ischemic changes,
e) Complex ventricular ectopy,
f) Rhythm disturbances and
g) Atrial conduction abnormality.
Intraoperatively, the IABC was inserted either as an emergency measure for hemodynamic instability, off CPB before chest closure or off CPB after chest closure (n=48).

Group III: The postoperative group included patients who received an IABC after leaving the operating room of the primary operation in the intensive care due to intractable LCOS requiring increasing dosage and/or multiple inotropes in the absence of significant residual surgical lesions and mechanical external compression (n=37).

Out of 120 patients, 35 patients underwent primary MVR: mechanical (n=17), bioprosthesis (n=18), 19 patients underwent primary AVR: mechanical (n=12), bioprosthesis (n=7), and 47 patients underwent primary mitral and aortic valve replacements: mechanical (n=29), bioprosthesis (n=18). Nineteen patients underwent redo prosthetic valve replacements using St. Jude Medical mechanical prosthesis (failed mitral valve repair, n=4; degenerated aortic bioprostheses, n=5, degenerated mitral bioprosthesis, n=10).

The indications for use of bioprosthesis in these patients were: i) patients coming from remote rural areas where routine follow-up and anticoagulation monitoring is practically difficult, ii) young women desirous of pregnancy, iii) contraindications to the use of anticoagulation, iv) patients undergoing redo mitral valve surgery due to previous mechanical valve dysfunction/thrombosis, and v) patient's choice because of lifestyle considerations.

Intraoperative Data

Details of operative procedures are listed in Table 1. Seventy-seven (64.2%) patients in the study group received a mechanical prosthesis and 43 (35.8%) patients received a bioprosthesis. Nineteen (15.8%) patients required aortic root enlargement using Nicks procedure. There were no differences with regard to prosthetic valve size among the three groups. The aortic cross-clamp time and cardiopulmonary bypass time were uniform among 3 groups of patients.

Characteristics	Number (%)
	22-72 years
	Mean±SD (49.68±22.6 years)
Gender	
- Male	70 (58.3%)
- Female	50 (41.7%)
Body surface area	
- <1.7m2	37 (30.8%)
- >1.7m2	83 (69.2%)
Diabetes	
- Present	21 (17.5%)
- Absent	99 (82.5%)
Hypertension (>140 mmHg)	
- Present	27 (22.5%)
- Absent	93 (77.5%)
Renal failure (dialysis dependency)	
- Yes	29 (24.2%)
- No	91 (75.8%)
Preoperative New York Heart Association class IV	82 (68.3%)
Preoperative New York Heart Association class III	38 (31.7%)
Preoperative use of inotropies	
- Yes	57 (47.5%)
- No	63 (52.5%)
Preoperatively on ventilator	
- Yes	27 (22.5%)
- No	93 (77.5)
Preoperative congestive heart failure	
- Yes	82 (68.3%)
- No	38 (31.7%)
Previous cardiac operation	
- Yes	19 (15.8%)
- No	101 (84.2%)
Acuity of presentation	
- Emergent / urgent	53 (44.2%)
- Elective	67 (55.8%)
Composite urgency of surgery	
- Yes	53 (44.2%)
- No	67 (55.8%)

Concomitant coronary artery bypass grafting	
- Yes	2 (1.6%)
- No	118 (98.4%)
Valve type	
- Mechanical prosthesis	77 (64.2%)
- Bio prosthesis	43 (35.8%)
Aortic cross-clamp time	
- >80 min	57 (47.5%)
- <80 min	63 (52.5%)
Mean cardiopulmonary bypass time (min.)	105.28±38.52
Mean aortic cross clamp time (min.)	58.16±22.46
Preoperative rhythm	
- Sinus	20 (16.6%)
- Supraventricular	92 (76.6%)
- Ventricular	8 (6.6%)
Atrial fibrillation	
- Preoperative	92 (76.6%)
- Postoperative	49 (53.2%)
Timing of intra-aortic balloon counterpulsation insertion	
- Preoperative	35 (29.2%)
- Intraoperative	48 (40%)
- Postoperative	37 (30.8%)
Type of operations	
Mitral valve replacement - high-risk	
- Yes	47 (90.4%)
- No	5 (9.6%)
Aortic valve replacement - high-risk	
- Yes	19 (90.5%)
- No	2 (9.5%)
Aortic and mitral valve replacement - high-risk	
- Yes	40 (85.1%)
- No	7 (14.9%)

Table 1: Clinical characteristics of the study population (n=120).

Surgical Technique

All operations were performed by single surgeon; standard cardiopulmonary bypass (CPB) was established using membrane oxygenator and moderate hypothermia (28°C to 32°C). Antegrade cold blood hyperkalemic cardioplegia [St.Thomas II solution (1:4)] was used in all patients for myocardial protection along with topical cooling. After debriding the valve annulus, the prosthesis was secured using interrupted sutures of 2-0 coated braided polyester suture (M/s Covidien, Santo Domingo, Dominican Republic, USA) reinforced with polytetrafluroethylene pledgets in mitral position. Sutures were carefully placed from above and through the annulus so that the valve annulus would be everted when the sutures were tied, thus inserting the prosthesis in an intra-annular position. MVR was performed with the valve placed in the anti-anatomic position and AVR with one of the pivot guards positioned against the ventricular septum and the other between the left coronary and non-coronary cusps. The mitral subvalvular apparatus was left intact to the maximum extent possible and partial or subtotal chordal preservation was done as deemed appropriate. Valve sizes for the 3 groups undergoing primary valve replacements (group I, group II, group III) ranged from 21 to 33 mm.

The St. Jude (St. Jude Medical Inc., St. Paul, MN) mechanical prosthesis was used in all patients undergoing

primary operation and a Medtronic open PivotTM AP 360° apex and AP, Medtronic Inc, Mx, USA, prosthesis was used in patients undergoing redo operations. The mean aortic cross-clamp time was 58.16± 22.46 minutes and the CPB time was 105.28± 38.52 minutes.

Mitral Valve Replacement

The mitral valve was analysed intraoperatively in a systematic manner to allow the optimal techniques to be chosen .The subvalvular apparatus was preserved using the technique described by Miki and colleagues [20]. The technical details of mitral valvular total and posterior chordal preservation, annular decalcification and reconstruction have already been mentioned in our earlier publication [9].

Extensive scarring, shortening, and thickening of the chordopapillary apparatus precluded the use of artificial Gore-Tex sutures (WL Gore and Associates, Flagstaff, AZ) to resuspend the remnant papillary muscle base to the mitral annulus. The left atrial appendage was routinely ligated. No surgical procedure was performed for atrial fibrillation.

Aortic Valve Replacement

The leaflets of the aortic valve were excised to the level of the annulus and the annulus was thoroughly debrided of any calcium, if present. Calcification was dealt with by excision of the calcified segment, shaving off the calcified leaflet margin, squeezing or milking out the calcific debris from the annulus. Aortic valve was replaced using St. Jude mechanical prosthesis placing the pivot guard perpendicular to the non-coronary cusp. Nineteen (15.8%) patients with a small aortic root underwent enlargement of the aortic root using Nicks procedure which allowed insertion of a 2-3 mm larger mechanical prosthesis.

Reoperations

All patients undergoing redo prosthetic valve replacement for failed mitral valve repair (n=4), degenerated aortic bioprostheses (n=5) and degenerated mitral bioprostheses (n=10) were subjected to a uniform surgical protocol standardized by the corresponding author. The redo operations were performed under moderately hypothermic cardiopulmonary bypass through femoral arterial cannulation (Medtronic Bio-Medicus Percutaneous Arterial Femoral, Medtronic Inc., Minneapolis, MN, USA) and bicaval venous cannulation through the femoral vein (Medtronic Bio-Medicus Percutaneous Venous Femoral) and superior vena cava. Redo sternotomy was performed under cardiopulmonary bypass in all these patients (n=19). Intermittent antegrade cold blood hyperkalemic cardioplegia was used in all patients for myocardial preservation. A mechanical heart valve [(Medtronic Open PivotTM AP360° Apex and AP, Medtronic Inc., Mx, USA); mitral: size 24mm, 6 patients; 26 mm, 8 patients; aortic: size 20mm] was used in patients undergoing redo operations.

Intra-aortic Balloon Pumps

The IABC catheter used was an 8F 40-mL sheathed Profile IABC catheter (Datascope, Oakland, NJ) connected to a Datascope portable computerized console (Datascope). Percutaneous femoral artery insertion was employed in all cases, except for 4 patients in group C who required surgical cut down to cannulate the femoral artery. Preoperative IABC insertion was performed under echocardiographic and/or radiological control using an image intensifier (without intravascular contrast material) in all cases.

IABP Related Morbidity

Major IABP-related complications were defined as aortic perforation, dissection or ischemia requiring a vascular operation, and fasciotomy or amputation. Minor complications included ipsilateral transient limb ischemia, which recovered after removal of the IABP, and local infection of bleeding at the site of insertion. Three (2.5%) patients in this series developed ipsilateral transient limb ischemia. One patient required fasciotomy.

Follow-up

Patients were followed up in the outpatient department as well as through telephone and mail. All valve-related complications were identified according to the guidelines for reporting morbidity and mortality after cardiac valve operations [21]. Apart from preoperative investigation each patient was followed up with cinefluroscopy before discharge, within first three months then at least at 6-months interval. Regular PT/INR was measured in every 3-monthly follow- up. People coming from far areas were asked to get their PT/INR checked every 3 monthly and to come for follow-up every 6 months. They were asked to report immediately if any complications occurred.

Postoperative Studies

These included three-monthly clinical examinations, electrocardiograms, chest radiographs, cinefluoroscopy,

and echocardiography. The functional class at follow-up was noted. Results were reported according to prescribed criteria [21,22]. At each visit, a short history was taken and patients were asked about thromboembolic or bleeding complications, other diseases, and hospital admissions. Prothrombin time (PT) was measured and the results were expressed in terms of the international normalized ratio (INR). All patients received warfarin and aspirin (100 mg/day) for anticoagulation to maintain INR between 2.5 to 3.5. The warfarin dose was regulated by the surgical team while the patient is in the hospital and by the referring physician after the patient was discharged.

Echocardiographic Studies and Measurements

Transthoracic two-dimensional (2D), color flow and Doppler echocardiography was performed using a Hewlett-Packard-Sonos-5500 with 2.7 or 3.5 MHz transducer. Prosthetic valve function was assessed on 2D apical four-chamber view, and M-mode parasternal long-axis view [23]. Preoperative studies were performed within 7 days before surgery. Postoperatively, all survivors were followed echocardiographically at the time of follow-up.

Selection of Variables for Analysis

In order to compare quantitatively the relative importance of preoperative patient characteristics in risk factor analysis, variables were simplified as much as possible and except for number of comorbidities, were dichotomized so that each could be evaluated as a single degree of freedom. Decisions in this process were made before the analysis began and were influenced by perceived clinical relevance and the results of similar clinical research.

The following preoperative factors were evaluated as potential predictors of in-hospital mortality following IABC in valve replacement: age, gender (female vs male), body mass index, diabetes, hypertension, renal failure requiring peritoneal dialysis or hemodialysis, NYHA functional class, preoperative congestive cardiac failure (CCF), preoperative cerebrovascular accidents, valve lesion (stenotic, regurgitant or mixed as determined by echocardiography), number of previous reoperative procedures, previous procedure type, current procedure type and preoperative use of IABC, LV grade [based on LVEF: grade I, normal >70%; grade II, mildly impaired 50-69%, grade III moderately impaired 30-49%; grade IV, severely impaired <30%, presence and number of comorbidities. Urgency of operation: elective: any patient who was at home before the operation or was receiving medical treatment in the hospital but did not require surgical intervention within 24 hours of a surgical consultation; urgent, indicating an operation within 24 hours to prevent further clinical deterioration or emergent, indicating an operation within 12 hours of an event e.g. following balloon valvuloplasty, in cardiogenic shock, acute pulmonary edema or acute renal failure.

Previous or current procedure type was categorized as follows: i) isolated mitral valve operation without severe pulmonary arterial hypertension (PAH), ii) isolated MVR with severe PAH, iii) isolated AVR with increased operative risk, iv) isolated AVR with low risk, and v) combined AVR and MVR. Presence and number of comorbidities (range 0-10), multiple valve procedures (>2 valves operated).

Additionally, 4 clinical factors reflecting preoperative instability were combined into a composite urgency variable to avoid collinearity between preoperative variables. The composite urgency variable was defined as one or more of the following: acute left ventricular failure causing cardiogenic shock, in acute pulmonary edema, renal decompensation, on ventilator, urgent or emergent operation, failed thrombolysis or prosthetic valve thrombosis causing acute cardiac decompensation. This composite urgency variable served as an index to denote the highest risk patients among the group of patients receiving valve replacements and IABC. Composite urgency variable (active endocarditis, acute rupture mitral leaflet, acute rupture bioprosthetic mitral leaflet, acute rupture bioprosthetic aortic leaflet, urgent/or emergent intervention or preoperative IABC).

Study Outcomes

The primary outcome measure in this study was in-hospital mortality after valve replacement. Data were obtained from the Institutional Registry, which is a prospectively collected clinical database that contains demographic data, comorbidities, intraoperative variables and postoperative outcomes of all patients undergoing MVR, AVR, MVR+AVR requiring IABC in the perioperative period. The database was used to select all patients meeting the inclusion criteria described earlier. The criteria for low cardiac output syndrome and perioperative myocardial infarction and arrhythmias have been defined under definitions (see under Definitions).

Statistical Analysis

Statistical analysis was performed using intercooled STATA 14.0 software (College Station, Texas, USA). Interval related data were expressed as mean±standard deviation or median (minimum-maximum) and categorical variables were expressed as percentages and were analyzed by $\chi 2$ or Fisher's exact test. All variables were defined in compliance with the guidelines established by the American Association for Thoracic Surgery and the Society of Thoracic Surgeons [22,23]. The clinical characteristics of patients who survived and died were examined univariately. Candidate variables for multivariate analysis were selected on the basis of clinical relevance or significance of univariate association with p less than 0.2. Multicollinearity was assessed using linear regression analysis, where a variance inflation factor greater than 4.0 indicated potential inter-correlation among variables. If multicollinearity existed, correlated variables were either combined into a single variable, or 1 variable from a set of correlated variables was selected for the multivariate analysis. To predict in-hospital mortality, a parsimonious logistic regression model was developed by backward selection, and variables were retained if the final p value was less than 0.05.

Mortality rates were calculated depending on the total number of years of follow-up for each patient. Actuarial estimates were calculated using the Kaplan-Meier technique and the log-rank test was performed to analyze statistically the difference of survival among the three groups. The results were expressed as probability of survival (95% CI) at various time intervals. Valve related events were reported as per the standard published criteria [21]. Statistical significance was set at $p<0.05$.

Results

Early Results

There were 23 early deaths (19.1%) due to low cardiac output syndrome (n=19) and malignant ventricular arrhythmias (n=4). Overall mortality in the total group of 120 cases were 19.1% (n=23). Mortality was 5.7% (n=2) in group I, 18.7% (n=9) in group II, and 32.4% (n=12) in group III. The causes of hospital death were LCOS (n=17), malignant ventricular arrhythmias (n=4) and severe sepsis (n=2).

Late Outcomes

There were 5 (5.1%) late deaths (group I, n=1; group II, n=2; group III, n=2) due to ventricular arrhythmias (n=2), anticoagulation related haemorrhage (n=1), congestive heart failure (n=2). Six patients had prosthetic valve thrombosis. One of these developed major cerebrovascular accident after streptokinase administration and subsequently died. Five patients had successful thrombolysis.

Thromboembolic Complications

Five patients had thromboembolic complications. Three recovered with residual weakness, and 2 recovered completely. No single factor was associated with incidence of thromboembolism.

Prosthetic Valve Endocarditis

No patient developed prosthetic valve endocarditis.

Postoperative Outcomes

Operative Mortality: The results of univariate analysis showed that operative mortality was significantly higher in patients with smaller BSA and BMI (OR 3.59, 95% CI: 0.99-12.9, p=0.05), in diabetic patients (OR 3.44, 95% CI: 1.22-9.73, p=0.01), patients with hypertension (OR 2.82, 95% CI: 1.05-7.52, p=0.03), patients undergoing emergency operation (OR 4.8, 95% CI: 1.60-16.1, p=0.001), patients with NYHA class IV symptoms including preoperative congestive heart failure (OR 6.2, 95% CI: 1.36-56.9, p=0.008), patients with an LVEF <30% (OR 7.1, 95% CI: 1.56-64.73, p=0.004), patients requiring preoperative ventilation (OR=3.6, 95% CI: 1.36-9.61, p=0.009), patients who had perioperative cardiogenic shock requiring inotropes (OR=3.1, 95% CI: 1.17-8.27, p=0.02) patients with renal failure requiring dialysis (OR 4.0, 95% CI: 1.35-11.69, p=0.003), patients undergoing a repeat operation (OR 4.8, 95% CI: 1.60-16.06) and patients requiring longer ACCT (>90 min) OR 3.12 (1.17-8.27, p=0.02) (Table 2).

Variables	Total number	In hospital mortality (number)	Odds ratio 95% CI	P value
Age				
- >70 years	4	1		
- <70 years	116	22		
Sex				
- Male	70	12		
- Female	50	11		
Body surface area				
- <1.7 m2	83	20		
- >1.7 m2	37	3		
Diabetes				
- Present	21	8		
- Absent	99	15		
Hypertension (>140 mmHg)				
- Present	27	9		
- Absent	93	14		
Renal failure (dialysis dependency)				
- Yes	29	11		
- No	91	12		
NYHA functional class				
- IV	82	21		
- III	38	2		
Preoperative congestive cardiac failure				
- Yes	82	21		
- No	38	2		
Preoperative cerebrovascular accident				
- Yes	8	1		
- No	112	22		
Left ventricular ejection fraction				
- <30%	79	21		
- >30%	41	2		
Acuity of presentation				
- Emergent/urgent	53	17		
- Elective	67	6		
Preoperative cardiogenic shock, on inotropes				
- Yes	27	9		
- No	93	14		
Preoperative use of inotropies				
- Yes	57	16		
- No	63	7		
Preoperatively on ventilator				
- Yes	27	10		
- No	93	13		
Composite urgency of surgery				
- Yes	53	17		
- No	67	6		
Reoperative surgery				
- Yes	19	8		
- No	101	15		

Concomitant CABG				
- Yes	2	1		
- No	118	22		
Aortic cross-clamp time				
- >90 min	57	16		
- <90 min	63	7		
MVR-high-risk				
- Yes	47	10		
- No	2	1		
AVR-high-risk				
- Yes	19	3		
- No	5	0		
DVR-high-risk				
- Yes	40	8		
- No	7	1		
Valve type				
- Bioprostheses	43	10		
- Mechanical	77	13		
Timing of IABC insertion				
- Group I: Preoperative	35	2	I vs II: 0.26 (0.03-1.42)	**0.08***
- Group II: Intraoperative	48	9		
- Group III: Postoperative	37	12		

*variables with higher risk

Table 2: Univariate predictors for inhospital mortality in patients undergoing mitral and/or aortic valve replacement with IABC (n=120).

Predictors of Operative Mortality

Stepwise multivariate logistic regression analysis identified timing of operation i.e., institution of IABC in the postoperative period (group III), small BSA and body mass index (BMI), advanced NYHA status, patients in the preoperative period with poor ventricular function, in congestive cardiac failure (CCF) and requiring inotropes, emergent surgical intervention and those undergoing reoperative surgery as 10 independent predictors of operative mortality. Odds ratio associated with these variables, along with 95% CI and p values, are depicted in table 3. Patients who died postoperatively required longer CPB times (238±62 vs 78.36±17.82 hours, p<0.001), required more hours of ventilator support (192±98 vs 29±16, p<0.001) and were in advanced NYHA class IV or V (Table 1).

Ninety-two survivors (76.6%) have been followed up periodically every 3 months. Follow up was 100% complete (range 1-254 months) and yielded 946.14 patient-years of data with a mean follow-up time of 123.41 months (standard error: SE±0.87; median 126.5 months). The actuarial survival was 90.8±0.05% in group I, 76.4±0.06% in group II, and 61.4±0.08% in group III (Figure 1).

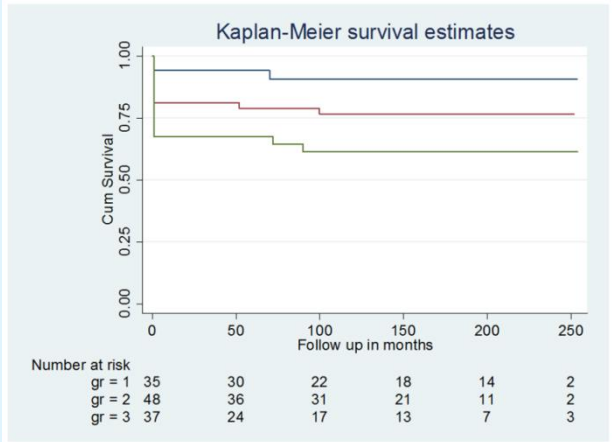

Figure 1: Actuarial survival curve (Kaplan-Meier) of three groups of patients undergoing valve replacement(s) requiring intra-aortic balloon counterpulsation.

By long-rank test, the difference of survival was statistically significant among the three groups (p=0.002). All survivors of the study group (n=92) were in NYHA functional class I and II at their last follow-up. A 72.82% (49 of 92) of survivors who had preoperative atrial fibrillation continue to remain in atrial fibrillation (Table 1). Chordopapillary preservation technique did not affect the outcome of postoperative atrial fibrillation (p=0.61). There were no structural deteriorations or reoperations among patients with mechanical prosthetic valve replacements.

Discussion

As far as we are aware and thus far there have been no studies addressing specifically the effect timings of insertion of intra-aortic balloon counterpulsation on perioperative mortality in patients undergoing valve replacements for rheumatic heart diseases [1-25]. Careful analyses of the published series substantiate improved outcomes of primary and redo mitral and/or aortic valve replacement over time. The management strategies leading to this improvement include aggressive preoperative medical management, advances in cardiac anaesthesia, perioperative critical care, hemodynamic monitoring and chordal preservation strategies during the past 3 decades [1-11].

Despite introduction of these management strategies and employment of a uniform protocol of myocardial preservation, the immediate and long-term results of a subset of patients undergoing mitral and/or aortic valve replacement are disappointing because of refractory LCOS following surgery [1-11]. In the peri-operative period, there exists some degree of transient dysfunction and inotropes are commonly used to maintain stable hemodynamics. Escalating inotropic requirement commonly preceeds institution of IABC.

Despite the fact that the use of IABC is common and well documented after high-risk CABG and ventricular aneurysmectomy, its use in the setting of biventricular dysfunction following valve replacement remains sporadic [1,10-12,15,25]. Perhaps, the major concern that has hindered the widespread use of IABC in the setting of valvular diseases is that such patients are less likely to have preserved right ventricle and pulmonary function and may not supportable with intra-aortic balloon pumping alone [1,10-12,15,25]. Extra-corporeal membrane oxygenation and left ventricular-assist devices are the most prevalent means of mechanical circulatory assistance in such a clinical situation which have been demonstrated by us on our previous investigation [24,25].

Principle of IABP and Advantage over other Devices

IABC decreases systolic impedance (afterload), increases aortic diastolic pressure, cardiac output, coronary blood flow, decreases left ventricular size and improves myocardial metabolism in both experimental and clinical studies [1,10-19]. Although IABC is a quite different modality of mechanical circulatory support compared with ECMO, ventricular-assist devices or both, balloon pumping facilitates recovery of left ventricular function by decreasing the left ventricular afterload and improving coronary perfusion. This, in turn decreases left ventricular end-diastolic pressure and left atrial pressure and indirectly helps the right ventricle by the phenomenon of ventricular interdependence [24,25]. The advantage of balloon counterpulsation over left atrial-to-aortic assist devices is the ease of application. Other assist devices like axial flow pumps have also been tried in the experimental settings [24,25].

Low Cardiac Output Syndrome following Valve Replacements

Advanced disease process with poor preoperative left ventricular function in the late presenters (NYHA class IV/V), patients undergoing operation on an urgent and emergency basis with associated co-morbidities, reoperations, preoperative use of inotropes and/or ventilator, preoperative hepatic/renal failure, supraventricular dysrhythmias, non-preservation of chordae tendinae, residual surgically correctable structural cardiac lesions have been variously implicated by several investigators as the causative factors for postoperative LCOS [1-15]. Our study concurs the observations of the previous investigators and also identifies prolonged aortic cross clamp time and longer cardiopulmonary bypass time as independent risk factors for postoperative LCOS. These factors may likely act as a surrogate for technical difficulties/complexities during surgical intervention or poor myocardial function requiring longer reperfusion times. Although, it is impossible to relate a low cardiac output state to a specific cause, above factors in isolation or combination may be the causative factors for intractable LCOS.

IABC in Preoperative Setting

The role of preoperative prophylactic IABC is subject to debate. The inclusion and exclusion criteria varies

between studies limiting generalizability, potential biasness including small patient numbers, lack of multicentre studies and variability in criteria for insertion [12,14,26]. The Benchmark Registry is a prospectively collected database that has recently reported the results of over 5,000 patients receiving IABCs at 132 US and European centers. Preoperative IABC insertion in high-risk patients accounted for 11% of patients [12,14,26-28]. In our practice, this indication accounted for 29.2% of cases. This higher rate may reflect both a difference in casemix seen at our institution as well as a lower threshold for preoperative IABC use on the basis of our encouraging results to date.

Although there are contradictory reports in the published literature, regarding the benefits of preoperative institution of IABC, recent meta-analysis of randomized control trials and cohort studies in patients undergoing CABG demonstrated lower mortality and reduced ICU stay in the preoperative group [9,16,19,27-29]. Variability in the selection criteria in the included series may account for the variable results. Our study highlight the benefits of preoperative balloon counterpulsation in terms of improved myocardial oxygen supply/demand ratio, hemodynamic stability during induction and prebypass, pulsatile flow during bypass and less inotrope requirement to maintain the viability of endorgans. Institution of IABC in the preoperative period was associated with a statistically significant reduction in operative mortality as compared to the intraoperative group (OR=0.26, 95% CI: 0.03-1.42, p=0.08) and the postoperative group as well (OR=0.13, 95% CI: 0.01-0.66, p=0.004) (Table 2). The pulsatile assist device is a simple and reliable device, both for intraoperative arterio-arterial counterpulsation and for the creation of pulsatile cardiopulmonary bypass (CPB).

Another important issue about preoperative IABC use is the timing of preoperative insertion [26-28]. We have done these 12 hours before operation in nearly all cases. This is mainly for logistic reasons, so that the IABC can be inserted in the intensive care unit the evening before surgery, with operation the next morning. Other investigators have found no difference in outcome whether the IABC is inserted 2, 12, or 24 hours preoperatively.

Postoperative & intra Operative Setting IABC

In group III, 37 out of 120 (30.8%) patients necessitated IABC because of increasing requirement of inotropes. The observed 30-day mortality for all patients requiring postoperative institution of IABC was 32.4%. This is comparable to the 36-61% in other reported series [13,27,28]. Arafa and colleagues reported a 10-years series of cardiac surgery patients operated on during the 1980s in which IABC use was associated with an early mortality rate of 52.6% and the actuarial survival rates at 1, 5 and 10 years was 40, 32 and 22%, respectively [13]. Both Benchmark registry data and Baskett's review of IABC use in cardiac surgery have demonstrated the evolution of the indications for IABC use [12,14,17,26]. Whereas the conclusions that were made in these early studies were valid, patient selection and improvements in peri-operative management may influence the results in a more recent cohort of patients.

However, the risk-adjusted mortality was significantly higher in the group receiving an IABC intraoperatively or postoperatively compared with the preoperative non-emergent high-risk group (group I vs group II: p=0.08, group I vs group III: p=0.004). In the intra- and postoperative group, a significant percentage had poor left ventricular function (LVEF <0.30), in CCF requiring inotropes in the preoperative period or underwent reoperation either due to failed mitral valvuloplasty or degenerated bioprostheses. In retrospect, this subset of patients may have fared better with a planned preoperative IABC, rather than one inserted urgently once their hemodynamic condition had deteriorated. Of note, all the IABC related vascular complications in this series three out of eighty-five patients (3.5%) occurred in the intraoperative/postoperative unplanned IABC group. This provides further evidence to support preoperative over urgent intraoperative / postoperative IABC insertion, although the difference did not reach statistical significance because of the low overall complication rate.

Low Cardiac Output Syndrome and Mortality

Published literature documents a decreased prevalence of LCOS following valvular operation over the period of years [1-11,30]. However, the postoperative mortality associated with LCOS continues to be significant. The effect of LCOS in a valvular population is more dramatic than that reported in patients undergoing isolated CABG [3]. Compared with a 17-fold increase in patients undergoing CABG, LCOS portended a 38-fold increase in mortality after aortic valve surgery and a 30-fold increase after isolated mitral valve surgery [24]. Also, the mortality associated with the development of LCOS is on the increase, from 23% in the earliest era to 35% in the most recent era [24]. Although the development of LCOS was associated with a significant increase in

operative mortality, from 1.3% to 30%, the independent predictors of LCOS and mortality were not alike. In this study, 19 out of 23 early deaths (82.6%) were primarily due to intractable LCOS. Despite use of multiple inotropes and institution of IABC, LCOS accounted for majority of deaths primarily in the intra and postoperative group. The risk of death was 5.88 times higher (95% CI: 2.81-36.80, p=0.001) in those receiving IABC in the postoperative period (Table 3).

Variables	Odds ratio	P value
Body surface area	4.15 (1.08-15.92)	**0.03***
Renal failure requiring dialysis	3.44 (1.22-9.73)	**0.02***
Advanced New York Heart Association status (class IV)	2.82 (1.05-7.5)	**0.03***
Preoperative congestive cardiac failure	3.68 (1.54-15.86)	**0.02***
Preoperatively on ventilator	2.92 (1.44-8.62)	**0.02***
Left ventricular ejection fraction <30%	3.15 (1.20-8.28)	**0.02***
Acuity of presentation (emergent / urgent)	4.46 (2.82-16.80)	**0.001***
Composite urgency of surgery	4.66 (2.97-17.85)	**0.002***
Re-operative surgery	3.83 (1.68-15.96)	**0.05***
Postoperative intra-aortic balloon counterpulsation (group III)	5.88 (2.81-36.80)	**0.001***

*variables with higher risk

Table 3: Predictors of mortality by stepwise logistic regression analysis applied to all 120 patients.

Predictors of Low Cardiac Output Syndrome

Timing of Surgery

In this patient population, the most significant predictor of LCOS and operative mortality was the timing of the operation. Patients undergoing operations on an urgent or emergency basis had significantly higher incidence of LCOS and operative mortality (32% vs 8.9%). Logistic regression analysis accounting for the effects of other variables identified 9 predictors of death after valve replacement and IABC support. The risk of death was 4.66 times higher (95% CI: 2.97-17.85, p=0.002) in patients requiring surgery on urgent or emergent basis (Table 3). These patients had several other comorbidities, which might have led to a higher incidence of LCOS and operative mortality. Our results are in agreement with published reports by Nowicki, Jamieson, Kang and colleagues, who reported an urgent and emergency presentation as one of the most important risk factors for death after mitral valve surgery [31-33].

Preoperative LV function, insufficiency vs. stenosis: In our study, preoperative LVEF <30% was a significant predictor for LCOS following aortic and/or mitral valve replacement. Surprisingly, preoperative LV function was more important in patients with aortic stenosis than regurgitation. Conventional wisdom dictates that poor preoperative LV function is associated with a worse prognosis after surgery in patients with aortic and mitral insufficiency than in patients with aortic/or mitral stenosis. However, a review of the literature reveals no differences in perioperative outcomes for patients with aortic stenosis or insufficiency in the setting of severe LV dysfunction [1-6].

In this study, poor preoperative LVEF was associated with a higher incidence of LCOS in patients with MR than in patients with MS (21% vs 10.3%, respectively). The risk of death was 3.15 times higher (95% CI: 1.20-8.28, p=0.02) in patients with poor left ventricular function in the preoperative period on multivariate analysis (Table 3). Although impaired LVEF is reported as one of the factors to deny surgical intervention in patients with severe symptomatic MR by some investigators, we do not justify the decision according to current knowledge based as ACC/AHA guidelines [5,32].

New York Heart Association Functional Class: Our results confirm the observations by other investigators that perioperative outcomes are usually worse in patients with severe symptomatic conditions in NYHA functional class-IV [1-14,34-44]. Patients presenting with severe functional disability was associated with 2.82 (95% CI: 1.05-7.5, p=0.02) times increased risk of in-hospital mortality (Table 3).

Other correlative parameters: Female gender, Body mass index, Aortic cross clamp time, Renal failure, Previous cardiac surgery, Patient-prostheses mismatch, Hypertension, Chordal preservation, Age at operation: Although an increased risk in female patients undergoing CABG have been hypothesized because of

smaller body size and small coronary anatomy, the relationship between BSA and LCOS in a valvular population is unclear [12,17,26]. Kenchaiah and colleagues reported that patients with a body mass index (BMI) of less than 23 enrolled in the Candesartan in Heart Failure: assessment of reduction in mortality and morbidity study had a significantly poorer survival. Accurate BMI data were available in 2601 (8%) members of their population, and of these, 698 (27%) had a BMI of less than 23 [37]. In our study BSA less than 1.7m^2 and low BMI was associated with 4.15 times higher risk of in-hospital death (95% CI: 1.08-15.92, p=0.03) and suggest that a significant proportion of our patient might have had cardiac cachexia reflecting the end stage of their valvular disease (Table 3) [37]. Duration of CPB and prolonged aortic cross-clamp time also emerged as independent risk factors for postoperative LCOS. Longer CPB times likely act as a surrogate for technical difficulties during surgical intervention or poor myocardial function requiring longer reperfusion times. The fact that prolonged clamp time also emerged as a risk factor and predictor of LCOS and mortality supports the above hypothesis (odds ratio: 3.12, 95% CI: 1.17-8.27, p=0.02) (Table 2).

Small prosthesis size and patient-prostheses mismatch has been incriminated as the causative factor of in-hospital death and adverse long-term postoperative outcome by several elegant studies [38-41]. Blais and associates demonstrated that the degree of patient-prosthesis mismatch influenced operative mortality after AVR with a risk of 3% in patients with no or mild mismatch rising to 24% in patients with severe mismatch [40]. In this study, 19 (15.8%) patients had a small aortic root and all underwent aortic root enlargement using Nicks procedure, thereby eliminating patient-prosthesis mismatch, The mean post bypass aortic transprosthetic gradient measured using intraoperative transesophageal echocardiography between 8-10 mmHg in all patients undergoing AVR and/or DVR.

Interestingly, hypertension emerged as a predictor of in-hospital mortality on bivariate analysis (OR 2.82, 95% CI: 1.05-7.52, p=0.03), but failed to emerge as a predictor of operative mortality on logistic regression analysis (Tables 2 & 3). Hypertension is usually associated with myocardial hypertrophy, which may be exacerbated by aortic stenosis. Myocardial hypertrophy is a risk factor for inadequate cardioplegia delivery (especially to the right ventricle) [16]. Inadequate myocardial protection emerged as a significant predictor for LCOS by several investigators [7-11,20,29]. Chordal preservation strategy is known to be protective against the development of both LCOS and operative mortality. Several investigators including ourselves have demonstrated the beneficial effects of chordal preservation in patients undergoing MVR on left ventricular size and function [7-12].

Renal failure and previous cardiac operation are widely reported as major risk factors of operative mortality in cardiac valve operation [32,42,43]. Jamieson and associates published independent predictors of operative mortality in 86,580 patients undergoing valve replacements using the Society of Thoracic Surgeons database [32]. Their study identified renal failure and reoperations as high-level risk factors [32]. Similarly, Herzog and co-workers identified more than 5000 dialysis patients undergoing aortic valve surgery, mitral valve surgery, or both through the US Renal Data System over a 20-year period [42]. The perioperative mortality was greater than 20%, and the 2-year survival rate was only 40%, irrespective of whether a mechanical or tissue valve was implanted. It is unclear whether perioperative dopamine, vasopressin, or N-acetylcysteine would prove to be more beneficial in patients undergoing mitral valve surgery [42,43]. In this study, 29 patients had preoperative renal failure requiring dialysis and 11 (37.9%) died after surgery. The risk of death was 3.44 times (95% CI: 1.22-9.73, p=0.02) higher in this group of patients with renal failure (Table 3).

Published literature also documents advanced age as one of the most important predictors of operative mortality in patients undergoing valve operations. Indeed, Mirabel and co-workers reported advanced age as one of the factors to deny surgical intervention in patients with severe MR in the Euro heart survey on valvular disease [5]. In our study, rheumatic heart disease was the etiologic factor in all patients undergoing valve replacements. The mean age of the study population was 49.68±22.6 years ranging between 22 and 72 years and only 4 patients were older than 70 years.

Results of Prophylactic IABC

Prophylactic IABC support in high-risk patients in several studies resulted in 1-year survival that did not differ significantly from that of patients who did not require IABC support [1,15-19]. Our findings corroborates the evidence from other investigators who demonstrated that preoperative intra-aortic balloon insertion in patients undergoing valve replacement with moderate or severe left ventricular dysfunction reduced the length of ICU stay and in-hospital mortality [1,15-19]. Recent meta-analysis of randomized controlled trials and

cohort studies demonstrated the relative benefits of preoperative institution of IABC in lowering mortality and hospital length of stay [16,19].

IABC Related Morbidity

The Benchmark Registry reports an overall IABC related morbidity rate of 3.2% and IABC-related mortality rate of 0.1% [12,14,17]. Our morbidity rate is comparable with this. As noted, we have not had any morbidity in the preoperative non-emergent or emergent groups, which may be due in part to the use of echocardiographic and radiological control (image intensifier) in all these cases, which is usually not practical in the urgent intraoperative setting.

In this series, only 3 (2.5%) of the postoperative group had major IABC-related complications. This is in contrast to other published reports of morbidity ranging between 8 and 18% [13,16,44]. The smaller catheters (7.5 Fr) used in this series and sheathless insertion in females, obese patients and aged patients could have been responsible for the apparent reduced complication rate. Recognized risks for IABC-related complications in the published literature include female gender, peripheral vascular disease, older age and obesity [11,13,44]. None of these associations are found to be significant in this study. In this study, all patients had percutaneous insertions. Method of insertion appears to have a significant effect on the complication rate [16].

On the basis of our results, we recommend the following guidelines for candidate selection for IABC insertion.

a) High-risk group of patients undergoing valve replacements in preoperatively advanced NYHA status (class IV or V) requiring increasing inotropes, on ventilator, with metabolic / lactic acidosis, in acute pulmonary edema, oliguria (<0.5 ml/kg/hour), in cardiogenic shock will in general do well with preoperative institution of IABC.

b) Following valve replacement, patients facing CPB weaning problems, requiring increasing dosage of multiple inotropes, having recurrent rhythm disturbances including complex ventricular ectopies with gross left or biventricular dysfunction without residual correctable cardiac lesions and mechanical external compression are useful clinical indicators of intraoperative institution of IABC before leaving the operating room.

c) Preoperative insertion of IABC improves myocardial oxygen supply / demand ratio, provides hemodynamic stability during induction and bypass, provides pulsatile flow during bypass and minimizes inotrope requirement to maintain viability of end organs.

d) The prohibitively high mortality in the postoperative group requiring IABC in the ICU suggest revision of our selection criteria of IABC insertion in the pre- or intraoperative period in patients undergoing valve replacement either as an adjunct during weaning from CPB or for circulatory support in the immediate postoperative period.

Clinical Implications

The clinical implications of this study are multifaceted. Preoperative risk profiling and patient selection will always benefit from repeated analyses of institutional results. However, an additional objective of this study was to predict those patients who might require mechanical circulatory support in the early postoperative period.

Study Limitations

This is a retrospective analysis involving data collected prospectively and validated and is subject to the limitations of all such studies. Selection bias is likely to have affected our results because the timing of insertion was based on clinical judgement and was not controlled by protocol. Controversy persists regarding the indications for IABC use. It would be impossible to arrange a randomized trial involving intra-and post-operative IABC insertion mainly because of issues related to consent and sample size. This study, however, gives an accurate picture of current clinical practice. Furthermore, although we restricted our analysis to rheumatic valvular replacements, there are diverse patient populations within our cohort, each with a varied level of independent operative risk. A longer study period may further highlight the differences identified.

Exploring the Unknown: Future Directions

This communication is not meant in any way to convince those surgeons satisfied with their own methods of myocardial preservation and LCOS management in high-risk patients requiring prolonged aortic cross-clamp times like re-operative surgeries. Rather it hopes to point out that an individualized myocardial and circulatory mechanical supported strategy as enunciated above in beneficial in the setting of high-risk single or multiple valve replacements.

Conclusion

We conclude that the timing and indications of balloon deployment is a matter of judgement and may indeed be difficult. For patients who cannot be weaned from cardiopulmonary bypass or who suddenly deteriorate after a satisfactory surgical repair, the decision to initiate balloon counterpulsation is relatively straightforward. There exists a clear distinction between patients with borderline hemodynamics with a high estimated preoperative risk (poor left ventricular ejection fraction, a large cardiothoracic ratio >0.7), patients in CCF requiring increasing dosage of inotropes and/or ventilator support who may benefit from prophylactic insertion of IABC and those patients who are hemodynamically compromised and require therapeutic IABC support either to get weaned from CPB or in the postoperative period for LCOS, since its use as an "absolute last resort" decreases the possibility of success.

Our study further demonstrates that advanced NYHA functional class, urgent surgical intervention, cardiac cachexia, poor preoperative ventricular function, reoperations, and renal failure are independent predictors of postoperative LCOS and mortality. Therefore, these high-risk patients should be evaluated preoperatively to facilitate intraoperative decision-making with respect to use of perioperative IABC. These patients undergoing primary and redo mitral and/or aortic valvular replacements can benefit from IABC when they have left or right ventricular dysfunction leading to biventricular failure. Clearly detailed attention must be paid to preoperative "optimization" with diuresis, afterload reduction, cardioactive medications, myocardial preservation and chordal preservation. Randomized studies should be considered to more clearly define specific indications, proper time of intervention and factors that can predict a successful outcome.

Study Outcomes: Operative Mortality and Low Cardiac Output Syndrome

The primary outcome measures in this study were low cardiac output syndrome (LCOS) and operative mortality. Operative mortality was defined as any postoperative death occurring within 30 days or during the same hospital admission.

Low cardiac output syndrome (LCOS) in patients undergoing valve replacement was diagnosed if the patient required an IABC to be weaned from cardiopulmonary bypass (CPB) or in the intensive care unit because of hemodynamic compromise. LCOS was also diagnosed if the patient required inotropic medication (dopamine at 4-10μg/[kg • min]), dobutamine at 5-10 μg/[kg • min], epinephrine at 0.01-0.1 μg/[kg • min] either isolated or in combination) in the operating room or in the intensive care unit to maintain systolic blood pressure at greater than 90 mm Hg and cardiac output at greater than 2.2 L . min^{-1}.m^{-2} for at least 30 minutes in the intensive care unit in the absence of residual structural lesions and mechanical external compression after correction of all electrolytes or blood gas abnormalities and after adjustment of the preload to its optimal value. Low-output syndrome was also diagnosed if there was an increasing requirement of the above-mentioned inotropes with or without intra-aortic balloon counterpulsation along with afterload reduction with sodium nitroprusside when possible.

Patients who received less than 4 μg/kg dopamine to increase renal perfusion were not considered to have LCOS. Patients who received vasoconstricting medications because of a high cardiac output (>2.5 L . min^{-1} . m^{-2}) and low peripheral resistance were also not considered to have LCOS. In patients who received an IABC before surgical intervention, LCOS was determined if they required significant postoperative inotropic support, as described above, in addition to IABC support.

Perioperative Myocardial Infarction and Arrhythmias

A postoperative myocardial infarction was diagnosed by the appearance of new Q waves associated with an increase in the levels of the myocardial-specific creatine kinase. Postoperative arrhythmias were classified into three categories: (1) sustained new onset supraventricular tachyarrhythmias of new onset necessitating antiarrhythmic therapy, with or without the need for direct-current cardioversion; (2) multifocal or coupled premature ventricular beats with a normal concentration of serum potassium necessitating antiarrhythmic drugs; and (3) ventricular tachycardia or fibrillation. Conduction defects were classified as (1) junctional rhythm, (2) bundle-branch block of new onset, and (3) complete heart block.

References

1. Downing TP, Miller DC, Stofer R, Shumwy NE (1996) Use of the intra-aortic balloon pump after valve replacement. J Thorac Cardiovasc Surg 92(2): 210-217.

2. Maganti M, Badiwala M, Sheikh A, Scully H, Feindel C, et al. (2010) Predictors of low cardiac output syndrome after isolated mitral valve surgery. J Thorac Cardiovasc Surg 140(4): 790-796.

3. Maganti MD, Rao V, Borger MA, Ivanov J, David TE (2005) Predictors of low cardiac output syndrome after isolated aortic valve surgery. Circulation 112(9): I448-I452.

4. Nowicki ER, Birkmeyer NJ, Weintraub RW, Leavitt BJ, Sanders JH, et al. (2004) Multivariable prediction of in-hospital mortality associated with aortic and mitral valve surgery in Northern New England. Ann Thorac Surg 77(6): 1966-1977.

5. Mirabel M, Iung B, Baron G, Messika-Zeitoun D, De'taint D, et al. (2007) What are the characteristics of patients with severe, symptomatic, mitral regurgitation who are denied surgery? Eur Heart J 28(11): 1358-65.

6. Sharony R, Grossi EA, Saunders PC, Schwartz CF, Ciuffo GB, et al. (2003) Aortic valve replacement in patients with impaired ventricular function. Ann Thorac Surg 75: 1808-1814.

7. Chowdhury UK, Rizvi A, Narang R, Seth S, Kalaivani M, et al. (2018) Mitral valve replacement using Carpentier-Edwards pericardial bioprosthesis in patients with rheumatic heart disease aged below 40 years: 17-year results. Heart, Lung and Circulation 27: 864-871.

8. Chowdhury UK, Sharma P, Kumari LS, Hasija S, Narang R, et al. (2018) Thromboembolic and bleeding complications following St. Jude Medical valve replacement. Annals of Short Reports 1: 1009.

9. Chowdhury UK, Kumar AS, Airan B, Mittal D, Subramaniam KG, et al. (2005) Mitral valve replacement with and without chordal preservation in a rheumatic population: Serial echocardiographic assessment of left ventricular size and function. Ann Thorac Surg 79(6): 1926-1933.

10. Chowdhury UK, Rizvi A, Hasija S, Patel K, Narang R, et al. (2018) Evaluation of thromboembolism and valve thrombosis in patients with rheumatic heart disease undergoing mitral tissue valve replacement in the presence of atrial fibrillation with or without or without left atrial clot: Review of a 17-year's experience. World J Surg Surgical Res 1: 1042.

11. Chowdhury UK, Venkataiya JKH, Patel CD, Seth S, Yadav R, et al. (2006) Serial radionuclide angiographic assessment of left ventricular ejection fraction and regional wall motion after mitral valve replacement in patients with rheumatic disease. Am Heart J 152(6): 1201-1207.

12. (1987) Veterans Administration Cooperative study on valvular heart disease: Clinical, hemodynamic and angiographic predictors of operative mortality in patients undergoing single valve replacement. J Thorac Cardiovasc Surg 93: 884-897.

13. Arafa OE, Pedersen TH, Svennevig JL, Fosse E, Geiran OR (1998) Intra-aortic balloon pump in open heart operations: 10-year follow-up with risk analysis. Ann Thorac Surg 65: 741-747.

14. Baskett RJ, Ghali WA, Maitland A, Hirsch GM (2002) The intra-aortic balloon pump in cardiac surgery. Ann Thorac Surg 74: 1276-1287.

15. Bolooki H, Williams W, Thurer RJ, Vargas A, Kaiser GA, et al. (1976) Clinical and hemodynamic criteria for use of the intra-aortic balloon pump in patients requiring cardiac surgery. J. Thorac Cardiovasc Surg 72(5): 756-768.

16. Christenson JT, Cohen M, Ferguson JJ III, Freedman RJ, Miller MF, et al. (2002) Trends in intra-aortic balloon counterpulsation complications and outcomes in cardiac surgery. Ann Thorac Surg 74: 1086-1090.

17. Cohen M, Urban P, Christenson JT, Joseph DL, Freedman RJ Jr, et al. (2003) Benchmark Registry Collaborators. Intra-aortic balloon counterpulsation in US and non-US centres: results of the Benchmark Registry. Eur Heart J 24: 1763-1770.

18. Dunning J, Prendergast B (2003) Which patients would benefit from an intra-aortic balloon pump prior to cardiac surgery? Interact Cardiovasc Thorac Surg 2(4): 416-419.

19. Dyub AM, Whitlock RP, Abouzahr LL, Cina CS (2008) Preoperative intra-aortic balloon pump in patients undergoing coronary bypass surgery: a systematic review and meta-analysis. J Card Surg 23(1): 79-86.

20. Miki S, Kusuhara K, Ueda Y, Komeda M, Ohkita Y, et al. (1988) Mitral valve replacement with preservation of chordae tendinae and papillary muscles. Ann Thorac Surg 45(1): 28-34.

21. Edmunds LH Jr, Clark RE, Cohn H, Grunkemeier GL, Miller DC, et al. (1996) Guidelines for reporting morbidity and mortality after cardiac valvular operations. Ann Thorac Surg 10(9): 812-816.

22. Bonow RO, Carabello B, de Leon AC, Edmunds LH, Fedderly BJ, et al. (1998) ACC/AHA guidelines for the management of patients with valvular heart disease: Executive summary: A report of the American College of Cardiology/American Heart Association Task-Force on Practice Guidelines (Committee of management of patients with valvular heart disease). J Heart Valve Dis 7(6): 672-707.

23. Cheitlin MD, Armstrong WF, Aurigemma GP, Beller GA, Bierman FZ, et al. (2003) Guideline update for the clinical application of echocardiography: summary article. J Am Soc Echocardiagr 108(9): 1091-1100.

24. Kumari LS, Chowdhury UK, Bansal N, Jena J, Hasija S. Intra-aortic Balloon Counterpulsation Following Bentall's Procedure for Annuloaortic Ectasia. Annals of Short Reports 1: 1023.

25. Gaines WE, Pierce WS, Prophet GA, Holtzman K (1984) Pulmonary circulatory support: a quantitative comparison of four methods. J Thorac Cardiovasc Surg 88(6): 958-964.

26. Ferguson JJ III, Cohen M, Freedman RJ Jr, Stone GW, Miller MF, et al. (2001) The current practice of intra-aortic balloon counterpulsation: results from the Benchmark Registry. J Am Coll Cardiol 38(5): 1456-1462.

27. Holman WL, Li Q, Kiefe CI, McGiffin DC, Peterson ED, et al. (2000) Prophylactic value of preincision intra-aortic balloon pump: analysis of a statewide experience. J Thorac Cardiovasc Surg 120(6): 1112-1119.

28. Lavana JD, Fraser JF, Smith SE, Drake L, Tesar P, et al. (2010) Influence of timing of intra-aortic balloon placement in cardiac surgical patients. J Thorac Cardiovasc Surg 140(1): 80-85.

29. Marra C, De Santo LS, Amarelli C, Dellacorte A, Onorati F, et al. (2002) Coronary artery bypass grafting in patients with severe left ventricular dysfunction: a prospective randomized study on the timing of perioperative intra-aortic balloon pump support. Int J Artif Organs 25(2): 141-146.

30. Den Uil CA, Valk SD, Cheng JM, Kappetein AP, Bogers AJ, et al. (2009) Prognosis of patients undergoing cardiac surgery and treated with intra-aortic ballon pump counterpulsation prior to surgery: a long-term follow-up study. Interact Cardiovasc Thorac Surg 9(2): 227-231.

31. Nowicki ER, Birkmeyer NJ, Weintraub RW, Leavitt BJ, Sanders JH, et al. (2004) Multivariable prediction of in-hospital mortality associated with aortic and mitral valve surgery in Northern New England. Ann Thorac Surg 77(6): 1966-1977.

32. Jamieson WR, Edwards FH, Schwartz M, Bero JW, Clark RE, et al. (1999) Risk stratification for cardiac valve replacement. National Cardiac Surgery Database. Database Committee of The Society of Thoracic Surgeons. Ann Thorac Surg 67(4): 943-951.

33. Kang N, Edwards M, Larbalestier R (2001) Preoperative intra-aortic balloon pumps in high-risk patients undergoing open heart surgery. Ann Thorac Surg 72(1): 54-57.

34. Meco M, Gramegna G, Yassini A, Bellisario A, Mazzaro E, et al. (2002) Mortality and morbidity from intra-aortic balloon pumps. Risk analysis. J Cardiovasc Surg (Torino) 43: 17-23.

35. Personnet V, Dean D, Berstein AD (1989) A method of uniform stratification of risk for evaluating the results of surgery in acquired adult heart disease. Circulation 79(6): I3-I12.

36. Nashef SA, Roques F, Gauducheau E, Lemeshow S, Salamon R (1999) European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg 16(1): 9-13.

37. Kenchaiah S, Pocock SJ, Wang D, Finn PV, Zornoff LA, et al. (2007) Body mass index and prognosis in patients with chronic heart failure: insights from the Candesartan in Heart Failure: Assessment of Reduction in Mortality in Morbidity (CHARM) program. Circulation 116(6): 627-636.

38. Christakis GT, Buth KJ, Goldman BS, Fremes SE, Rao V, et al. (1998) Inaccurate and misleading valve sizing: A proposed standard for valve size nomenclature. Ann Thorac Surg 66: 1198-1203.

39. Blais C, Dumesnil JG, Baillot R, Simard S, Doyle D, et al. (2003) Impact of valve prosthesis-patient mismatch

on short-term mortality after aortic valve replacement. Circulation 108(8): 983-988.

40. Pibarot P, Dumesnil JG, Lemieux M, Cartier P, Metras J, et al. (1998) Impact of prosthesis-patient mismatch on hemodynamic and symptomatic status, morbidity and mortality after aortic valve replacement with a bioprosthetic heart valve. J Heart Valve Dis 7(2): 211-218.

41. Rao V, Jamieson WR, Ivanov J, Armstrong S, David TE (2000) Prosthesis patient mismatch affects survival after aortic valve replacement. Circulation 102(3): 5-9.

42. Herzog CA, Ma JZ, Collins AJ (2002) Long-term survival of dialysis patients in the United States with prosthetic heart valves: should ACC/AHA practice guidelines on valve selection be modified? Circulation 105(11): 1336-1341.

43. Wijeysundera DN, Karkouti K, Beattie WS, Rao V, Ivanov J (2006) Improving the identification of patients at risk of postoperative renal failure following cardiac surgery. Anaesthesiology 104(1): 65-72.

44. Meharwal ZS, Trehan N (2002) Vascular complications of intra-aortic balloon insertion in patients undergoing coronary revascularization: analysis of 911 cases. Eur J Cardiothorac Surg 21(4): 741-747.