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Effect of Off-pump Coronary Artery Bypass Grafting on the Intraoperative Hemodynamics

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ABSTRACT

Background: The hemodynamic instability during off-pump coronary bypass grafting (CABG) may impair the complete coronary revascularization. We evaluated the effect of off-pump CABG on intraoperative hemodynamic parameters.
Aim of work: The purpose of this study is to assess the patients' hemodynamics during off-pump coronary artery bypass graft surgery. And the main challenge during the operation is to maintain hemodynamic stability during this procedure.
Patient and Methods: We included 40 patients who underwent off-pump CABG from 2017 to 2019. The mean age was 55.75± 6.73 years, and 28 patients were males (70%). The mean ejection fraction was 60.08 ± 3.81%. Study endpoints were the intraoperative hemodynamic parameters and postoperative complications.
Results: Heart rate was significantly higher during the grafting of the posterior descending artery (PDA)(79.3± 2.8beats/min) and right coronary artery (79.5 ± 1.8 beats/min) compared to all other grafts ($p<0.001$). The highest central venous pressure(12.6± 1.2 mmHg)and mean pulmonary artery pressure (33.2± 1.4 mmHg) and the lowest mean arterial and pressure (68.1± 3.3 mmHg) were recorded during PDA grafting ($p<0.001$, for all parameters). There was no significant difference in adrenaline dose infused during the anastomosis of all grafts ($p= 0.2$). Ejection fraction significantly decreased predischarge (52.18 ± 2.58 %) and at 6 months (52.83 ± 3.57%) compared to the preoperative value ($p<0.001$).
Conclusion: Off-pump CABG was associated with significant hemodynamic instability, which was more evident during the posterior descending artery grafting. Proper anesthetic management and fluid infusion are required, especially during the anastomosis of the right and posterior coronary systems.

Keywords: *off-pump; cabg; grafting; stabilizer; pericardial stitch; Hemodynamics .*

INTRODUCTION

The surgical technique for myocardial revascularization continues to be debated[1]. Cardiopulmonary bypass (CPB) is associated with inflammatory response, depression of the immune system, and consumption of the coagulation factors[2]. Off-pump coronary artery bypass grafting (CABG) avoids the use of cardiopulmonary bypass, which yielded superior results in some patients compared to on-pump CABG [3].

On the other hand, off-pump CABG is associated with hemodynamics instability because of the manipulation of the heart and ventricular compression, which may be an obstacle against complete revascularization[4]. Additionally, the hemodynamic alterations and transient depression of the cardiac functions during off-pump CABG may precipitate acute myocardial ischemia. Therefore, some surgeons had limited the use of off-pump CABG to high-risk surgical patients[5].

The outcomes of off-pump CABG had improved with the introduction of new stabilizers and proper management of hemodynamics during surgery[6]. The objective of this study was to evaluate the effect of off-pump CABG using one deep pericardial stay sutures and a stabilizer on patients' intraoperative hemodynamic parameters.

PATIENTSAND METHODS

Design and patients: We performed a prospective study that included 40 patients who had off-pump CABG between June 2017 and November 2019. We included hemodynamicallystable patients with normal preoperative ejection fraction and multivessel coronary artery disease. We excluded patients who underwent redo CABG or had a concomitant cardiac procedure. Additionally, we excluded patients with reduced ejection fraction (< 40%) and those who needed preoperative inotropic support. Patients with end-organ failure (renal or hepatic failure) and those with recent myocardial infarctions (within two weeks of the operation) were excluded.

The Institutional Review Board approved the study, and patients' consent was obtained prior to enrollment.

Data collection and techniques: All patients had a preoperative clinical examination.Preoperative dataincluded age, gender, dyspnea class, and the associated comorbidities, and the echocardiographic data included ejection fraction, regional wall motion abnormalities, and cardiac dimensions. All patients had a cardiac catheterization to identify the lesion and its extension.

Anesthesia and monitoring protocols were the same for all patients. Nitroglycerin infusion for ischemia prophylaxis was used before induction. Trendelenburg position was used during surgery to increase the venous return and improve hemodynamics during cardiac manipulation. Heparin was used in a dose of 1-2 mg/kg to maintain activated clotting time (ACT) above 300. Surgery was performed through a median sternotomy, and Ringer lactate was infused at a fixed rate of 8 ml/kg/h, and the amount of blood lost was replaced with colloid solutions or blood infusion guided by hematocrit levels.In case of hypotension, epinephrine and or norepinephrine were given to maintain mean systemic arterial pressure (MAP) above 60 mmHg.During the period of heart displacement and grafting, a mean systemic arterial pressure was maintained above 60 mmHg with using either a Trendelenburg position or a norepinephrine infusion.When severe hypotension was observed (MAP below 40 mmHg), the manipulations were immediately interrupted, and the heart was returned to the normal position. The anastomosis was resumed once the patients became hemodynamically stable. We used one deep pericardial suture to aid in the exposure of the vessels.

The internal mammary artery was anastomosed to the left anterior descending artery (LAD) in all patients, and the saphenous vein was used on other target vessels. Pleural spaces were opened widely in all patients. Stabilizers(Octopus Tissue Stabilization System, Medtronic Inc. USA)were used during distal anastomosis, and the flow was controlled using Silastic tapes. We used CO_2 blowers to clear the field from the blood. Proximal anastomoses were performed using partial aortic clamping. Intraoperative data included the mean arterial blood pressure, heart rate (HR), central venous pressure (CVP), mixed venous saturation,mean pulmonary artery pressure (PAP), and the inotropic support.

Postoperative data included length of intensive care unit (ICU) and hospital stay, the need for inotropic support, andpostoperative complications.

Statistical analysis:We used SPSS version 9.0 to perform all analyses (IBM Corp- Chicago- IL- USA). Continuous variables were presented as mean and standard deviation.The changes in the hemodynamic parameters from the baseline were compared using a one-way analysis of variance (ANOVA) with Bonferroni posthoc test. The changes in the ejection fraction were compared using repeated-measures ANOVA. Binary variables were presented as numbers and percentages. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Preoperative data : The mean age was 55.75± 6.73 years, and 28 patients were males (70%). The mean ejection fraction was 60.08 ± 3.81%. Preoperative comorbidities are presented in table 1.

Variables	n= 40
Age (years)	55.75± 6.73
Males	28 (70%)
NYHA II NYHA III	10 (25%) 30 (75%)
DM (type I) DM (type II)	10 (25%) 5 (12.5%)
Hypertensives	25 (62.5%)
Hyperlipidemia	6 (15%)
Smokers	19 (47.5%%)
LVEDD (cm)	5.13 ± 0.32
LVESD (cm)	3.28 ± 0.20
Ejection fraction (%)	60.08 ± 3.81

Table 1: Preoperative data.

(Continuous data are presented as mean and standard deviation and categorical variables as numbers and percentages) DM: diabetes mellitus; LVEDD: end-ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter; NYHA: New York Heart Association

Hemodynamic parameters during surgery:

Heart rate was significantly lower during anastomosis of the ramus intermedius compared to all other grafts, and the highest heart rate was reported during the anastomosis of the posterior descending artery (PDA) and the right coronary artery (RCA) ($p<0.001$). The highest CVP and mean pulmonary artery pressure (PAP) and the lowest mean arterial and pressure (MAP) wererecorded during PDA grafting. Intraoperative hemodynamic parameters are presented in table 2.

	Baseline (n=40)	LAD (n= 40)	Diagonal (n= 15)	OM (n= 25)	Ramus (n= 8)	RCA (n= 23)	PDA (n= 11)	p
HR	72.5± 3.8	76.7±3.1	78.1± 1.95	81.98 ± 3.8	67.7±29.9	79.5 ± 1.8	79.3± 2.8	<0.001
CVP	8.4± 1.6	10.5± 1.4	10.6± 1.8	10.3± 1.7	11.4± 1.7	11.3± 1.2	12.6± 1.2	<0.001
MAP	87.8± 5.8	76.8± 6.7	72.4± 3.5	71± 4.3	68.8± 4.3	69.95 ± 4.1	68.1± 3.3	<0.001
Mean PAP	29.6± 4.1	29.7± 3.2	31.7± 3.1	30.6± 2.4	31.5±3.1	31.7± 1.3	33.2± 1.4	<0.001
SvO2	81.6± 2.4	79.1± 2.4	78.1± 1.4	78± 1.6	77.5± 1.2	77.2± 2.1	77± 1.6	<0.001
Adrenaline	40.3± 6.9	44.5± 3.3	56.5± 17.4	58.5± 18.7	63.1± 9.5	56.7± 21.7	60.9± 10.9	0.2

Table 2: hemodynamic changes during off-pump coronary artery bypass grafting.

(Continuous data were presented as mean and standard deviation) CVP: central venous pressure; HR: heart rate; LAD: left anterior descending artery; MAP: mean arterial pressure; OM: obtuse marginal; PAP: pulmonary artery pressure; PDA: posterior descending artery; RCA: right coronary artery; SvO2: mixed central venous saturation

Postoperative data: All patients were transferred to the ICU ventilated, and no patient was weaned in the operating room. Two patients (5%) required re-exploration for bleeding, and two patients (5%) needed an intra-aortic balloon pump. Postoperative data are presented in table 3.

Variables	n= 40
Bleeding	2 (5%)
Myocardial infarction	3 (7.5%)
Atrial fibrillation	6 (15%)
Wound infection	1 (2.5%)
ICU stay (days)	1.92 ± 0.81
Hospital stay (days)	6.95 ± 0.93

Table 3: Postoperative complications.

(Continuous data are presented as mean and standard deviation and categorical variables as numbers and percentages) ICU: intensive care unit

Echocardiographic data:

Ejection fraction significantly decreased predischarge (52.18 ± 2.58 %) and at 6 months (52.83 ± 3.57%) compared to the preoperative value ($p<0.001$).

DISCUSSION

Off-pump coronary artery bypass grafting became a common practice in many centers. The technique offers the advantage of avoiding cardiopulmonary bypass and its consequences [7]. However, off-pump CABG is associated with several intraoperative difficulties, including compression of the right ventricle, distortion of the mitral, and tricuspid annuli leading to valvular regurgitation and hemodynamic instability[8]. The myocardial is potentially subjected to ischemia and dysfunction due to the occlusion of the coronary vessels and compression by the stabilizers [9]. Recently, new stabilizing devices and heart positioners have been developed to improve the outcomes after off-pump CABG [10].

The short and long-term results of off-pump CABG were comparable to the on-pump technique, primarily when performed by experienced surgeons[9,11]. The hemodynamic instability associated with off-pump CABG increased the rate of incomplete revascularization and conversion to the on-pump CABG[12]. Hemodynamic compromise during the off-pump CABG resulted from bi-ventricular dysfunction [13], rather than right ventricular dysfunction only [14].

Hemodynamic changes during off-pump CABG include an increase in the mean pulmonary artery pressure and central venous pressure and a decrease in the mean arterial pressure and oxygen saturation [15]. These changes are usually transient and disappear after returning the heart to its normal position [16].

We performed this study to evaluate the effect of off-pump CABG during grafting of different vessels on the patients' hemodynamics. The study included 40 patients with multivessel disease and stable hemodynamics who underwent elective off-pump CABG. Similar to other studies, we found that grafting the posterior descending artery was associated with the most significant hemodynamic changes [15,17].

The hemodynamic changes during off-pump CABG were related to many factors, including the preoperative hemodynamics, the location of the grafted vessels, the preoperative ventricular function, and the types of stabilizers [10,18].

We reported an increase in the mean PAP during the anastomosis of the posterior system, and the results from the literature are controversial [16,19]. The different results could be attributed to the different baseline patients' characteristics and right ventricular function. We faced the greatest changes in hemodynamics with the anastomosis of the posterior system because of the extensive mobilization of the heart, which impaired the venous and pulmonary blood flow and distorted the mitral and tricuspid annuli.

Mixed venous saturation is an indicator of the global tissue oxygenation [15], and values below 50% indicate improper tissue oxygenation and increased risk of organ ischemia. We found a decrease in mixed venous saturation during the anastomosis of all grafts, while the marked decrease was with the PDA and RCA similar to other studies[19,20]. The changes we reported in the heart rate, blood pressure, and central venous pressure are consistent with other studies [16,19,20].

This study showed that PDA, followed by RCA grafting during off-pump CABG was associated with the most significant hemodynamic changes. These observations warrant careful anesthetics and fluid management during the anastomosis of these vessels.

Study limitations:

The study has several limitations, including the single-center experience and the variable experience of the surgeons. Other limitations are the small sample size and short-term follow-up. We do not know if these hemodynamic changes could affect the long-term patency of the grafts. A longer study is recommended to evaluate the effect of these hemodynamic changes on graft patency.

CONCLUSION

Off-pump CABG was associated with significant hemodynamic instability, which was more evident during the posterior descending artery grafting. Proper anesthetic management and fluid infusion are required, especially during the anastomosis of the right and posterior coronary systems.

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