MYOCARDIAL PERFORMANCE INDEX IS BETTER THAN EJECTION FRACTION AS A PREDICTOR OF POSTOPERATIVE ADVERSE CARDIAC EVENTS

Thesis submitted for the partial fulfillment for the requirement of the degree of DM (Cardiac Anesthesia)

of

SCTIMST

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DECLARATION

I hereby declare that this thesis entitled, has been prepared by me under the capable supervision and guidance of Prof Rupa Sreedhar, Dr. Shrinivas V.G. Department of Anesthesiology, and Dr Jaya Kumar.K, Professor and Head, Department of C.T.V.S. at Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram.

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Dr. Murali Krishna.T

Contents

Introduction

Coronary artery bypass grafting (CABG) is a commonly performed cardiac surgical procedure. The spectrum of patients who undergo CABG vary from those with well preserved cardiac function to those with poor cardiac function. Risk assessment in CABG is useful in prognosticating the patients, allotment of resources and predicting the outcome of a specific patient. Various preoperative and intraoperative factors have been shown to alter the outcome following CABG[1, 2].

Traditionally, left ventricular ejection fraction (LVEF) calculated from echocardiography has been used as a measure of the cardiac function. Several studies have shown that patients with poor preoperative ejection fraction have more incidences of both early and late postoperative morbidity and mortality[1 - 7]. Studies have also shown that LVEF is an independent predictor of events like prolonged postoperative ventilation[8]. Although, LVEF is a consistent preoperative factor in various models that assess the risk and outcome following CABG, it is a measure of only the systolic function of left ventricle. It does not take into account the diastolic function of the heart. Previous studies have shown that diastolic failure or dysfunction is an independent predictor of patient outcome[9]. The measurement of LVEF both in the preoperative and intraoperative period is influenced by factors such as volume status of the patient. Inter-observer and intra-observer variation can occur in the calculation of the LVEF by echocardiography. Moreover, several

techniques are described in the calculation of LVEF and values measured by one technique may not correlate with that of another. .

Tei described an echocardiographic index known as 'myocardial performance index (MPI)', which is a reliable indicator of both the systolic and diastolic functions of the heart[10]. This is the summation of isovolumetric contraction and isovolumetric relaxation time divided by the ejection time[10]. Previous studies have shown that MPI is an easily measurable echocardiographic parameter and that there is little intra-observer and inter-observer variability in the measurement of MPI[10]. Studies have also shown that the MPI is independent of changes in heart rate and volume status of the patient[10 – 17]. This is of advantage during the intraoperative period when changes in heart rate, volume status, and blood pressure are common. MPI has been shown to be useful for assessing the cardiac function in patients with dilated cardiomyopathy and drug induced cardiotoxicity[11, 14, 18 - 20]. It has also been shown to predict the outcome following congestive cardiac failure[21 - 25], pulmonary thromboembolectomy[26 - 27] and acute myocardial infarction[28 - 33]. Al-Mukhaini et al. have shown that MPI > 0.7 is a potential predictor of postoperative mortality and adverse events in patients undergoing mitral valve surgeries[34]. They also found that MPI is more specific and sensitive than LVEF in predicting postoperative events[34]. Feroze Mahmood et al. have shown that perioperative MPI value > 0.36 is associated with statistically

significant adverse events in patients undergoing abdominal aortic aneurysm surgery[35]. There are no studies in literature that had evaluated the usefulness of MPI in predicting the outcome after CABG in the perioperative period. The investigators of the present study presumed that the outcome following CABG is dependent upon both the systolic and diastolic functions of the heart. MPI has the advantage of being a composite measure of both the functions. It is not dependent upon the heart rate or volume status and can be obtained easily in the intraoperative period. The authors wanted to examine the association of MPI and EF with postoperative outcomes (in terms of inotropic requirement, cardiac failure and prolonged mechanical ventilation) to determine which parameter is a better predictor of outcome.

Aims & Objectives

The main aims and objectives of the present study were

- To see whether the measurement of MPI is feasible in the prebypass period.
- To investigate whether the prebypass MPI and LVEF values correlate with the postoperative inotropic infusion requirement (dose, number and duration).
- To investigate whether the prebypass MPI value can predict postoperative adverse cardiac events (IABP requirement, CCF, prolonged ventilation and mortality).
- To investigate whether the prebypass MPI is better than LVEF in predicting postoperative adverse cardiac events.

Review of Literature

Tei et al[10] described an echocardiographic index 'myocardial performance index' (MPI or Tei index) as a reliable assessment of both systolic and diastolic function of the left ventricle. The myocardial performance index is the summation of the isovolumetric contraction and relaxation times divided by the ejection time[10]. It has been proven in previous studies that MPI reflects both the systolic and diastolic function of the left ventricle and correlates well with both peak positive and negative ***dP/dt***[10, 12]. Multiple studies had evaluated the validity of MPI and found it to be independent of loading conditions of the left ventricle and heart rate[10 - 17]. Studies had shown that measurement of MPI is reliable with little inter-and intra-observer variability[10].

Previous studies by Tei et al and Dujardin et al had shown that MPI is an useful echo parameter in quantification of severity of dilated cardiomyopathy, it is also shown to have prognostic value with higher MPI having a poor prognosis[10, 14].

Studies done by Eidem BW et al and Ishii M et al had shown the usefulness of MPI in early detection of anthracycline induced cardiotoxicity in children[18, 19]. Based on the results, they had recommended that pediatric patients receiving anthracycline should have serial evaluation of MPI for early detection of cardiotoxicity[18, 19]. Paolo Pattoneri et al had shown

in their study that, MPI can be used as an adjunctive parameter in conventional echocardiography for detection of subclinical cardiac toxicity caused by Mitoxantrone[20].

Moradian SJ et al[37] had done serial evaluations of MPI in pediatric patients who underwent heart transplant and correlated it with graft rejection. They found that MPI value can predict rejection in pediatric heart transplant patients[37]. Eidem et al had proved in a study that the MPI is useful in assessment of right ventricular function in children with congenital heart disease[36].

Daniel G Blanchard et al[26] evaluated the utility of right ventricular MPI in the noninvasive evaluation of chronic thromboembolic pulmonary hypertension before and after pulmonary thromboendarterectomy. Their results showed that MPI correlated well with the right ventricular hemodynamics particularly with the pulmonary vascular resistance. They had suggested that MPI may be a valuable noninvasive parameter for monitoring disease severity in chronic thromboembolic pulmonary hypertension and outcome after pulmonary thromboembolectomy[26]. Thomas Menzel et al[25] in their study on patients undergoing pulmonary thromboembolectomy had shown that MPI values of right and left ventricle are useful for assessment of ventricular function, further the postoperative MPI values correlated with the improvement in cardiac function after surgery[25].

Bruch et al[22] studied the utility of MPI in patients with congestive cardiac failure (CCF). They compared the distribution of the conventional echo parameters (LVEF, Transmitral inflow doppler wave analysis and deceleration time) and MPI in normal persons and in patients with CCF. Further the echo parameters and MPI were correlated with the LVEDP value (measured in cardiac catheterization laboratory) of these patients. They found that there was no difference in the distribution of conventional echo parameters between the patients with CCF and normal persons. However the MPI value was significantly different between both the groups. Using a cut off value of > 0.47 for MPI, CCF was predicted with a sensitivity of 86% and specificity of 82%. They concluded that MPI is a sensitive indicator of overall cardiac function in patients with CCF[22].

Fragiskos I et al[23] in their study in CCF patients had shown that MPI value correlates inversely with left ventricular performance, reflects disease severity and is a useful complimentary variable in the assessment of cardiopulmonary exercise tolerance in patients with CCF[23]. Kristen VM et al[24] in their study had shown that the MPI value correlates with the value of B-Natriuretic peptide. They concluded that progressive ventricular dysfunction in patients with CCF can be identified by monitoring either MPI or B-Natriuretic peptide [24].

Poulsen SH et al[29] studied the serial changes in MPI and other echo variables in patients who presented with acute myocardial infarction (AMI). They serially followed 90 patients for 5 years. They found that, MPI value was significantly higher in patients who had events like cardiac failure and mortality when compared with patients without events. On multivariate analysis they found that MPI < 0.6 is an independent factor for long term survival and prognosis. They concluded that MPI had incremental prognostic value in patients with AMI[29].

Moler JE et al[28] studied in 125 patients the correlation of MPI value at the time of AMI with long term left ventricular dilatation and mortality. They found that MPI value correlates well with the long term LV dilatation after AMI, further on multivariate analysis a MPI value > 0.65 is shown to be an independent predictor of long term mortality[28].

Szymanski P et al[31] studied the predictive value of MPI on long term prognosis post AMI in 90 patients. They followed these patients for 5 years. On multivariate analysis MPI > 0.55 was found to be an independent predictor of mortality[31].

Kato M et al[30] studied the usefulness of MPI for assessment of left ventricular outcome in successfully recanalised anterior myocardial infarction. They recorded the MPI in 32 patients on second day after revascularization and correlated it with short term and long term changes in wall motion score

index (WMSI), LVEDP, LVEF, LVEDV. They found that MPI on second day post revascularization significantly correlated with the short term changes of LVEDP and both short and long term changes in WMSI, LVEF, and LVEDV. They concluded that the MPI on second day post revascularization is a representative of coronary vasculature state and reflects the long term outcome of left ventricle[30].

Mabarouk ZN et al[34] tested the hypothesis that MPI is useful in assessing the perioperative cardiac function in patients undergoing mitral valve repair. They measured the prebypass MPI and fractional area change (FAC) values in 25 patients and correlated them with the post bypass values. They found that there is a significant difference between the pre and post bypass FAC values, where as there was no significant difference between the pre and post bypass MPI values. Further the post bypass FAC value correlated closely with the prebypass MPI value than pre bypass FAC value. They concluded that the prebypass MPI value helps in predicting the post bypass FAC and ventricular function, further it helps in identifying the patients with ventricular dysfunction who may have difficulty in weaning from bypass[34].

Al –Mukhaini M et al[32] in their study titled 'MPI as a predictor of postoperative adverse outcomes following mitral valve surgery' prospectively measured preoperative MPI in 22 patients with moderate to severe mitral regurgitation undergoing mitral valve corrective surgery. The primary end

point in their study was either death or CCF. The primary endpoint occurred in nine patients. Five of the six patients with MPI > 0·7 had primary endpoints. Chi-square testing demonstrated that the primary endpoint was signi?cantly associated with advanced age (>70 years) and MPI > 0·7 (P=0·003 and 0·01 respectively). There was a trend towards signi?cant association of depressed LVEF (left ventricle ejection fraction < 40%) and the primary endpoint (P=0·09). Although left ventricle ejection fraction < 40% was more sensitive in predicting the primary endpoint, it had lower speci?city, accuracy and predictive values than MPI > 0·7. They concluded that MPI is a potentially useful predictor of increased risk of peri-operative death or congestive heart failure, in patients with moderate–severe mitral insufficiency undergoing corrective mitral valve surgery[32].

Feroze Mahmood et al[33] studied the association between the perioperative echo parameters (MPI, LVEF, Vp) and postoperative adverse outcome in patients undergoing abdominal aortic surgery. Fifty one patients were enrolled for the study and in the intraoperative period MPI, LVEF and transmitral propagation velocity (Vp) were calculated. Postoperative adverse outcomes like myocardial infarction, congestive cardiac failure, arrhythmias, prolonged ventilation and mortality were noted. Distribution of echo parameters between the patients with and without adverse cardiac events was compared. They found that subjects who had an adverse outcome had a

signi?cantly higher MPI compared with subjects without adverse outcome. The perioperative LVEF was found to be associated only with postoperative prolonged ventilation, similarly Vp was found to be associated only with postoperative arrhythmias. However the perioperative MPI value was found to be associated with all adverse events (CCF, arrhythmias, prolonged ventilation, myocardial infarction and mortality). They concluded that perioperative MPI may be useful as a prospective risk stratification index [33].

Roques F et al[1, 2] designed the EURO score, the primary objective of their study was to assess risk factors for mortality in adult cardiac surgical patients. They collected data regarding various preoperative and intraoperative factors from 128 different centres. A scoring system was developed, after doing multivariate analysis for association between the pre and intra operative factors to the postoperative outcome. The scoring system predicts the risk of mortality of a patient undergoing adult cardiac surgery. Preoperative left ventricular dysfunction was identified as one of the risk factor for mortality in that study. LVEF of 30 – 50 % was given a score of 1 where as LVEF < 30% was given a score of 3 in the calculation of the total risk score[1, 2].

Parsonnett et al[3] devised a scoring index to aid in assessment of risk. Data regarding 47 potential risk factors were acquired from 10 New Jersey centers for all consecutive open heart procedures performed on 10,703 patients during 1994 and 1995. A logistic regression model was developed after

analyzing the distribution of risk factors and their association with outcome. LV ejection fraction was identified as one of the preoperative variable that influences the postoperative outcome[3].

Several scoring systems are designed to assess the risk of the cardiac surgery and to predict the outcome. LVEF is consistently identified in all the scoring systems as a preoperative variable that will determine both the early and late postoperative outcome in terms of mortality and morbidity[1 - 5].

Risum O et al[6] studied the relation between the preoperative left ventricular ejection fraction and postoperative morbidity and mortality after cardiac surgery in 934 patients. The patients were divided in to four subgroups according to their level of left ventricular ejection fraction: <40%, 41-60%, 61-80% and >80%. For mortality within 30 days patients with left ventricular ejection fraction < 40% had a relative risk of 10-2 (1-9-17-2), for left ventricular ejection fraction 41-60% the relative risk was 0 9 (01-8-9) and for left ventricular ejection fraction 61-80% the relative risk was 2-8 (0-6-17-2). Left ventricular ejection fraction >80% was defined as relative risk = 1. Patients with LVEF < 40% had a significant risk for late mortality also when compared with patients with LVEF > 40%. They concluded that low LVEF is a risk factor for both early and late mortality[6].

Veli KT et al[7] analyzed the data of 55, 515 patients to assess the effect of low LVEF on outcomes after CABG. Patients were stratified into 1 of the 4

EF groups: Group I (EF < 20%), Group II (EF 21% to 30%), Group III (EF 31% to 40%), and Group IV (EF > 40%). Upon analysis they found that Group I experienced a higher incidence of postoperative respiratory failure (10.1% versus 2.9%), renal failure (2.5% versus 0.6%), and sepsis (2.5% versus 0.6%) compared with Group IV. In-hospital mortality was significantly higher in Group I (6.5% versus 1.4%; P<0.001). They concluded that patients with low EF are sicker at baseline and have more than four times higher mortality than patients with high EF[7].

Legare JF et al[8] evaluated the data of 1829 patients undergoing CABG to determine the pre and intraoperative factors that are associated with prolonged mechanical ventilation. Preoperative LVEF < 50% was found to be an independent predictor of prolonged postoperative ventilation[8].

Vaskelyte J et al[9] did a study to evaluate the in?uence of left ventricular diastolic ?lling impairment on postoperative results in patients with low LVEF (<35%) undergoing coronary artery bypass grafting (CABG). The study covered 56 patients (mean age 58·9±17·1 years). Two dimensional Doppler echocardiographic investigations were performed pre- and 10–14 days post-CABG. Patients were divided into three groups according to the LV diastolic filling. Early postoperative mortality rate (including perioperative period and 2 weeks after surgery) was highest in the restriction group (33%) vs. pseudonormalization (12·5%) vs. impaired relaxation (13·6%). Postoperative

cardiovascular complications rate was highest also in the restriction group, 55·5%, and did not differ between pseudonormalization (25%) and impaired relaxation group (27·2%). Logistic regression analysis showed that restrictive LV filling pattern, early diastolic filling deceleration time and LV end-diastolic diameter independently in?uence perioperative mortality. In the early postoperative period mean LV wall motion score (WMS) did not improve in 8/19 (42%), 6/14 (43%) and 8/12 (67%) patients, respectively, in the impaired relaxation, pseudonormalization and restriction group. They concluded that in patients with severe LV dysfunction undergoing CABG, impaired relaxation and pseudonormalization pattern of LV diastolic filling are correlated with postoperative improvement in LV regional contraction. Whereas the restrictive pattern of diastolic filling is associated with high early postoperative mortality, morbidity and minimal improvement in LV systolic function[9].

Materials & Methods

Methodology

This is a prospective observational single centre study conducted at the hospital wing of SCTIMST. Institutional ethics committee approval was obtained for this study. Principle investigator recruited the participants for this study. Adult patients who are posted for elective coronary bypass grafting on cardiopulmonary bypass (CPB) and have already given consent for the surgical procedure were considered on the day before the surgery for inclusion in the study. Those patients who met all the inclusion criteria and did not have any of the exclusion criteria were approached. They were told about the study process and the data that would be collected, they were told that they had the right to opt for not being included in the study. They were also told that they were free to withdraw from the study at any time, without giving any reason, and without their medical care or legal rights being affected

Informed written consent was taken if the patient agreed to participate in the study. The patient was than considered as a subject in the study and relevant data needed for the study was collected.

Inclusion criteria –

1. Adult patients (>18 years)
2. Both male and female patients

3. Undergoing elective coronary artery bypass grafting (CABG) on cardiopulmonary bypass at SCTIMST cardiac surgery operation theatre

4. Preoperative sinus rhythm

Exclusion Criteria –

1. Refusal by patient

2. Whenever placement of transesophageal echocardiography probe is contraindicated

3. Patients who are not in sinus rhythm during preoperative and intraoperative (pre CPB) periods

4. Associated moderate or severe ischemic mitral regurgitation or any other valvular lesion

5. Emergency procedure

6. Patients' who are on preoperative inotropic infusion

7. Patients who are on preoperative intra-aortic balloon counter pulsation pump (IABP)

8. Patients with preoperative renal dysfunction.

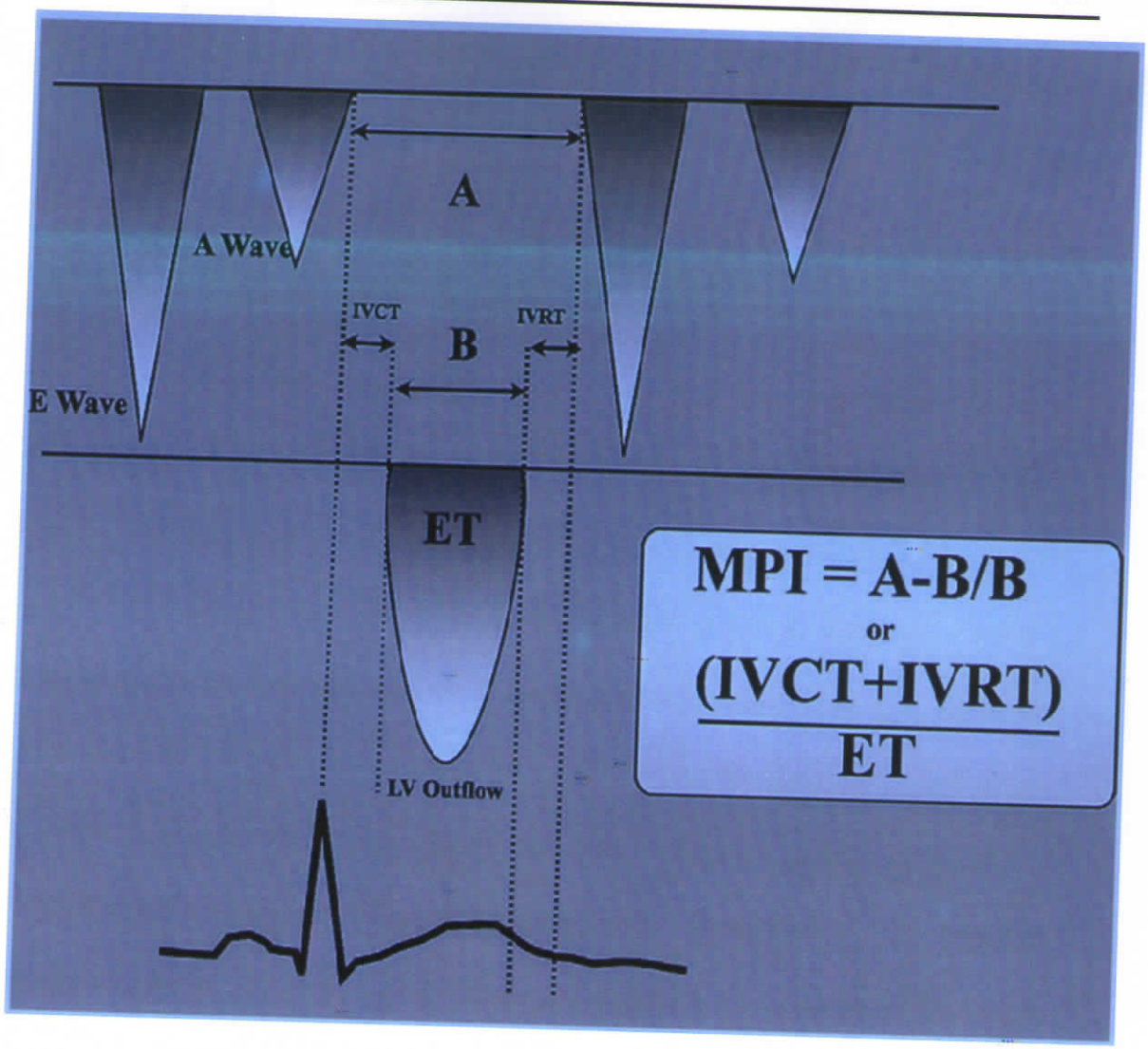
9. Patients who are not fully competent to give consent

The patient's preoperative data (history, examination findings, and investigations) were reviewed by the investigators. All patients were premedicated with oral diazepam (0.1mg/kg) and intramuscular morphine (0.1mg/kg) as per institutional standard practice. Anesthesia was induced with oxygen, fentanyl (2 -4 micrograms/kg), midazolam (0.03 – 0.07 mg/kg), and sleep dose of thiopentone / propofol. Vecuronium / pancuronium were used for muscle relaxation. Anesthesia was maintained with oxygen & air, isoflurane, fentanyl (boluses when needed), morphine infusion (40 – 80 micrograms/kg /hr), midazolam, and pancuronium.

Standard pre-induction monitoring in all patients included electrocardiography (ECG), pulse oximetry (SPO_2), heart rate (HR), end-tidal carbon-di-oxide ($ETCO_2$), gas analysis, & direct arterial blood pressure. After induction of anesthesia, central venous pressure (CVP) catheter, temperature probe, and Foleys catheter were placed. Transesophageal Echocardiography (TEE) probe was placed (after induction) in all patients and a routine comprehensive intraoperative TEE examination was done. The following were calculated for study purpose:

1. **Myocardial performance index (MPI)** - The midesophageal 4 chamber view was obtained, the Doppler beam was aligned parallel to the mitral inflow and pulse wave Doppler (PWD) recording of mitral inflow was recorded at the tips of the mitral leaflets. **Interval A** was recorded from the

end of ***a*** wave of mitral inflow to the beginning of the ***e*** wave. This interval includes isovolumetric contraction time (IVCT), ejection time (ET) & isovolumetric relaxation time (IVRT). The probe is then advanced to obtain the deep transgastric long axis view and the Doppler beam was aligned to the left ventricle outflow tract (LVOT). A PWD sample volume was placed in the LVOT and the flow velocity profile across the LVOT is obtained. **Interval B** is measured as the duration of the flow profile and this measure the duration of the ejection time (ET). All measurements were taken during periods of apnea, and the final value was obtained as the average of three readings obtained in close succession. All the measurements were obtained during a period when the patient was hemodynamically stable. Care was taken to ensure that the hemodynamic parameters (HR, IBP) of the patient remained unchanged during the process of recording. Any recordings obtained during conditions that did not satisfy the above criteria were not taken for the study purpose. MPI was obtained from the equation {**(A-B) ÷ B**}. This effectively gives the value of {**(IVCT+IVRT) ÷ ET**}.



For the sake of study, patients were divided into three groups based on MPI value; **GROUP 1 –** MPI < 0.36, **GROUP 2 –** MPI 0.36 – 0.5, **GROUP 3 –** MPI > 0.5.

2. Ejection fraction (EF) – This is calculated from the mid-esophageal 4 chamber and mid-esophageal 2 chamber views using the modified Simpsons

method. An average of three recordings obtained in close succession was taken. Patients were classified into four groups based on LVEF value; **group A** – LVEF > 50% , **group B** – LVEF 40 – 50%, **group C** – LVEF 30 – 40%, **group D** – LVEF < 30%.

All the patients underwent CABG on CPB and were operated by a single surgeon. The standard surgical procedure was to anastomose the left internal mammary artery to the left anterior descending coronary artery and to anastomose the saphenous venous grafts to other graftable diseased coronary arteries (proximal anastomosis on ascending aorta). Distal anastomoses to the coronary arteries were done during the period when the aorta remained cross-clamped. When the distal anastomoses were completed, aortic cross clamp was released and the proximal anastomoses were done with a side clamp on ascending aorta. The surgery was done under mild hypothermia (30^0C). Tepid Antegrade blood cardioplegia (20 -25 ml/kg) was used for induction of diastolic arrest. Antegrade cardioplegia (10 -12 ml/kg) was repeated every 30 minutes for maintenance of arrest.

Attempts to wean off CPB were done after grafting was completed, the patient was fully warmed, heart rate and contractility were satisfactory, & metabolic as well as electrolyte parameters were normal. Pacing was performed in patients with low heart rate and good contractility. Inotropic

infusion was started when the contractility was not satisfactory. According to the standard institutional protocol adrenaline was used as the inotrope of first choice in patients with poor contractility. Mean arterial pressure of 70 mmHg and above were accepted targets once the patient was off cardiopulmonary bypass. If the blood pressure was low, a quick assessment (clinical and TEE guided) was done. Low pressure due to low systemic vascular resistance (dilated patient) was treated by the use of an alpha agonist (Noradrenaline). If the contractility was poor, intraaortic balloon pump insertion was done to maintain adequate perfusion pressure. Additional vasopressors or inotropic agents were started whenever required. The number of attempts needed to wean the patient off cardiopulmonary bypass was noted.

Post cardiopulmonary bypass volume supplementation was guided by filling pressures, clinical assessment, hemodynamic monitoring, and TEE. The inotropic requirement after chest closure was noted for the study purpose. At the end of surgery, patients were shifted to the intensive care unit for elective ventilation and further management.

The management of patients in intensive care unit was guided by the standard institutional practices and protocols. The management of patient in the intensive care unit was by a separate team of doctors who were blinded to the MPI value of the patient.

❖ All patients who were hemodynamically stable were actively warmed to maintain a peripheral temperature of more than 32^0C.

❖ The hemodynamics were actively managed to maintain a mean arterial pressure between 70 – 90 mm of Hg. Management of low pressures were guided by filling pressures and clinical assessment. Hypotension in patients with low filling pressure was managed by volume supplementation and if the hypotension persisted even with adequate filling pressures, inotropic infusion was increased. If the mean arterial pressure was more than 90 mm of Hg, inotropic infusion was titrated to bring down the pressure.

❖ Echocardiographic assessment of cardiac function (by cardiologist) was done in patients with persistent hypotension and in patients who were on IABP (at needed intervals as determined by the intensivist). IABP support was gradually weaned off when the contractility improved (as assessed by echocardiography) and the patient was. hemodynamically stable.

❖ Weaning from mechanical ventilation was started when the patient was warm, hemodynamically stable, conscious and other parameters were satisfactory. The patient was then gradually weaned and the trachea extubated. Patients who were not hemodynamically stable, those having poor cardiac function, and those on IABP were electively ventilated till the cardiac function and hemodynamic parameters were satisfactory.

- ❖ Postoperative episodes of cardiac failure (defined by episodes of pulmonary edema, low cardiac output, poor contractility on echocardiography done by cardiologist, and S3 gallop) were managed according to the clinical scenario by diuretics, inotropic infusion, medications, oxygen supplementation, and noninvasive or invasive ventilation.

- ❖ The general management of the patient including fluid balance, medications, investigations, analgesia, removal of lines and drains, restoration of oral feeding and shifting to the ward were done according to the standard institutional practices and protocols.

The following postoperative data were collected by the investigators for the study purpose. These data were collected from the patient's charts and files in the intensive care unit (ICU).

- ➢ Inotrope requirement (dose, number & duration in hours),

- ➢ Duration of ventilation (hours, divided into three groups A = < 10 hours, B = 10 -24hours, C = > 24 hours)

- ➢ IABP usage

- Episodes of cardiac failure (defined as clinical or radiological evidence of pulmonary edema that requires diuretics, oxygen supplementation, noninvasive or invasive ventilation)
- Mortality
- Any other events which the investigators thought was significant

Statistical methods

Results obtained from the study were expressed as mean +/- SD. For non parametric data Kruskal Wallis test was applied. For data with continuous variables ANOVA for repeated measures followed by post hoc analysis with Scheffe multiple comparisons was performed. A p value less than 0.05 was regarded as statistically significant. Pearson correlation coefficient was done to find relationship between selected continuous variables. A significant difference between two correlation coefficients was calculated. Appropriate statistical procedures from SPSS 11.0 were used for analysis.

Observations & Results

Results obtained from the study are expressed in the tabular format.

Demographic data

TABLE NO – 1 DEMOGRAPHIC DATA

		Number of patients	Percent (%)
Age	**50 - 59**	24	26.7
	60 - 69	63	70.0
	>=70	3	3.3
	Average	62.4 ± 4.6	
Sex	**Male**	62	68.9
	Female	28	31.1

The demographic data are expressed in table no -1. The mean (±S.D) age of the patients in the present study is around 62.4 (± 4.6) years. Of the total 90 patients 28 patients were female while the rest were male.

Distribution MPI values across the study population.

Table no – 2 DISTRIBUTION OF MPI ACROSS THE STUDY POPUALATION (data expressed as absolute number followed by percentage among the total study population).

		Number of patients	Percentage (%)
MPI	**<0.36**	48	53.3
	0.36 - 0.5	33	36.7
	>0.5	9	10.0
	Average (mean ± S.D)	0.4 ± 0.1	

For the purpose of comparison the authors have divided the patients into three groups based on the value of MPI, **Group 1** – MPI < 0.36, **Group 2** – MPI 0.36 – 0.5, **Group 3** – MPI > 0.5. Of the total 90 subjects in the present study 48 patients had a MPI value of < 0.36, where as 33 patients had a MPI value between 0.36 – 0.5. 9 patients had a MPI value of > 0.5. The overall mean (±S.D) of MPI for all patients in the present study is 0.4 (± 0.1). Based on the data from previous studies on MPI, this distribution of MPI values in the study population shows that there is a good representation of patients of all types of cardiac function in the present study.

Distribution of LVEF across the study population

Table no – 3 DISTRIBUTION OF LVEF ACROSS THE STUDY POPULATION

(data expressed as absolute number followed by percentage among the total study population).

		Number of patients	Percentage (%)
LVEF	**>50**	37	41.1
	40 – 50	29	32.2
	30 – 40	18	20.0
	<30	6	6.7
	Average (mean ± S.D)	46.5 ± 9.4	

Patients were divided into four groups for the purpose of study. **Group A** – good LV function with LVEF - >50%, **Group B** – mild LV dysfunction with LVEF 40 – 50%, **Group C** – moderate LV dysfunction with LVEF 30 -40%,

Group D – severe LV dysfunction with LVEF < 30%. From analyzing the results it is found that 37 (41.1 %) of patients had good LV function, 29 (32.2%) patients had mild LV dysfunction, where as 18 (20%) patients had moderate LV dysfunction. 6 patients (6.7%) had severe LV dysfunction.

Comparison of dose of inotropic infusion at chest closure and echo variables

Table no -4 Comparison of dose of inotropic infusion at chest closure and MPI. (Data are represented as mean ± S.D.)

The dose of inotropic infusion at the time of chest closure is noted and is compared with the value of MPI.

		Mean	SD	N	p value	
MPI	**Group 1 (<0.36)**	0.038	0.022	48	Total	< 0.01
	Group 2 (0.36 - 0.5)	0.068	0.026	33	**1 vs 2**	< 0.01
	Group 3 (>0.5)	0.100	0.000	9	**1 vs 3**	< 0.01
					2 vs 3	0.001

The results of the comparison have shown that in patients with MPI < 0.36 requirement of inotropic infusion is less than the other groups. When the requirement was compared in between groups it showed that there is a statistically significant difference between the dose of inotropic infusion requirement between group 1 and group 2, group 1 and group 3 and in between group2 and group 3.

Table no – 5 COMPARISON OF DOSE OF INOTROPIC INFUSION AT CHEST CLOSURE AND LVEF (Data are represented as mean ± S.D.)

	LVEF	Mean	SD	N	p value	
LVEF	**Group A >50%**	0.048	0.025	37	Total	0.001
	Group B 40 – 50%	0.049	0.029	29	**A vs B**	1.000
	Group C 30 – 40%	0.068	0.034	18	**A vs C**	0.102
	Group D < 30%	0.090	0.024	6	**A vs D**	0.012
					B vs C	0.152
					B vs D	0.452

The dose of inotropic infusion at the time of chest closure is noted and is compared in between the patients with reference to LVEF. It is found that there is no statistically significant difference in the required dose of inotropic inotropic infusion in between Group A vs. group B, Group A vs. Group C. how ever there was a statistically significant difference between group A and group D. when the required dose of inotropic infusion was compared between Group B vs. Group C and Group B vs. Group D there was no significant difference.

Comparison of duration of inotropic infusion and echo variables

Table no -6 comparison of duration of inotropic infusion and MPI (Data represented as hours in mean ± S.D.)

		Mean (Hours)	SD	N	p value	
MPI	**Group 1 <0.36**	6.7	4.0	48	Total	< 0.01
	Group 2 0.36 - 0.5	15.2	7.9	33	**1 vs 2**	< 0.01
	Group 3 >0.5	32.2	8.6	9	**1 vs 3**	< 0.01

					2 vs 3	< 0.01

The mean ± S.D. duration of inotropic infusion for Group 1 is 6.7 (±4.0) hours, for Group 2 is 15.2 (± 7.9) hours and for Group 3 is 32.2 (± 8.6 hours). There was a statistically significant difference ($p < 0.01$) between group 1 vs. group 2, group1 vs. group 3, and group 2 vs. group 3 in terms of duration of the requirement of inotropic infusion.

Table no -7 comparison of duration of inotropic infusion and LVEF (Data represented as hours in mean ± S.D.)

		Mean	SD	N	p value	
LVEF	**Group A >50 %**	9.0	4.8	37	Total	< 0.01
	Group B 40 – 50 %	10.7	8.1	29	**A vs B**	0.903
	Group C 30 – 40 %	17.2	12.9	18	**A vs C**	0.018
	Group D <30 %	26.8	14.0	6	**A vs D**	< 0.01
					B vs C	0.110

					B vs D	0.144

The mean ± S.D. duration of inotropic infusion (in hours) for Group A is 9.0 (± 4.8), for Group B is 10.7 (± 8.1), for Group C is 17.2 (± 12.9) and for Group D (26.8 ±14.0). There was a statistically significant difference in terms of duration of inotropic infusion between the Group A and Group D. How ever there was no significant difference when any other two groups were compared.

Comparison of correlation between the dose of inotropic infusion at chest closure and MPI and LVEF.

Table No - 8 Comparison of correlation between dose of inotropic infusion at chest closure and MPI and LVEF

	r	N	CR	Sig.
MPI	0.8	90	9.30	p<0.01
LVEF	-0.4	90		

Pearson correlation coefficient was used to find relationships between the dose of inotropic infusion at chest closure and MPI and LVEF. Test of significance between the two correlation coefficients was calculated. When the dose of inotropic infusion at chest closure was compared with the MPI, it was found to have a correlation coefficient of r = 0.8, which means that the MPI value correlates well (positive correlation) with the required dose of inotropic

infusion at the time of chest closure. When the dose of inotropic infusion at chest closure was compared with the LVEF, it was found to have a correlation coefficient r = - 0.4. This means that the value of LVEF correlates (negative) with the dose of inotropic infusion at chest closure, though the correlation is not that strong. When the significant difference between both the correlations were calculated using Test of significance between two correlations, it showed a critical ratio CR = 9.3 and the p value was less than 0.01. This implies that MPI value correlates better than the LVEF value with the dose of inotropic infusion at chest closure.

Comparison of correlation between duration of inotropic infusion and MPI and LVEF.

Table No - 9 Comparison of correlation duration of inotropic infusion and MPI and LVEF

	r	N	CR	Sig.
MPI	0.9	90	11.68	p<0.01
LVEF	-0.5	90		

Pearson correlation coefficient was used to find relationships between the duration of inotropic infusion and MPI and LVEF. Test of significance between the two correlation coefficients was calculated. When the duration of

inotropic infusion was compared with the MPI, it was found to have a correlation coefficient of r = 0.9, which means that the MPI value correlates well (positive correlation) with the duration of inotropic infusion. When the duration of inotropic infusion was compared with the LVEF, it was found to have a correlation coefficient r = - 0.5. This means that the value of LVEF correlates (negative) with the duration of inotropic infusion, though the correlation is not that strong. When the significant difference between both the correlations were calculated using Test of significance between two correlations, it showed a critical ratio CR = 11.68 and the p value was less than 0.01. This implies that MPI value correlates better than the LVEF value with the duration of inotropic infusion.

Comparison between the MPI and selected variables

Table No- 10 comparison between the MPI and selected variables. *(Data represented as absolute number of events followed by percentage in brackets).*

		MPI			P value
		<0.36	**0.36 - 0.5**	**>0.5**	
Attempts to wean	1	48 (55.2)	32 (36.8)	7 (8)	< 0.01 #
	2	0 (0)	1 (33.3)	2 (66.7)	
IABP	No	48 (55.8)	33 (38.4)	5 (5.8)	< 0.01#
	Yes	0 (0)	0 (0)	4 (100)	
Inotropes number	0	7 (100)	0 (0)	0 (0)	< 0.01#
	1	40 (60.6)	26 (39.4)	0 (0)	
	2	1 (7.7)	7 (53.8)	5 (38.5)	
	3	0 (0)	0 (0)	4 (100)	

- For MPI value more than 0.5

Selected postoperative variables were compared with the prebypass MPI. A total number of three patients required more than one attempt to wean off from CPB. When the distribution of MPI was compared between them it showed that two of them had MPI more than 0.5 and the third one had MPI between 0.36 – 0.5. When the ANOVA was used to see the significance of association

it showed a p value of < 0.01. Four patients required IABP in the entire study group. All four of them had MPI values more than 0.5. When ANOVA was applies it showed a significant association (p <0.01) between the MPI value of more than 0.5 and requirement of IABP.

Of the total 90 patients in the present study 7 patients required no inotropic infusion, 66 required one inotropic infusion, 13 patients required two inotropic infusions and four required three or more than three inotropic infusions. Of the thirteen patients who required two inotropic infusions one had MPI less than 0.36, seven had MPI between 0.36 – 0.5 and five of them had MPI more than 0.5. All of the four patients who required three or more inotropic infusions had MPI more than 0.5. When the ANOVA test was applied to test for significance it showed that the MPI is significantly (p <0.01) associated with the number of inotropic infusions required postoperatively.

Table No- 11 comparison between the MPI and selected variables. *(Data represented as absolute number of events followed by percentage in brackets).*

VARIABLE		MPI			P value
		< 0.36	**0.36 – 0.5**	**> 0.5**	
Duration of ventilation	<=10	34 (69.4)	15 (30.6)	0 (0)	< 0.01#
	10 - 24	14 (38.9)	18 (50)	4 (11.1)	
	>24	0 (0)	0 (0)	5 (100)	
Failure (CCF)	No	48 (54.5)	33 (37.5)	7 (8)	< 0.01#
	Yes	0 (0)	0 (0)	2 (100)	
Mortality	No	48 (53.9)	33 (37.1)	8 (9)	--
	Yes	0 (0)	0 (0)	1 (100)	

For MPI value of more than 0.5

The duration of ventilation was compared with the prebypass MPI values. Of the total 90 patients 49 patients were extubated within 10 hours in the postoperative period, 36 patients were extubated between 10 – 24 hours and 5 patients were ventilated beyond 24 hours. When the ANOVA test was applied to see the significance it showed that there was a statistically significant association ($p < 0.01$) between the duration of ventilation and MPI value. Two patients in the study population developed postoperative congestive cardiac

failure (CCF). Both the patients had prebypass MPI value of more than 0.5. When the ANOVA test was applied it showed a statistically significant association between the MPI value of more than 0.5 and postoperative CCF. There was only one case of postoperative mortality in our study population. The prebypass MPI value of this patient was more than 0.5. Since the number of mortality is only one, statistical association between the higher MPI values and postoperative mortality could not be done.

Comparison between the LVEF and selected variables

Table No- 12 comparison between the MPI and selected variables. *(Data represented as absolute number of events followed by percentage in brackets).*

		LVEF				p
		>50	**40 - 50**	**30 - 40**	**<30**	
Attempts to wean	1	37 (42.5)	28 (32.2)	17 (19.5)	5 (5.7)	0.186
	2	0 (0)	1 (33.3)	1 (33.3)	1 (33.3)	
IABP	No	37 (43)	29 (33.7)	16 (18.6)	4 (4.7)	< 0.01
	Yes	0 (0)	0 (0)	2 (50)	2 (50)	
Inotropes number	0	1 (14.3)	3 (42.9)	3 (42.9)	0 (0)	< 0.01*
	1	33 (50)	23 (34.8)	9 (13.6)	1 (1.5)	
	2	3 (23.1)	3 (23.1)	5 (38.5)	2 (15.4)	
	3	0 (0)	0 (0)	1 (25)	3 (75)	

* - For LVEF less than 40 %

Selected postoperative variables were compared with the prebypass LVEF value. Of the three patients who required more than one attempts to come off CPB, one had VEF between 40 -50%, second one had LVEF between 30 – 40% and the third patient had LVEF < 30%. When the ANOVA test was used to see the statistical significance it showed that there is no statistically

significant association ($p = 0.186$) between prebypass LVEF and number of attempts required to wean from CPB.

Of the four patients who required IABP, two patients had LVEF between 30 -40% and the other two had LVEF < 30%. When ANOVA test was applied it showed that the prebypass LVEF is significantly associated ($p < 0.01$) with postoperative IABP requirement.

Among the thirteen patients who required two inotropic infusions in the postoperative period, three of them had LVEF > 50%, three had LVEF between 40 – 50%, five patients had LVEF between 30 - 40% and two patients had LVEF < 30%. When the ANOVA test was applied to see for statistical significance it showed that prebypass LVEF < 40% is significantly associated ($p < 0.01$) with requirement of two or more inotropic infusions.

Table No- 13 comparison between the LVEF and selected variables. *(Data represented as absolute number of events followed by percentage in brackets).*

		LVEF				P value
		> 50%	**50 – 40%**	**30 – 40%**	**< 30%**	
Duration of ventilation	<=10	31 (63.3)	14 (28.6)	4 (8.2)	0 (0)	< 0.01*
	10 - 24	6 (16.7)	15 (41.7)	11 (30.6)	4 (11.1)	
	>24	0 (0)	0 (0)	3 (60)	2 (40)	
Failure	No	37 (42)	29 (33)	16 (18.2)	6 (6.8)	0.044*
	Yes	0 (0)	0 (0)	2 (100)	0 (0)	
Mortality	No	37 (41.6)	29 (32.6)	18 (20.2)	5 (5.6)	-
	Yes	0	0	0	1	

* - For LVEF < 40%.

The duration of prebypass LVEF was compared with the post bypass ventilation requirement. Of the thirty six patients who required ventilation between 10 – 24 hours, six patients had prebypass LVEF > 50%, eleven patients had prebypass LVEF 40 – 50%, eleven patients had prebypass LVEF 30 – 40% and four had prebypass LVEF < 30%. Among the five patients who required ventilation more than 24 hours three had LVEF 30 – 40% and two had LVEF < 30%. When the statistical analysis was done with ANOVA test it showed that there is a significant association between the prebypass LVEF and

postoperative duration of ventilation with patients LVEF < 40% requiring prolonged ventilation.

Two patients in the study population developed postoperative CCF and both of them had prebypass LVEF of 30 -40%. When the statistical association was done it showed that there was significant association (0.044) between prebypass LVEF < 40% and postoperative CCF. There was only one case of postoperative mortality in our study population. The prebypass LVEF value of this patient was < 30%. Since the number of mortality is only one, statistical association between the higher MPI values and postoperative mortality could not be done

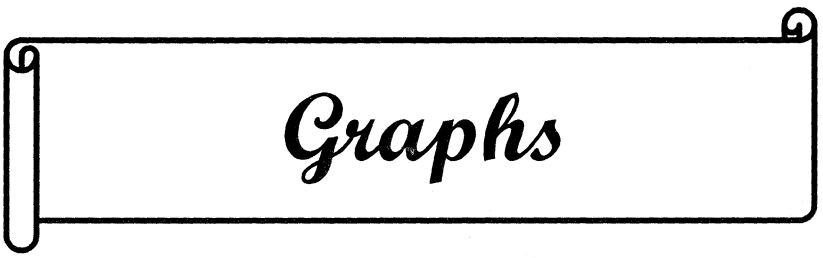

Graphs

Fig 1. Percentage distribution of the sample according to age

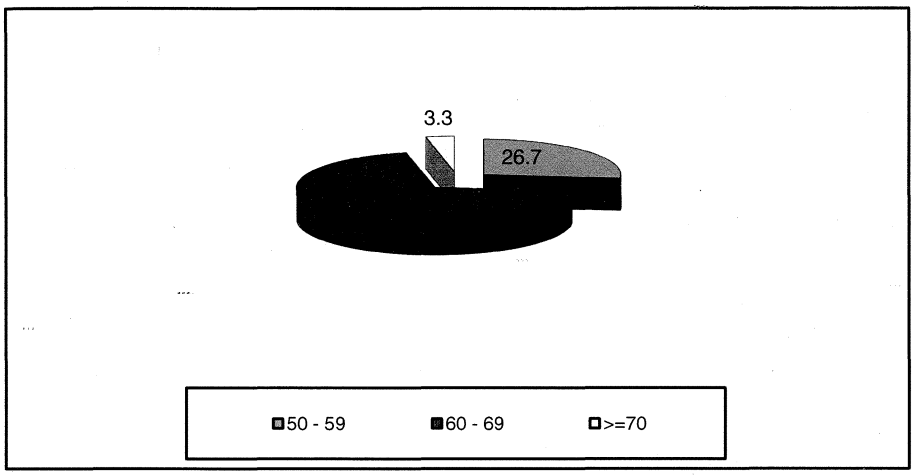
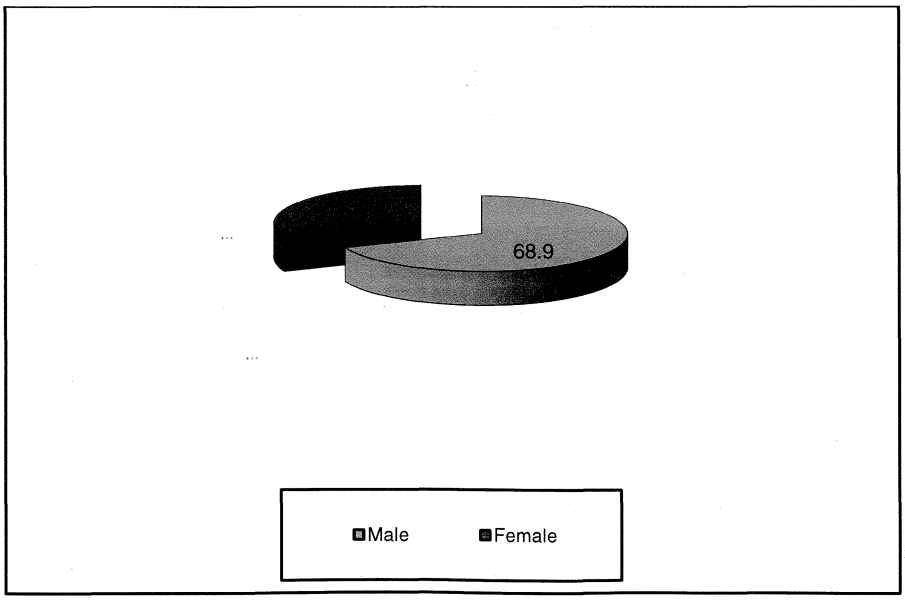
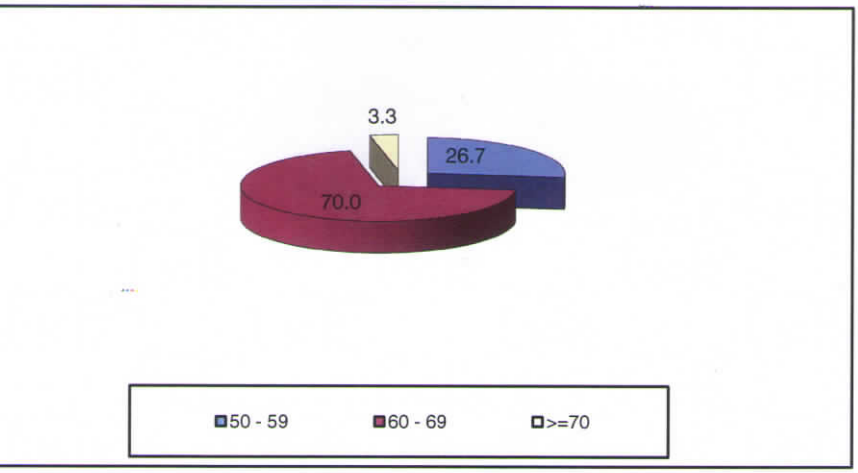


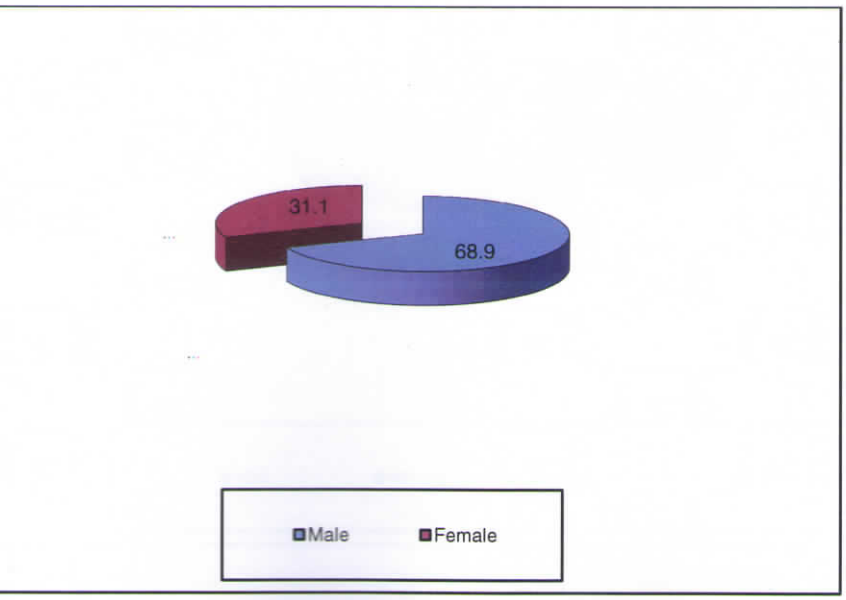
Fig 2. Percentage distribution of the sample according to sex



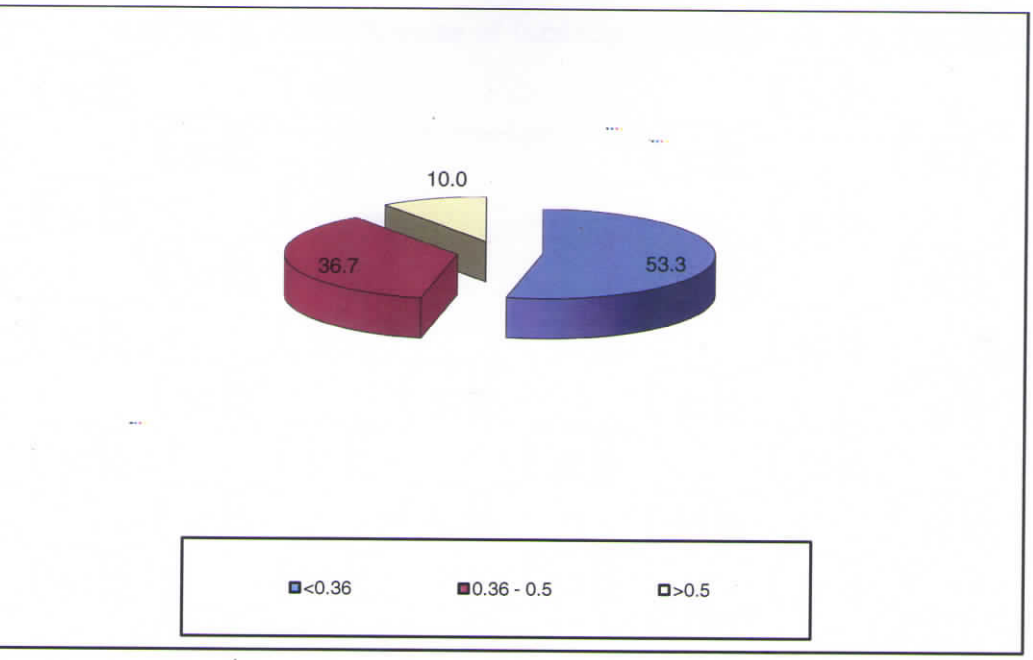
1. Percentage distribution of the sample according to age



2. Percentage distribution of the sample according to sex



g 3. Percentage distribution of the sample according to MPI



g 4. Percentage distribution of the sample according to LVEF

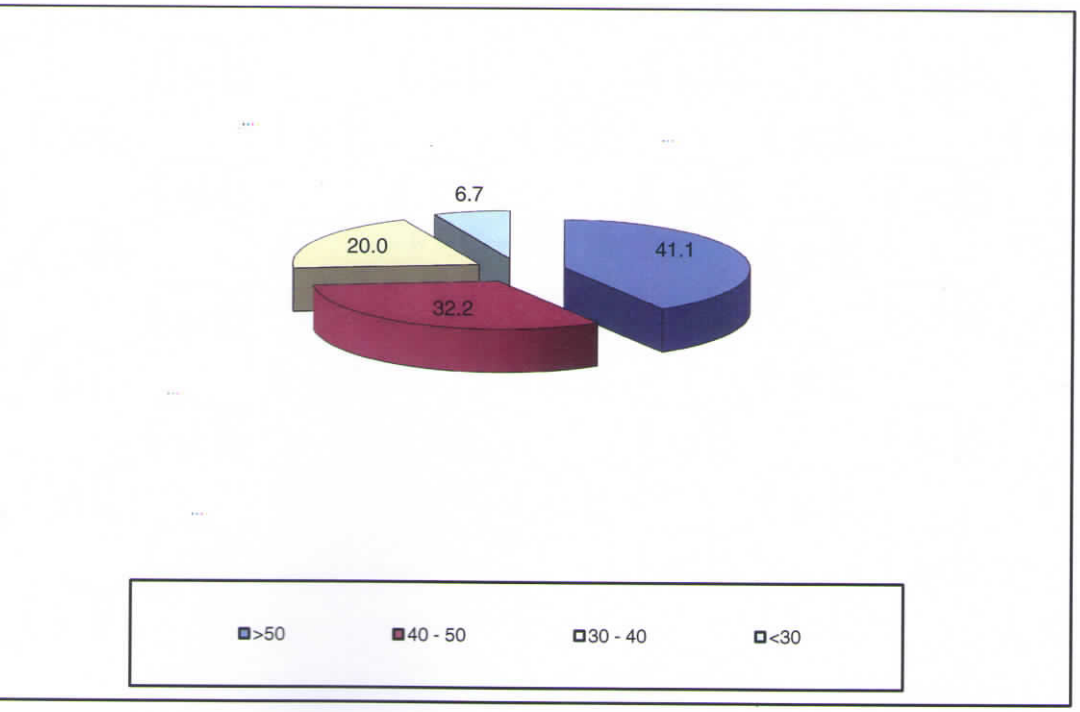
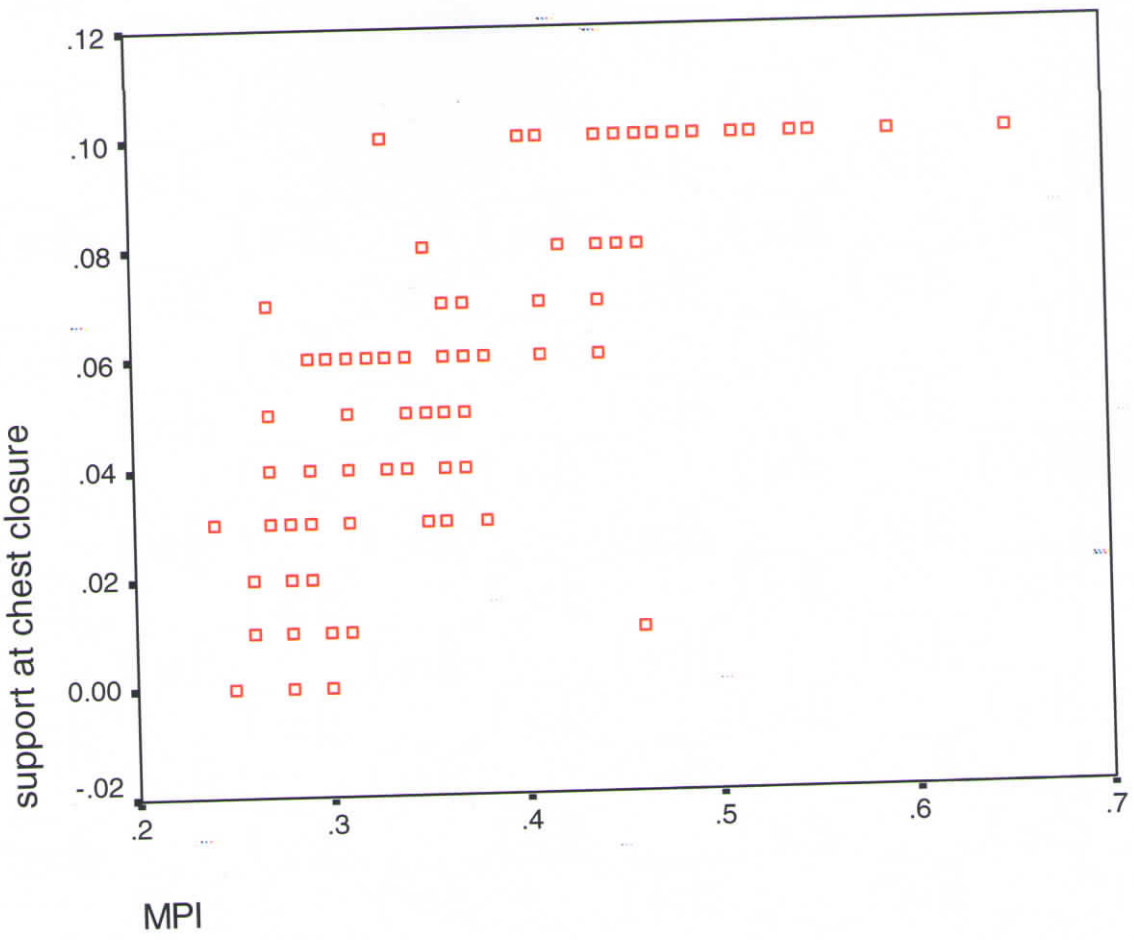
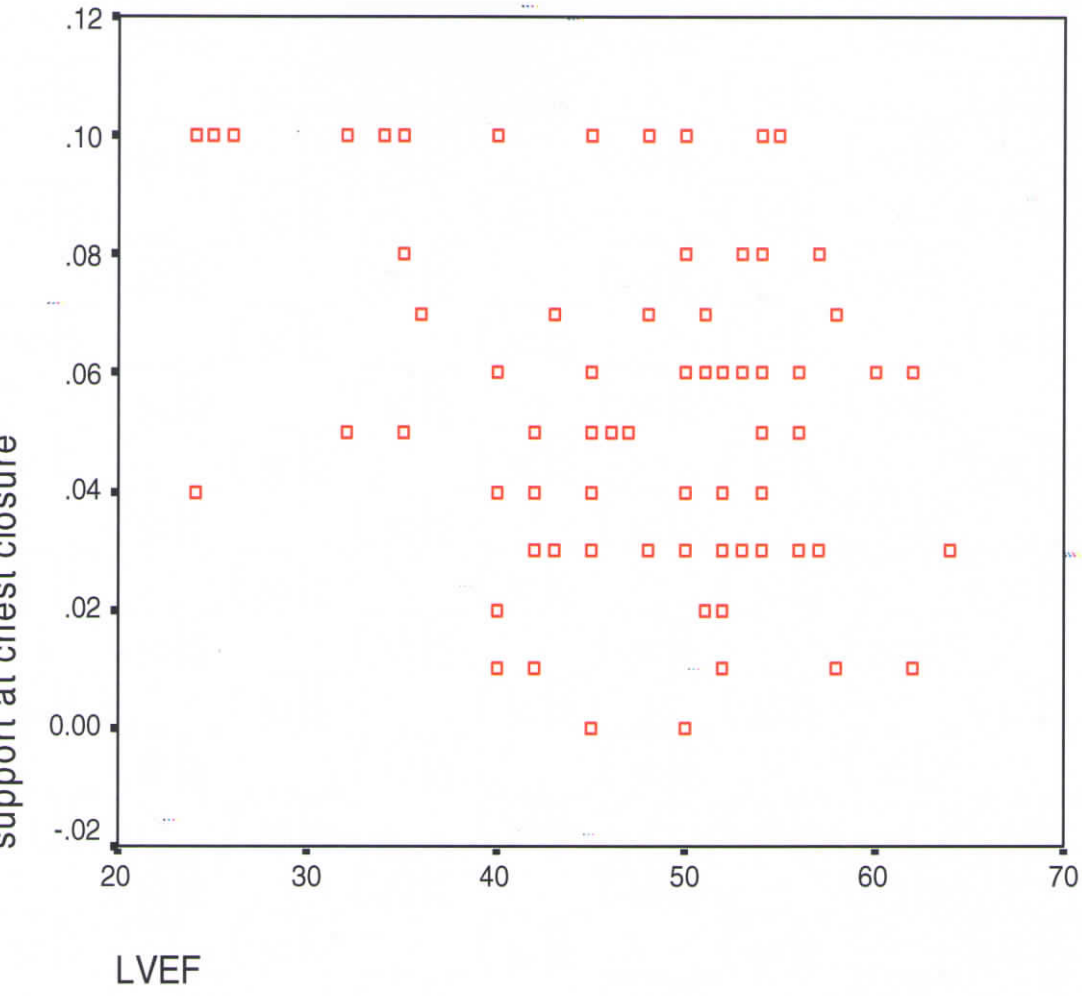


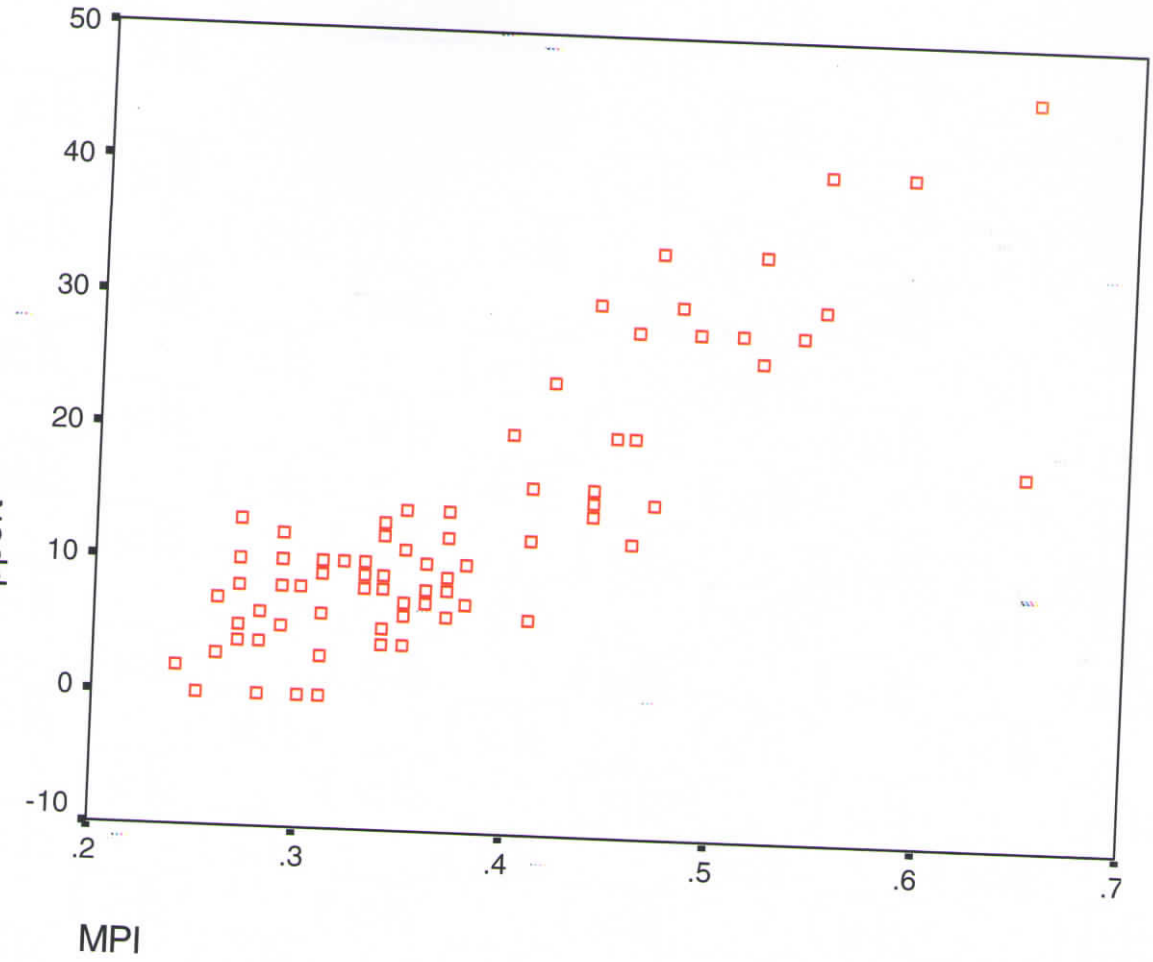
Fig 5. Scatter plot of MPI & dose of inotropic infusion at chest closure



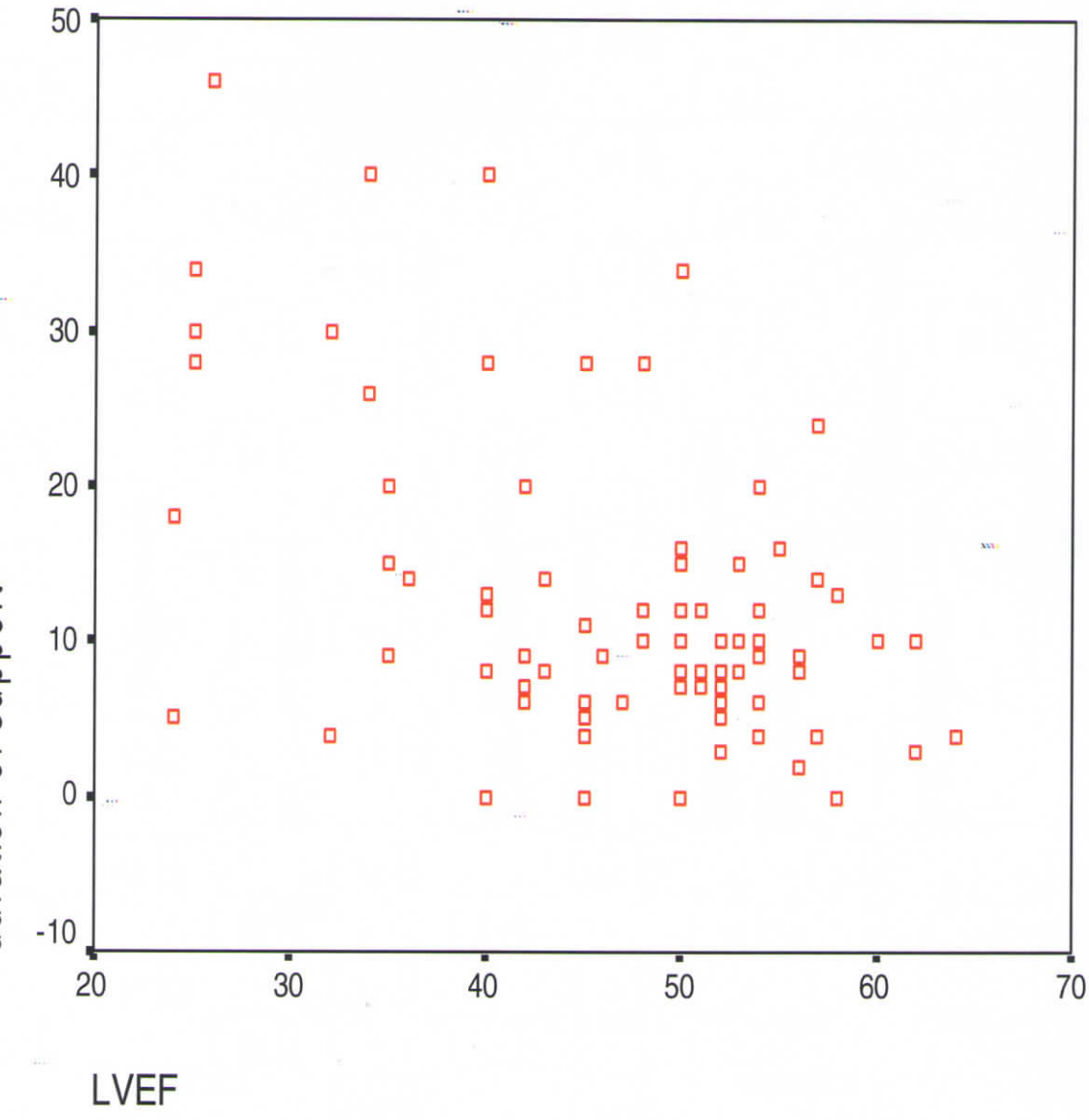
. Scatter plot of LVEF & dose of inotropic infusion at chest closure



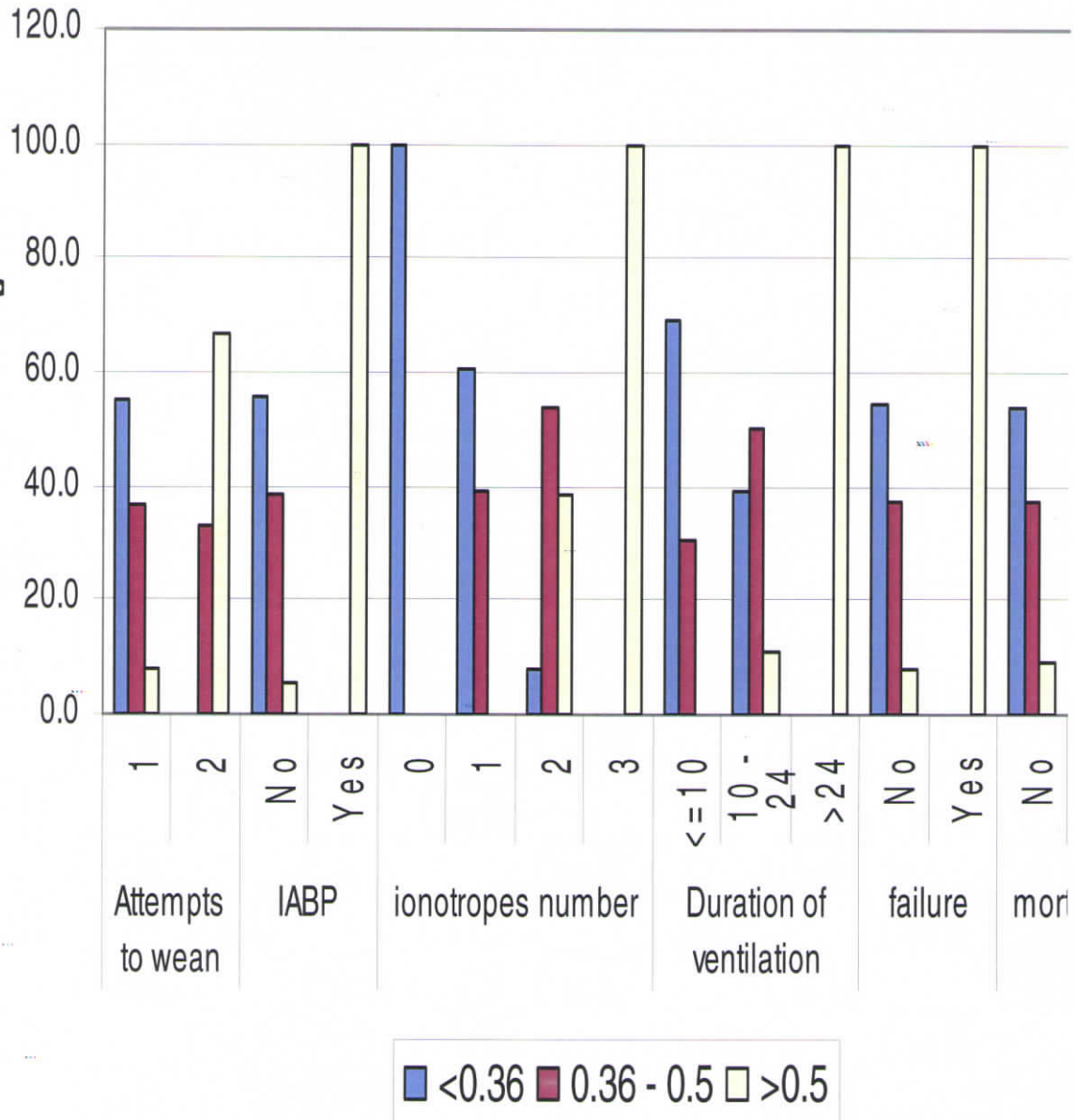
. Scatter plot of MPI & duration of inotropic infusion



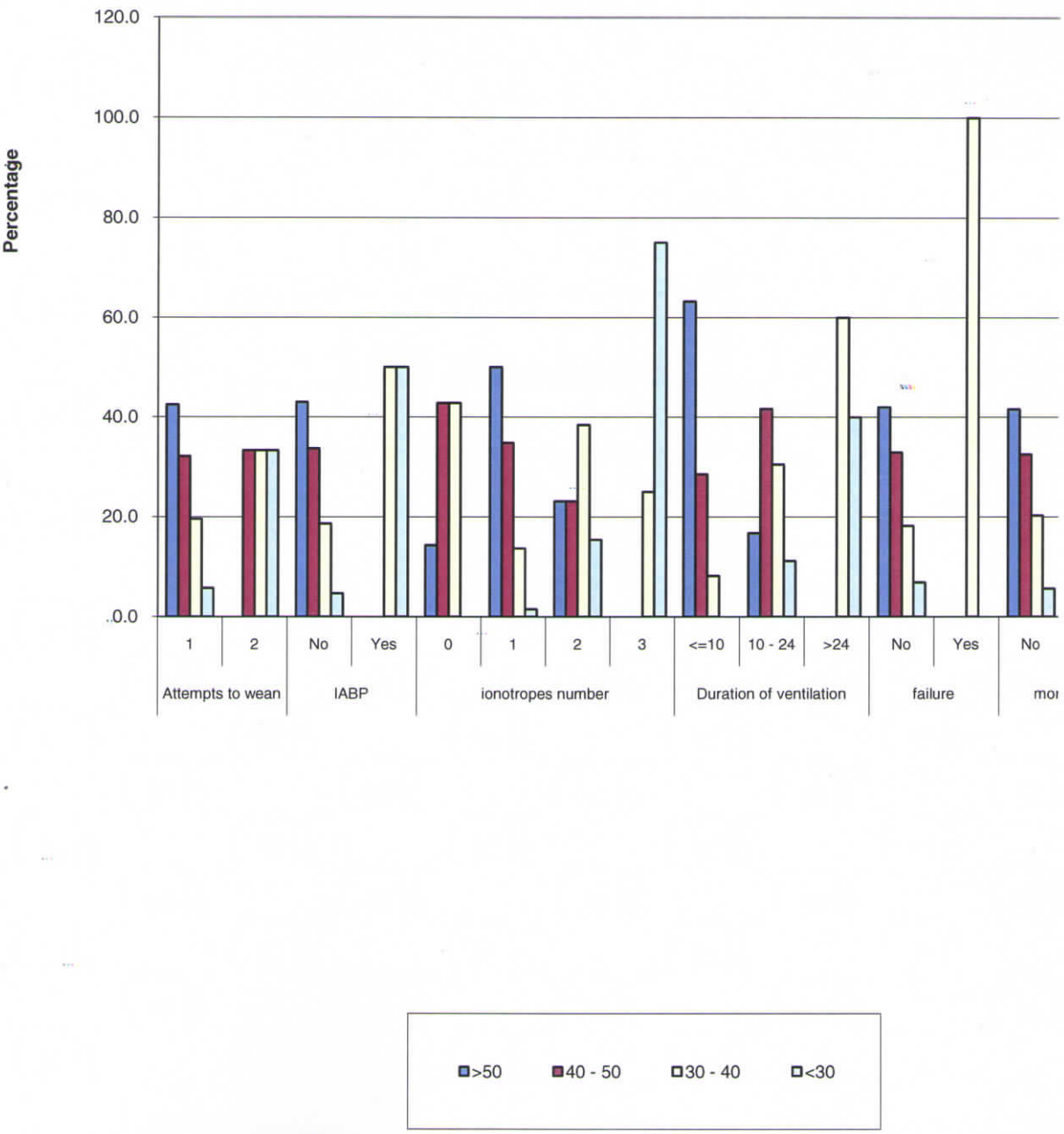
Scatter plot of LVEF & duration of inotropic infusion

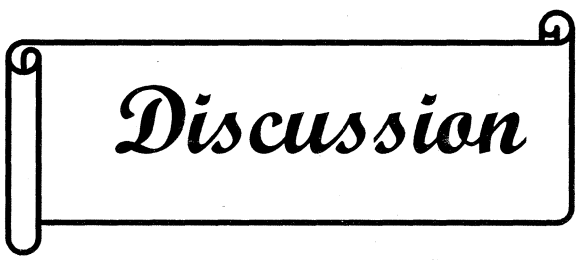


comparison of the MPI based on selected variables



g 10. comparison of the LVEF based on selected variables




Discussion

In the present study the main findings are

- Measurement of MPI in the prebypass period was feasible and it could be done in all of the patients in the present study

- There was a statistically significant association between the MPI value and inotropic infusion requirement (dose and duration).

- The association between the LVEF and inotropic infusion requirement (dose and duration) was not consistent. Only patients with LVEF < 30% showed a significant association. There was no association between the LVEF > 30% and inotropic infusion requirement (dose and duration).

- Both the prebypass MPI and LVEF values correlated with the number of postoperative inotropic infusions required.

- Prebypass MPI value was shown to correlate with postoperative adverse events.

- Both the MPI and LVEF were shown to be equally reliable predictors of postoperative adverse cardiac events like requirement of IABP, CCF, and prolonged ventilation. However the number of attempts required to wean off from CPB was correlating with MPI only.

- MPI > 0.5 in the prebypass period is associated with higher incidence of postoperative adverse cardiac events.

We found that the prebypass MPI values are directly correlating with the postoperative hemodynamic factors. The dose of inotropic infusion required in the postoperative period, duration of inotropic infusion, and the requirement of multiple inotropic infusions are directly correlated with the preoperative MPI value. In the present study we had classified the patients according to MPI into three groups, < 0.36, 0.36 - 0.5, > 0.5. We found that in terms of the dose and requirement of inotropic infusion there was a statistically significant difference among the groups, the patients in the higher MPI group requiring more inotropic infusion. When the dose and duration of inotropic infusion was correlated with the prebypass LVEF, we found that there was a significant difference only between the patients with good LV function (>50%) and severe LV dysfunction (< 30%). There was no statistically significant difference in between the patients with, good vs. mild, good vs. moderate, mild vs. moderate LV function.

The number of inotropic infusions required by the patients in the postoperative period were noted and compared with the prebypass echo variables. Of the total ninety patients, seven patients did not required any inotropic infusion, sixty six required one inotropic infusion, thirteen required two inotropic infusions and four required three inotropic infusions. When the statistical association between the MPI and the number of inotropic infusions was done it showed that the patients with high prebypass MPI values had a

higher requirement of postoperative inotropic infusion. All of the nine patients who had MPI > 0.5 required either two or three inotropic infusions in the postoperative period. There was a statistically significant association between the preoperative LVEF and the postoperative inotropic requirement.

Four patients among the total subjects (ninety) of our study population required the intraaortic balloon pump (IABP). The IABP was used when the MAP could not be maintained inspite of one inotropic infusion and the reason for hypotension is poor contractility. We found that all four patients who required the IABP in the postoperative period had a higher value of MPI (>0.5) in the prebypass period, signifying the underlying poor contractile function of the heart which did not improved much in the postoperative period. When the statistical relation between the MPI value and the requirement of postoperative IABP was done, it revealed that there is a statistically associated relation between the higher MPI (> 0.5) and the requirement of IABP. Of the four patients who required IABP two had severe LV dysfunction (LVEF < 30%), one had moderate LV dysfunction (LVEF – 34%), the fourth patient had preop LVEF – 40%. The association between the LVEF and IABP requirement was found to be statistically significant, but MPI seems to have better predictive value than LVEF as all the patients who required the IABP in the postoperative period had higher MPI values in the prebypass period.

Two patients in our study population had postoperative congestive cardiac failure (CCF) that is defined as clinical or radiological evidence of pulmonary edema that requires diuretics, oxygen supplementation, noninvasive or invasive ventilation. Both the patients required to be reintubated for the management of CCF. Both the patients were optimized with medical management, extubated and then discharged from hospital. The prebypass MPI values in both the patients were more than 0.5. There was a statistically significant association between the higher MPI values and postoperative CCF. Both the patients who had CCF in the postoperative period had prebypass moderate LV dysfunction (LVEF 30 -40). There was a significant association between the LVEF and CCF ($p = 0.044$), but the predictive value of LVEF was limited because none of the patients in the severe LV dysfunction group had episodes of CCF. Since MPI is a composite measure of both systolic and diastolic function of the heart and its measurement is not affected by the volume status of the patient, MPI is a better predictor of postoperative CCF with patients having MPI > 0.5 having a higher risk for postoperative CCF.

Three patients in the present study had taken two attempts to wean off from CPB, the reason being the poor contractility. All the three were successfully weaned off in the second attempt, two patients requiring IABP and one multiple inotropic infusions. When the association between the

number of attempts to wean off and preop echo variables was done it showed that there was a significant association between the higher preop MPI value and attempts to wean, but there was no significant association between the prebypass LVEF and the attempts to wean off.

The duration of postoperative ventilation was noted in the present study and was compared in between the groups in relation to pre bypass MPI and LVEF. Since the duration of ventilation is dependent on multiple factors like intraop anesthesia requirement, postoperative sedation, age of the patient and hemodynamic factors, we had grossly divided the requirement of postop ventilation into three groups. Group 1 – duration less than 10 hours, this group has patients who are stable and all other parameters optimized these patients were weaned and extubated once the satisfactory criteria for weaning were met. Group 2 – duration between 10 to 24 hours this group consisted of patients with some hemodynamic or other problems which needed to be optimized before weaning. Group 3 – duration of ventilation more than 24 hours, this group consisted of patients with poor cardiac function. Of the total 90 subjects in the present study 49 patients were extubated within 10 hours, 36 patients were extubated between 10 to 24 hours and 5 patients were ventilated beyond 24 hours. When the distribution of MPI was studied in the patients in relation to the duration of ventilation it was found that the patients with higher MPI values had a more significant chance of prolonged ventilation. There was

a significant association between the moderate and severe LV dysfunction and the requirement of prolonged postoperative ventilation.

There was one death amongst all patients in the present study. The patient was a male patient with severe LV dysfunction in the preoperative echo. Intraoperatively in the prebypass period the echo showed a LVEF of 24% and a MPI of 0.65. In the postoperative period the patient required multiple inotropic infusions and IABP, the patient died of poor cardiac function. Since the number of mortality in the present study is only one, it may not be significant enough number to do a statistical association with the pre bypass echo variables. But the prebypass MPI (0.65) of this patient was in the higher group, emphasizing the validation of MPI in identifying patients with poor cardiac function.

The aim of our present study was to see whether the prebypass MPI value has a predictive value of postoperative adverse cardiac events. Conventionally LVEF is used the echo parameter for predicting postop outcome. We defined the immediate postop outcomes in terms of inotropic infusion requirement (dose and duration), difficulty weaning from CPB, requirement of IABP, CCF, prolonged ventilation and mortality. It had been shown in the previous studies that LVEF is a predictor of postoperative outcome. We thought that since MPI is also an echo parameter which represents cardiac function; its value may be correlated with postoperative

outcome. Hence we compared the postoperative outcomes with reference to MPI and LVEF.

MPI was described by Tei et al[10], it s the summation of the isovolumetric contraction and relaxation times divided by the ejection time. It is considered to be a composite measure of both the systolic and diastolic function of the heart. Previous studies had shown that MPI calculation is independent of volume status of the patient and heart rate[10 - 17]. It is also shown that there is little to no inter and intra observer variability in calculation of MPI[10].

Risk assessment is an important part of preoperative assessment of patient. It helps in identifying the patients who may have adverse outcome, prognosticating the patient, optimizing the modifiable risk factors and allotment of resource. Several studies had identified several risk factors for patients undergoing CABG. Preoperative echo parameters are indicative of preoperative cardiac function; LVEF is the most commonly used echo parameter that is useful for identifying patients with poor ventricular function. Its reliability as a predictor of outcome is validated in several studies. LVEF is a preoperative variable in various risk assessment models that predict the intraop and postop risk[1 - 5]. However calculation of LVEF has some limitations like it takes into account only systolic function of the heart, depends upon the volume status of the patients, its measurement may vary from one to another

method of its calculation and inter observer variability may be there. During the intraoperative period changes in the hemodynamics and volume status are common thus limiting the measurement of LVEF and its value.

Standard risk assessment models like EURO score, Parsonnett score, and many others use preoperative LVEF as a variable that predicts outcome[1 - 5]. Studies by Veli KT et al, Risum O et al had shown that the preoperative low LVEF is a risk factor for postoperative mortality and morbidity[6, 7]. Legar GF in their study identified that preoperative poor LVEF is an independent risk factor for postoperative prolonged ventilation[8]. The results from our study are consistent with that of previous studies in literature that prebypass LVEF was significantly associated with postoperative inotropic requirement, IABP requirement, CCF and prolonged ventilation.

However the effect of diastolic function of the heart was not taken into account in any of the above studies or risk assessment models. Diastolic dysfunction / failure are independent factors that influence the outcome, adverse cardiac events, morbidity and mortality.

Vaskelyte J et al[9] did a study to evaluate the influence of left ventricular diastolic filling impairment on postoperative results in patients with low LVEF (<35%) undergoing coronary artery bypass grafting (CABG). They concluded that in patients with severe LV dysfunction undergoing CABG, impaired relaxation and pseudonormalization pattern of LV diastolic filling correlated

with postoperative improvement in LV regional contraction, while restrictive pattern correlated with high early postoperative mortality, morbidity and minimal improvement in LV systolic function[9]. One of the limitations of the above study was the study population size, the authors had only 56 patients in their study. This may be one reason why they could not find any difference in outcome in patients with normal, grade 1 and grade 2 diastolic dysfunction. However the above study highlights the importance of diastolic function of the heart especially in those with impaired systolic function.

The advantage of MPI over LVEF is that it assesses both the systolic and diastolic functions of the heart. The utility of MPI as a tool to monitor cardiac function and predict its outcome had been proved in several studies on subjects with different cardiac problems; MPI had been shown to be useful in monitoring the severity of drug induced cardiotoxicity[18-20], dilated cardiomyopathy[11, 14], cardiac amyloidosis[35], rejection after pediatric cardiac transplantation[37]. The utility of MPI as a predictive, monitoring and prognosticating tool in patients with CCF is proved in multiple studies[21-24]. Bruch et al[22] in their study had shown that using a cut off value of > 0.47 for MPI, CCF was predicted with a sensitivity of 86% and specificity of 82%. They concluded that MPI is a sensitive indicator of overall cardiac function in patients with CCF[22]. The results from our study are in consistent with the

previous study that the patients having MPI > 0.5 had episodes of postoperative CCF.

The predictive value of MPI as a prognosticator in patients with acute myocardial infarction had been proved in previous studies. Moler JE et al[28] in their study had shown that MPI > 0.65 is shown to be an independent predictor of long term mortality[28]. Szymanski P et al[31] studied the predictive value of MPI on long term prognosis post AMI in 90 patients. They followed these patients for 5 years. On multivariate analysis MPI > 0.55 was found to be an independent predictor of mortality[31]. The results of our study are consistent that patients with MPI > 0.5 had more incidences of adverse events and the single patient who had mortality in our study had a MPI of 0.65. This validates that higher MPI is a risk factor for postoperative mortality.

However the number of studies that had assessed application of MPI as a predictor of outcome in the perioperative period is limited. Al –Mukhaini M et al[32] did a study to compare MPI with LVEF in relation to death or CCF in patients with moderate to severe MR undergoing corrective surgery. They found that MPI > 0.7 was significantly associated with death and CCF. Although left ventricle ejection fraction < 40% was more sensitive in predicting the primary endpoint, it has lower specificity, accuracy and predictive values than MPI > 0·7. They concluded that MPI is a potentially useful predictor of increased risk of peri-operative death or congestive heart

failure[32]. Our results had shown that MPI > 0.5 is a risk factor for adverse cardiac events.

Feroze Mahmood et al[33] in their study on patients undergoing abdominal aortic aneurysm surgery found that subjects who had adverse events of postoperative CHF, arrhythmia, or prolonged intubation had a statistically higher MPI than those with an uncomplicated postoperative course. The evaluation of neither LVEF nor Vp was associated with an adverse outcome. The data from their study showed that the MPI values of patients who had CCF were 0.48±0.17 (mean ± S.D.), who had prolonged ventilation were 0.51±0.2 (mean ± S.D.) and arrhythmias was 0.53 ± 0.13 (mean ± S.D.)[33]. The results of our study also show the same that patients with MPI > 0.5 had more incidences of adverse events.

Another novel thing which we found in our study was the relationship between the requirement of inotropic infusion (dose and duration) and echo variables (MPI & LVEF). We found a statistically significant association between the MPI and inotropic infusion requirement, that patients with MPI < 0.36 requiring lesser dose than patients with MPI 0.36 – 0.5, in turn less than patients with MPI > 0.5. We also found the same consistency of results when MPI was compared with the number of inotropic infusions required. However the relationship between LVEF and inotropic infusion requirement (dose, duration and number) was less divided that only patients with severe LV

dysfunction requiring more compared to others, we did not found any difference in between the groups with normal, mild and moderate dysfunction. This finding highlights the fact that the postoperative inotropic infusion requirement is majorly dependent upon the preoperative cardiac function and both adequate systolic and diastolic functions are important for the cardiac pump.

Another important aspect and advantage of MPI in CABG patients can be predicted from the results of our study and study by Mabrouk ZN et al. Mabrouk ZN et al[34] compared the FAC and MPI in severe mitral regurgitation (MR) patients, they found that prebypass MPI value is a better predictor of systolic function in MR patients[34]. The clinical application is patients undergoing CABG may have different grades of ischemic MR, in these subsets of patients the value of LVEF may be erroneously high. However MPI values are not altered by the presence of MR, thus MPI may be a better predictor of postoperative cardiac function and events in those patients

The main limitations of our study are

- ✓ We did not do a long term follow up of our patients to comment on outcome.
- ✓ The study population is only ninety subjects; (studies done in large number of subjects may be needed to validate the MPI).
- ✓ We had only one mortality, so association with echo variables cannot be commented

Conclusion

Conclusion

The main conclusions from our present study are

- Measurement of MPI is feasible in the intraoperative setup
- Both MPI and LVEF can predict the adverse postoperative events like IABP requirement, multiple inotropic infusions requirement, CCF, prolonged ventilation, but the association was stronger with MPI > 0.5.
- The dose and duration of inotropic infusion is better correlated with MPI value than LVEF
- We propose a classification of severity of MPI as follows < 0.36, 0.36 – 0.5, > 0.5
- Preoperative MPI can predict the outcome in CABG patients.

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List of abbreviations used

CAD – Coronary Artery Disease

CABG – Coronary Artery Bypass Grafting

MPI – Myocardial Performance Indicator

LVEF – Left Ventricular Ejection Fraction

LV – Left Ventricle

IVCT – Iso Volumetric Contraction Time

IVRT – Iso Volumetric Relaxation Time

ET – Ejection Time

IABP – Intra Aortic Balloon Pump

CCF – Congestive Cardiac Failure

LVEDV – Left Ventricular End Diastolic Volume

LVEDP – Left Ventricular End Diastolic Pressure

WMS – Wall Motion Score

WMSI – Wall Motion Score Index

TGA – Transposition of Great Arteries


Master Chart

age	sex	MPI 1	MPI 2	MPI 3	LVEF	ionotropic support at chest closure	Attempts to wean	IABP	ionotropes number	duration of ionotropic support	DURATION OF VENTILATION	failure	mortality
70	1	0.3	0.3	0.3	40	0.01	1	NO	0	0	B	NO	NO
52	1	0.5	0.5	0.52	48	0.1	1	NO	2	28	B	NO	NO
65	1	0.28	0.28	0.28	57	0.03	1	NO	1	4	A	NO	NO
59	1	0.35	0.38	0.36	50	0.03	1	NO	1	8	B	NO	NO
69	1	0.42	0.45	0.45	53	0.08	1	NO	2	15	A	NO	NO
62	2	0.36	0.38	0.38	40	0.04	1	NO	1	12	B	NO	NO
65	1	0.45	0.45	0.45	35	0.08	1	NO	1	20	A	NO	NO
67	1	0.6	0.58	0.6	40	0.1	2	YES	3	40	C	NO	NO
63	2	0.28	0.28	0.28	40	0.01	1	NO	0	0	A	NO	NO
65	2	0.25	0.23	0.25	56	0.03	1	NO	1	2	A	NO	NO
67	1	0.41	0.43	0.43	57	0.08	1	NO	1	24	A	NO	NO
58	1	0.47	0.46	0.48	50	0.1	2	NO	2	34	B	NO	NO
70	1	0.45	0.43	0.43	32	0.1	1	NO	2	30	B	NO	NO
64	2	0.27	0.26	0.27	64	0.03	1	NO	1	4	A	NO	NO
51	1	0.35	0.35	0.37	54	0.05	1	NO	1	10	A	NO	NO
57	1	0.37	0.38	0.38	52	0.03	1	NO	1	7	A	NO	NO
63	2	0.43	0.45	0.43	50	0.08	1	NO	1	15	A	NO	NO
60	2	0.34	0.35	0.35	54	0.03	1	NO	1	4	B	NO	NO
65	1	0.5	0.52	0.53	34	0.1	1	NO	2	26	B	NO	NO
56	1	0.25	0.27	0.27	62	0.01	1	NO	1	3	A	NO	NO
69	2	0.38	0.38	0.36	40	0.04	1	NO	1	8	B	NO	NO
51	1	0.46	0.46	0.45	42	0.01	1	NO	1	20	B	NO	NO
60	1	0.27	0.27	0.27	53	0.03	1	NO	1	10	A	NO	NO
65	1	0.34	0.34	0.34	32	0.05	1	NO	1	4	B	NO	NO
63	1	0.32	0.31	0.31	58	0.01	1	NO	0	0	A	NO	NO
66	2	0.34	0.34	0.34	24	0.04	1	NO	1	5	B	NO	NO
68	1	0.5	0.47	0.47	25	0.1	1	NO	2	30	B	NO	NO
64	2	0.32	0.3	0.3	52	0.01	1	NO	1	6	A	NO	NO
58	1	0.25	0.25	0.25	45	0	1	NO	0	0	A	NO	NO
68	2	0.56	0.54	0.56	34	0.1	1	YES	2	40	C	YES	NO
57	1	0.31	0.31	0.31	52	0.04	1	NO	1	10	A	NO	NO
61	1	0.27	0.28	0.28	54	0.03	1	NO	1	6	A	NO	NO
68	1	0.35	0.35	0.35	57	0.08	1	NO	2	14	A	NO	NO
60	2	0.3	0.3	0.28	60	0.06	1	NO	1	10	B	NO	NO
59	1	0.35	0.35	0.36	45	0.05	1	NO	1	11	B	NO	NO
69	2	0.3	0.3	0.3	53	0.06	1	NO	1	8	A	NO	NO
65	1	0.29	0.27	0.27	50	0	1	NO	0	0	A	NO	NO
71	1	0.4	0.4	0.4	35	0.1	1	NO	1	20	B	NO	NO
67	2	0.26	0.26	0.26	51	0.02	1	NO	1	7	A	NO	NO

65	1	0.55	0.55	0.55	32	0.1	1	NO	2	30	C	YES	NO
62	1	0.39	0.37	0.36	43	0.07	1	NO	1	14	B	NO	NO
64	2	0.3	0.31	0.31	54	0.05	1	NO	1	10	A	NO	NO
57	1	0.28	0.26	0.28	58	0.07	1	NO	1	13	A	NO	NO
60	1	0.28	0.3	0.3	52	0.02	1	NO	1	5	A	NO	NO
53	1	0.35	0.34	0.33	50	0.06	1	NO	1	12	A	NO	NO
65	2	0.5	0.53	0.53	25	0.1	1	NO	3	34	B	NO	NO
60	1	0.34	0.34	0.33	35	0.05	1	NO	1	9	A	NO	NO
68	1	0.4	0.4	42	51	0.07	1	NO	1	12	A	NO	NO
61	2	0.35	0.35	0.34	52	0.03	1	NO	1	7	A	NO	NO
66	1	0.31	0.31	0.3	42	0.05	1	NO	1	9	B	NO	NO
57	2	0.29	0.29	0.3	48	0.03	1	NO	1	12	A	NO	NO
62	1	0.42	0.42	0.4	55	0.1	1	NO	2	16	B	NO	NO
69	1	0.35	0.34	0.34	40	0.06	1	NO	1	13	A	NO	NO
65	2	0.27	0.27	0.28	45	0.03	1	NO	1	5	A	NO	NO
58	1	0.33	0.32	0.33	52	0.06	1	NO	1	10	A	NO	NO
60	1	0.42	0.45	0.45	36	0.07	1	NO	1	14	B	NO	NO
55	1	0.33	0.33	0.34	50	0.1	1	NO	1	8	B	NO	NO
63	1	0.27	0.27	0.27	45	0.04	1	NO	1	4	B	NO	NO
60	1	0.65	0.66	0.65	24	0.1	2	YES	3	18	C	NO	YES
67	2	0.32	0.34	0.32	54	0.04	1	NO	1	9	A	NO	NO
62	2	0.35	0.35	0.34	42	0.03	1	NO	1	6	B	NO	NO
59	1	0.37	0.37	0.37	56	0.06	1	NO	1	9	B	NO	NO
66	2	0.3	0.32	0.32	50	0.03	1	NO	1	10	A	NO	NO
63	1	0.38	0.37	0.37	47	0.05	1	NO	1	6	B	NO	NO
68	1	0.48	0.48	0.5	45	0.1	1	NO	2	28	A	NO	NO
64	1	0.35	0.35	0.32	46	0.05	1	NO	1	9	A	NO	NO
51	1	0.65	0.66	0.65	26	0.1	1	YES	3	46	C	NO	NO
63	1	0.32	0.33	0.32	52	0.06	1	NO	1	10	A	NO	NO
64	2	0.37	0.37	0.35	42	0.04	1	NO	1	7	B	NO	NO
60	1	0.43	0.44	0.44	50	0.06	1	NO	1	16	A	NO	NO
67	2	0.46	0.46	0.47	54	0.08	1	NO	1	12	B	NO	NO
58	1	0.28	0.28	0.27	40	0.02	1	NO	0	0	B	NO	NO
62	1	0.3	0.3	0.3	45	0	1	NO	0	0	A	NO	NO
69	1	0.37	0.35	0.35	52	0.04	1	NO	1	8	A	NO	NO
62	1	0.32	0.3	0.3	45	0.06	1	NO	1	6	B	NO	NO
59	1	0.35	0.34	0.34	51	0.06	1	NO	1	8	A	NO	NO
67	1	0.46	0.46	0.46	25	0.1	1	NO	2	28	B	NO	NO
61	2	0.36	0.37	0.36	48	0.07	1	NO	1	10	B	NO	NO
60	1	0.31	0.3	0.32	52	0.01	1	NO	1	3	B	NO	NO
65	1	0.37	0.35	0.35	50	0.04	1	NO	1	7	A	NO	NO
59	1	0.42	0.4	0.4	45	0.06	1	NO	1	6	A	NO	NO
65	2	0.47	0.47	0.47	35	0.1	1	NO	1	15	B	NO	NO
62	1	0.3	0.3	0.28	54	0.04	1	NO	1	10	A	NO	NO
67	2	0.52	0.54	0.55	40	0.1	1	NO	2	28	B	NO	NO
59	1	0.29	0.29	0.28	43	0.03	1	NO	1	8	A	NO	NO
61	1	0.36	0.36	0.36	54	0.06	1	NO	1	10	A	NO	NO

Proforma

Case Number -

Preoperative –

Patient I.D. – Age - sex-

Diagnosis –

Preoperative Echo report –

Intraoperative -

Echo data

Echo parameter	Value 1	Value 2	Value 3	Average value
Myocardial Performance Indicator				
Ejection Fraction				

Other intraoperative data

Parameter	observation
Number of attempts to wean from CPB	
Ionotropic support (after chest closure)	
IABP usage	Yes/no

Postoperative data

Parameter		Observation
Ionotropic support	**a.** Drug	
	b. Duration (in hours)	
	c. IABP usage (yes /no) & duration	
Duration of ventilation(in hours)		
Postoperative cardiac failure	Yes / no	

Other postoperative data

Mortality (from cardiac causes) – yes / no