Off pump versus on pump coronary artery bypass grafting Intra operative graft assessment by transit time flowmetry

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Abstract

Background and Objectives: CABG (coronary artery bypass grafting) is a successful procedure for restoring adequate blood flow to the ischemic myocardium. In the current study, we used transit time flowmetry to assess intraoperative grafts in off pump and on pump coronary artery bypass grafting. **Methods**: One hundred patients undergoing coronary artery bypass grafting (CABG) were randomly divided into two groups, group(A): off pump coronary artery bypass grafting (OPCABG). Group (B): on pump coronary artery bypass grafting (ONCABG). During surgery, transit time flowmetry (TTFM) was routinely used to evaluate graft patency and flow. **Results:** There was no statistically significant difference in preoperative evaluation in terms of age, gender, hypertension, diabetes, smoking, positive family history of cardiac diseases, New York Heart Association (NYHA), or ejection fraction. In terms of intraoperative evaluation, there was no statistically significant difference in operative time, intraoperative graft numbers, or graft revision, but there was a statistically significant difference in mean flow in grafts in ml/min, pulsatility index, and percentage of backward flow. **Conclusions**: According to the findings of our study, we believe that transit time flow measurement is useful in clinical practice because it prompts surgeons to investigate the cause of poor graft flow, and off-pump coronary bypass surgery can achieve the same anastomosis as on-pump coronary bypass surgery. The surgeon's experience and expertise determine the outcome of off-pump coronary bypass surgery. **Keywords**: Transit time flowmetry- off pump coronary artery bypass grafting- on pump coronary artery bypass grafting.

Introduction

Coronary artery bypass grafting (CABG) is an effective procedure for providing adequate blood flow to the ischemic myocardium. Off-pump coronary bypass surgery (OPCAB) has been rediscovered and refined in order to avoid cardiopulmonary bypass. However, it is a highly technical skill. And blood flow measurements must be accurate. Intraoperatively, transit time flow measurement (TTFM) is used to assess graft flow and anastomosis patency. The explanation of the TTFM parameters determines the accuracy of graft flow **(1).**

Graft flow, the pulsatility index, and the proportion of patients with systolic reverse flow all increased as the severity of the coronary stenosis raised. The possibility of flow competing between the native coronary artery and the bypass graft increased in mild coronary artery stenosis **(2).**

Internal mammary artery (IMA) grafting is the most common route for coronary artery bypass graft surgery, and it improves survival. Among the most essential stages in the process is to guarantee graft patency at the end. The transit-time flowmeter (TTFM) is a

dependable intraoperative graft analysis tool that European guidelines advise for reducing technical errors in coronary anastomoses. Abnormal measurements after cardiopulmonary bypass or protamine administration, in most cases, prompt the surgeon to investigate the graft and consider revision **(3)**.
The purpose of this study was to use transit time flowmetry to evaluate intra - operative grafts during off pump machine and on pump machine coronary artery bypass grafting.

Patients & Methods
One hundred patients were randomly assigned to one of two groups: off-pump and on-pump. Transit time flowmetry (TTFM) was routinely used to assess graft patency and flow during surgery. The TTFM findings influence graft revision.
Study setting:
Between January 2020 and January 2022, 100 patients underwent coronary artery bypass grafting (CABG) in the Cardio-thoracic Surgery Department at Kasr El-Aini Hospital, Cairo University, and El Agouza Police Hospital and were randomly assigned to two groups using the block method: **Group A:** 50 patients underwent off pump Coronary artery bypass grafting (OPCABG). **Group B:** 50 patients underwent on pump Coronary artery bypass grafting (ONCABG).
After providing institutional and informed consent, these patients were chosen at random for this study based on the inclusion and exclusion criteria listed below:
Inclusion criteria: Age below 70 years old, coronary artery disease and ejection fraction above 40%
Exclusion criteria: Ejection fraction below 40%, concomitant valve disease, emergency CABG, redo CABG, left ventricular cardiac aneurysm, significant symptomatic carotid lesion, bleeding tendency and renal dysfunction (serum creatinine ≥ 2.0 mg/dl), Hepatic dysfunction (serum bilirubin ≥ 3.0 mg/dl), Concomitant respiratory disease, Central nervous system disease.
Methodology in details: One hundred patients underwent coronary artery bypass grafting (CABG) were randomly divided into two groups of fifty patients each using the block method. The same group of surgeons performed all of the surgical procedures. Patients were randomly assigned to either OPCABG or ONCABG without regard for medical criteria such as coronary artery anatomical structure, heart size, or left ventricular ejection fraction (LVEF). Data was gathered from medical records as well as structured interviews with the cases. The study compared both fixed and variable data from patients before, during, and after surgery:
Patients were subjected to the following:
Preoperative assessment: History taking: A thorough and detailed history was taken, as regards the age, sex, hypertension, diabetes mellitus, medical treatment. **Clinical examination:** A complete clinical general and local cardiological examination was performed.
Investigations: Laboratory investigations: Complete blood count, Liver function tests, Kidney function tests, fasting blood sugar and serum electrolytes, Electrocardiogram (ECG), Radiological examination and Echocardiography:
Intra-operative procedure:
Anesthetic technique: Fentanyl 5-10 mic/kg was used as an intraoperative anesthetic technique for all patients, with endotracheal intubation aided by Pancuronium0.02 mg/kg and 0.5-1 mg/kg of propofol as a hypnotic supplement. An additional dose of Fentanyl 100-200 mic was administered.
Surgical technique in on-pump CABG group: Two partial-thickness concentric diamond-shaped purse-string sutures are placed in the distal ascending aorta using 2-0

braided or monofilament nonabsorbable suture (ProleneTM), The aortic cannula is placed and correctly positioned, and the purse strings are tightened. A 2-0 Prolene purse-string suture is wrapped around the tip of the right atrial appendage, A two-stage venous cannula is implanted into the right atrial appendage, and the venous line is attached to the pump tubing. Antegrade cardioplegia is achieved by inserting an aortic root cannula into the ascending aorta. The patient is placed on 2.4 L/min/m2 cardiopulmonary bypass and cooled to 34°C. Flow ventilation is turned off once the patient is on full bypass. Because the target vessels are fully distended prior to cardioplegic arrest, they are simpler to identify. The locations of planned distal anastomoses are marked with a scalpel. The pump flow is temporarily reduced, and the aortic cross-clamp is applied just proximal to the arterial cannula, with bypass flow restored to normal. Warm blood cardioplegia (10 mL/kg) is administered, and additional cardioplegia (5 mL/kg) is administered via the antegrade catheters every 30 minutes for the remainder of the cross-clamp period. The redosing of cardioplegia should be timed so that it does not disrupt the 'flow' of the operation. The aortic cross-clamp is removed once all anastomoses have been finished, and a stable heart rhythm is created. Allow the heart to recover for 10 minutes on full bypass for every 60 minutes of aortic cross-clamp time. During this period of recovery, the patient is getting ready to transition from supported to native circulation. The aortic root vent and retrograde catheters are removed, and the wounds are sutured closed. The bypass grafts are examined for kinks, twists, and tension, as well as the presence of hemostasis.

Surgical technique in off-pump CABG group: During internal mammary artery (IMA) harvest, the radial artery and saphenous vein conduits are harvested simultaneously. Cardiac positioning devices are used to ensure adequate exposure of the target vessels; suction-based positioning is well tolerated because the heart is not compressed, allowing it to maintain its functional geometry. The coronary stabilizer devices are placed on the epicardium with minimal tension to allow for mechanical stabilization. A soft silastic retractor tape is constructed on a blunt needle in preparation for distal anastomosis is wrapped widely around the proximal vessel for transient atraumatic occlusion. A humidified CO2 blower, controlled by the scrub nurse or second assistant, keeps the field free of blood. To avoid injury to the coronary endothelium, set the blower to the lowest setting required for exposure (5 L CO2) and use it only when passing the needle through the vessel. In patients with a lot of epicardial fat, an epicardial fat retractor may be used to expose the coronary target. The anastomosis is otherwise performed in the same manner as with on-pump grafting. It is critical to maintain communication with the anesthesia team so that appropriate steps can be taken as soon as hemodynamic conditions deteriorate. At this point, a decision must be made as to whether the procedure should be converted "electively" to an on-pump procedure or completed off-pump with better preparation (eg, fluids, inotropes, vasopressors, pacing, and shunt). The anastomosis can usually be completed off-pump. The use of intra-aortic balloon counter-pulsation for mechanical support during cardiac displacement and positioning is another option for patients at high risk of CPB complications. The grafting pattern is crucial because regional myocardial perfusion is momentarily disrupted during anastomosis on the beating heart. In general, the collateralized vessel(s) is grafted first, followed by the collateralizing vessel. In patients with an occluded RCA and a PDA supplied by collaterals from the LAD, for example. Not only would the anterior wall be ischemic during the anastomosis if the LAD was grafted first, but flow to the septum, inferior wall, and right ventricle would be disrupted as well. To ensure adequate flow to the inferior wall while the proximal LAD is occluded during IMA-LAD anastomosis construction, a more conservative approach

would be to graft the PDA first, followed by a proximal anastomosis. A large moderately stenotic RCA is another scenario that could cause issues. Temporary occlusion frequently causes profound bradycardia and hypotension. Temporary epicardial pacing must be provided by the surgeon.

Intraoperative flow measurement: Following the completion of the bypass, flow values and flow curves were obtained using the transit time flowmetry (TTFM) device (Medi-stim butterfly flowmeter, Medi-stim, Oslo, Norway).

The TTFM probe was snugly wrapped around the graft. To avoid graft distortion or compression, different-sized probes were used. A small section of the mammary artery had to be skeletonized to minimize the amount of tissue between the vessel and the probe. Before taking any measurements, the grafts were adequately de-airing, and then systolic blood pressure was kept between 100 and 120mmHg.pericardium traction was released, and the stabilizer from the epicardial surface was removed, allowing the heart to return to its normal anatomical position.

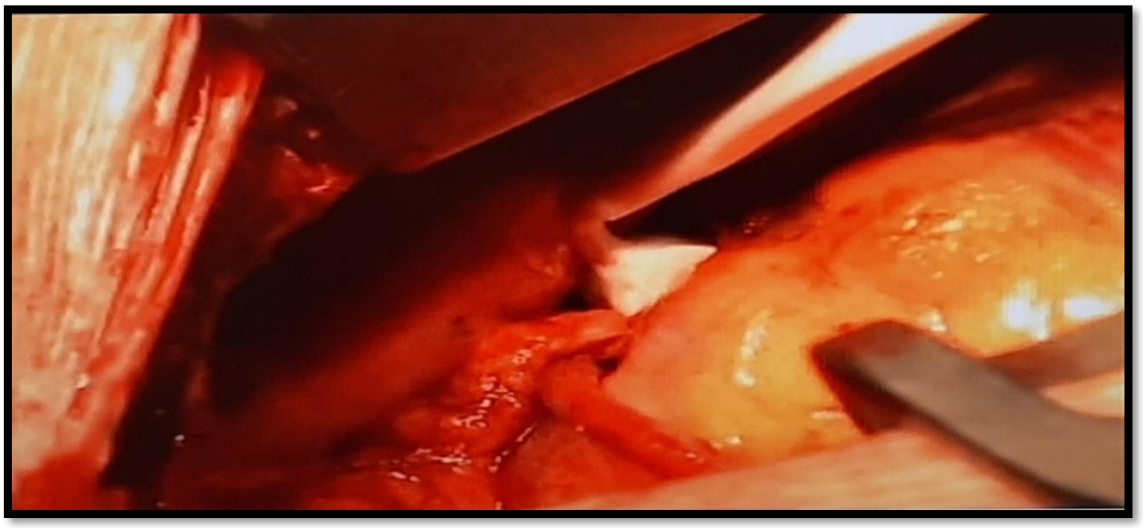

Figure 1: The TTFM probe was snugly wrapped around the graft.

Operative parameters: Total operative time, Number of grafts done, Revision of grafts, pulsatility index (PI) ([maximal flow _ minimal flow]/mean flow); The percentage of backward flow (% BF) (or insufficiency ratio - IR) is defined as the amount of flow directed backward across the anastomotic Site through the graft, blood transfusion, inotropic support and mechanical support (IABP)

Post-operative evaluation of both groups: Mechanical support (IABP), Inotropic support, weaning from ventilator, elevated cardiac biomarkers (CK-MB,Troponine), post-operative ischemic ECG changes, arrhythmias, post-operative bleeding, blood transfusion and reopening for hematoma evacuation, neurological, hepatic and renal complications, fever, Infection, ICU Mortality, ICU Stay and hospital Stay.

Statistical analysis: For the analyses, SPSS version 26.0 [SPSS Inc., Chicago, IL, USA] was used. To determine the normality of the distribution, the Shapiro-Wilk test was used as one of the normality tests. The independent t test was used to compare two means of normally distributed quantitative variables, while the Man-Whitney test was used for variables that were not normally distributed. The chi-squared and Fisher's exact tests were used for qualitative variables. The Z test was used to compare graft proportions. The threshold for statistical significance was set at $P = 0.05$.

Results

Between January 2020 and January 2022, one hundred patients underwent coronary artery bypass grafting (CABG) in the Cardio-thoracic Surgery Department at Kasr El-

Aini Hospital, Cairo University, and El Agouza Police Hospital. Patients were randomly divided into two groups using the block method after providing institutional and informed consent: **Group A**: 50 patients underwent off pump Coronary artery bypass grafting (Off-pump CABG). **Group B**: 50 patients underwent on pump Coronary artery bypass grafting (On-pump CABG).

Transit time flowmetry (TTFM) was routinely used to assess graft patency and flow during surgery. The TTFM findings influence graft revision.

Table 1: General and Medical Characteristics of the studied groups

	Coronary artery bypass grafting				**Test of sig**	**P value**
	Off-Pump (No.=50)		**On-Pump (No.=50)**			
	No	**%**	**No**	**%**		
Age (Y): Mean ±SD	60.5±4.6		61.1±4.6		t=0.67	0.504
Sex						
Male	34	68.0	34	68.0	-	-
Female	16	32.0	16	32.0		
Hypertension	35	70.0	35	70.0	-	-
Diabetes Mellitus	20	40.0	18	36.0	χ^2=0.17	0.680
Smoking	26	52.0	22	44.0	χ^2=0.64	0.423
Positive Family history	27	54.0	27	54.0	-	-

***: significant, P-value ≤0.05 is considered significant, P value>0.05 is considered insignificant, (T test), χ^2 (chi-squared).**

In **group A** (off-pump CABG), age ranged from 53-68 years with mean of 60.5±4.6, while in **group B** (on-pump CABG) age ranged from 50-68 years with mean of 61.1±4.6, and there was no statistical significance (P>0.05).

Table 2: Operative time between the studied groups

	Coronary artery bypass grafting		**Test of sig**	**P value**
	Off-Pump (No.=50)	**On-Pump (No.=50)**		
	Mean ±SD	**Mean ±SD**		
Operative time(min)	164.3±7.8	184.7±9.2	t=0.67	0.504

***: significant, P-value ≤0.05 is considered significant, P value>0.05 is considered insignificant, (T test), No (number), min (minutes).**

Intra operative assessment for operative time showed that: in **group A** (off-pump CABG) the Mean ±SD was 164.3±7.8, while in **group B** (on-pump CABG) the Mean ±SD was 184.7±9.2 with no statistical significance (P>0.05).

Table 3: Intra operative TTFM measurements between the studied groups:

	Coronary artery bypass grafting				**Test of sig**	**P value**
	Off-Pump (No.=50)		**On-Pump (No.=50)**			
	Mean ±SD		**Mean ±SD**			
Number of revised grafts: No, %						
0	45	90.0%	48	96.0%	χ^2=1.38	0.436 FE
1	5	10.0%	2	4.0%		

Mean flow in grafts in ml/Min	45.7±3.1	47.7±3.5	t=3.12	**0.002***
Pulsatility index	1.9±0.18	1.7±0.17	t=4.83	**<0.001***
BF%	2.1±0.21	2.0±0.19	t=2.71	**0.008***

***: significant, P-value ≤0.05 is considered significant, P value>0.05 is considered insignificant, (T test), χ^2 (chi-squared), No (number).**

In **group A** (off-pump CABG) we revised 1graft in 5 patients (10%), while in **group B** (on-pump CABG) we revised 1 graft in 2 patients (4%) cause of unsatisfactory TTFM findings due to graft twist or stenosis at the anastomosis site with no statistical significance(P>0.05).

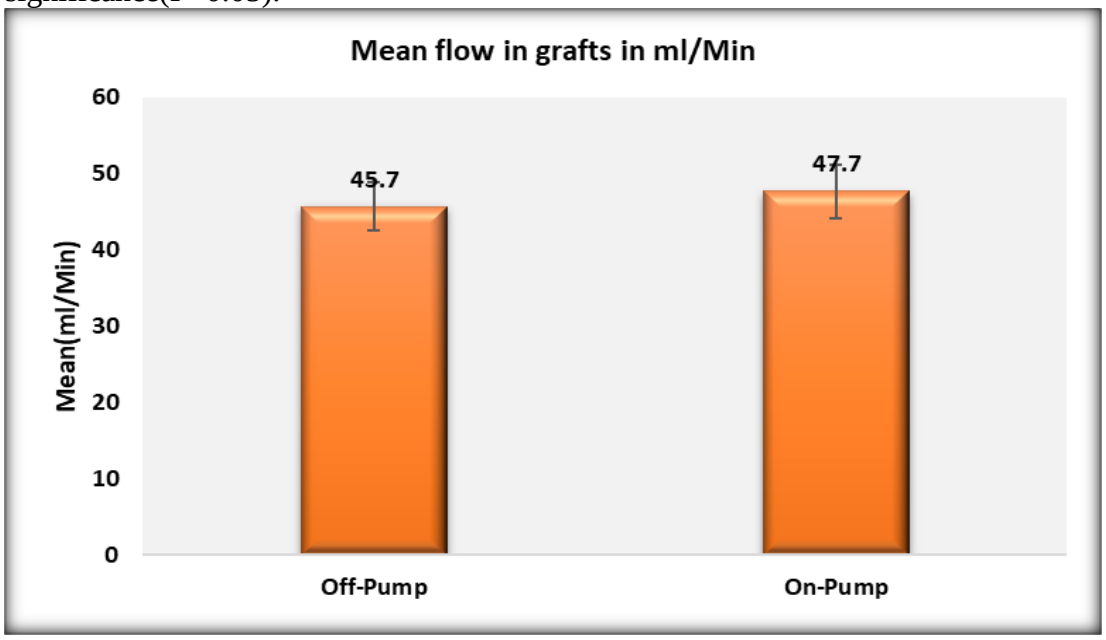

Figure 2: Distribution of the studied groups regarding Mean flow in grafts in ml/Min

The percentage of backward flow (% BF), in **group A** (off-pump CABG) the Mean ±SD was 2.1±0.21, while in **group B** (on-pump CABG) the Mean ±SD was 2.0±0.19, The percentage of backward flow (% BF) was significantly higher in **group A** (off-pump CABG) (**P=0.008**).

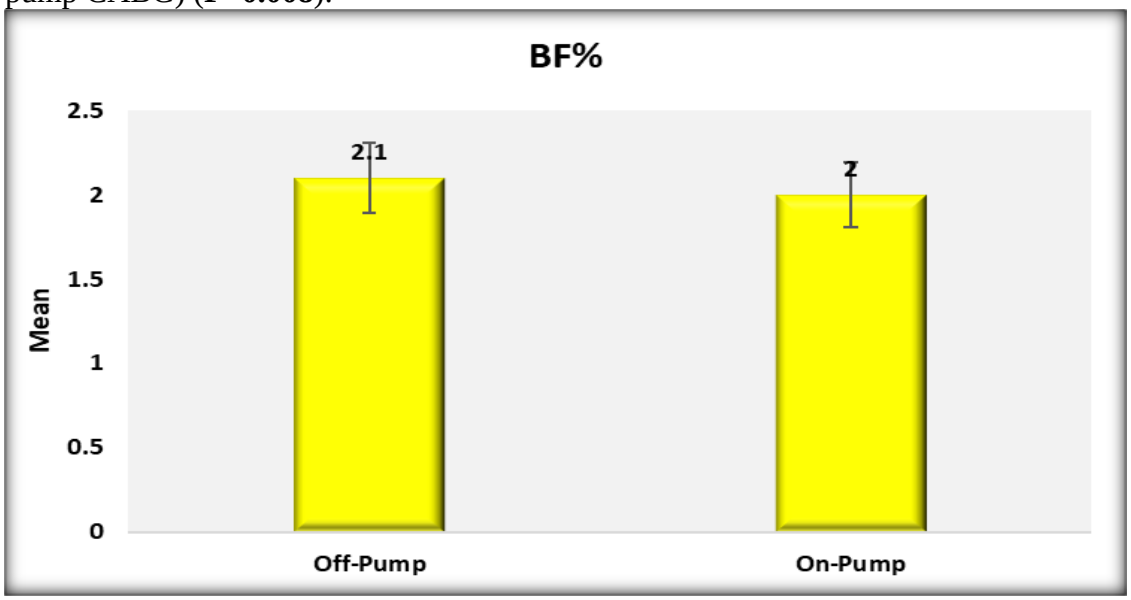

Figure 3: Distribution of the studied groups regarding Mean BF%

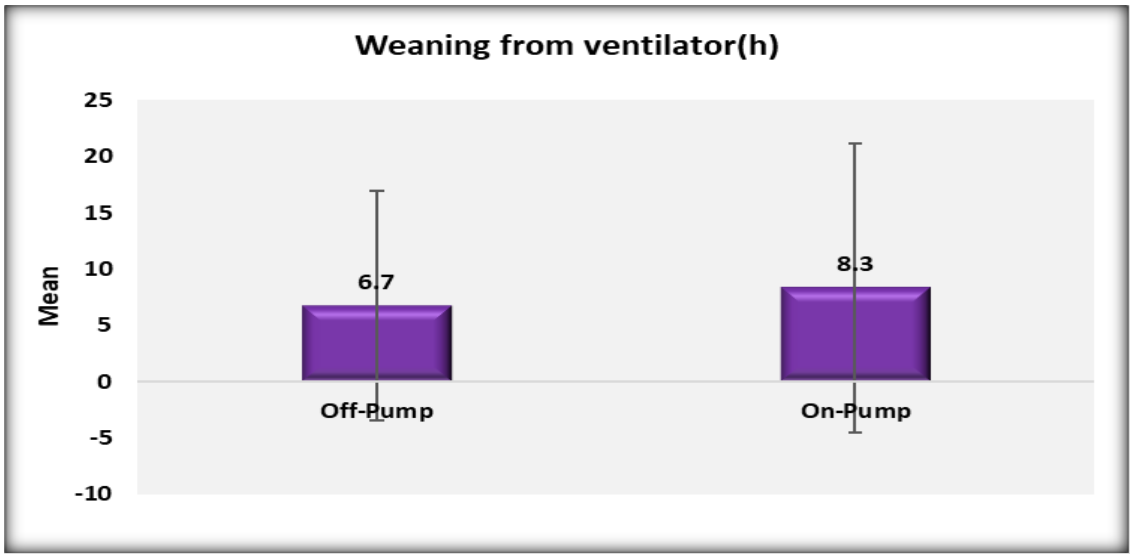

Figure 4: Distribution of the studied groups regarding Mean Weaning from ventilator

Table 4: ICU and Hospital stay between the studied groups:

	Coronary artery bypass grafting		Test of sig	P value
	Off-Pump (No.=50)	On-Pump (No.=50)		
ICU (d): • **Mean ±SD.** • **Median[range]**	2.4±0.9 2[2-6]	2.3±0.9 2[2-6]	MW=0.50	0.611
Hospital stays(d): **Mean ±SD**	6.7±1.8	7.1±1.0	t=1.20	0.233

***: significant, P-value ≤0.05 is considered significant, P value>0.05 is considered insignificant, (T test), No (number), MW (Man-Whitney test).**

In **group A** (off-pump) the Mean ±SD of ICU stay was 2.4±0.9, while in **group B** (on-pump) the Mean ±SD of ICU stay was 2.3±0.9, with no statistical significance(P>0.05). In **group A** (off-pump) the Mean ±SD of hospital stays was 6.7±1.8, while in **group B** (on-pump) the Mean ±SD of hospital stays was 7.1±1.0, with no statistical significance(P>0.05).

Table 5: Post-operative complications between the studied groups:

	Coronary artery bypass grafting				Test of sig	P value
	Off-Pump (No.=50)		On-Pump (No.=50)			
	No	%	No	%		
Elevated cardiac Biomarkers	5	10.0	4	8.0	χ^2=0.12	1.0^{FE}
ECG ischemic changes	5	10.0	4	8.0	χ^2=0.12	1.0^{FE}
Arrythmia	13	26.0	10	20.0	χ^2=0.50	0.476
Reopening for bleeding control	3	6.0	2	4.0	χ^2=0.21	1.0^{FE}
CNS complications	1	2.0	1	2.0	-	-
Liver complications	5	10.0	4	8.0	χ^2=0.12	1.0^{FE}
Renal complications	5	10.0	4	8.0	χ^2=0.12	1.0^{FE}
Fever	3	6.0	2	4.0	χ^2=0.21	1.0^{FE}

Wound infection	3	6.0	2	4.0	χ^2=0.21	1.0^{FE}
Mortality	2	4.0	1	2.0	χ^2=0.34	1.0^{FE}

***: significant, P-value ≤0.05 is considered significant, P value>0.05 is considered insignificant, (T test), χ^2 (chi-squared), ^{FE} (Fisher's exact tests).**

In **group A** (off-pump) the percentage of Elevated cardiac biomarkers was 10.0%, while in **group B** (on-pump) the percentage of Elevated cardiac biomarkers was 8.0%, with no statistical significance(P>0.05). In **group A** (off-pump) the percentage of ECG ischemic changes was 10.0%, while in **group B** (on-pump) the percentage of ECG ischemic changes was 8.0%, with no statistical significance(P>0.05). In **group A** (off-pump) the percentage of mortality was 4.0%, while in **group B** (on-pump) the percentage of mortality was 2.0%, with no statistical significance(P>0.05).

Discussion

CABG (coronary artery bypass grafting) is a successful procedure for restoring sufficient blood supply to the ischemic myocardium. To avert cardiopulmonary bypass, off-pump coronary bypass surgery (OPCAB) has been reproduced and perfected. However, it is a highly technical skill. Moreover, accurate blood flow measurement is crucial. Transit time flow measurement (TTFM) is used intraoperatively to evaluate graft flow and anastomosis patency. The accuracy of graft flow is determined by the interpretation of the TTFM parameters **(1).**

This study included 100 patients, who underwent coronary artery bypass grafting (CABG) between January 2020 and January 2022 in the cardiothoracic surgery departments of Kasr Elainy hospital and El Agouza police hospital,

Transit time flowmetry (TTFM) was routinely used to assess graft patency and flow during surgery. The TTFM findings influence graft revision.

In our study, the mean age in group A (off-pump CABG) was 60.5±4.6, while in group B (on-pump CABG) it was 61.1±4.6, The age groups in our study is relatively younger than the age groups in the other studies,**Zhuang et al., (1**) reported a mean age group above 65 years, this may be due to high prevalence of smoking, high cholesterol diet, hereditary diseases and sedentary life. There was no statistically significant difference in our study, in the mean ages of the two groups.

Regarding intra operative assessment for operative time, in group A (off-pump CABG) the Mean ±SD was 164.3±7.8, while in group B (on-pump CABG) the Mean ±SD was 184.7±9.2 with no statistical significance, and this was comparable with the results of **Zhuang et al., (1**).

Regarding intra operative number of grafts, in group A (off-pump CABG) 3 grafts was 20%, 4 grafts was 80% and the Mean ±SD of total number of grafts was 3.8±0.4, while wider range of grafts from 2 grafts to 5 grafts in group B (on-pump CABG) 2 grafts 6%, 3 grafts 44%,4 grafts 46%, 5 grafts 4% and the Mean ±SD of total number of grafts was 3.5±0.7, while in study of **Zhuang et al., (1**) The numbers of distal anastomoses varied from three to six per patient, with the average number similar in both groups (Off Pump CABG group: 3.83±0.93, on pump CABG group:3.78±1.11). which is very close to our study with no statistical significance between both groups of our study.

In terms of graft revision, Most of the grafts were detected with satisfactory TTFM findings, in group A (off-pump CABG) we revised 1graft in 5 patients 10%, two LIMA-LAD graft was re anastomosed due to stenosis at the anastomosis site, three SV grafts were re-anastomosed due to graft twist, while in group B (on-pump CABG) we revised 1 graft in 2 patients 4% cause of unsatisfactory TTFM findings ,two SV grafts re-anastomosed for anastomosis stenosis, with no statistical significance, in study of **Zhuang et al., (1)** Eleven grafts were detected with unsatisfactory TTFM findings in

Off Pump CABG group and Nine grafts were detected with unsatisfactory TTFM findings in on pump CABG group but the number of patients included is larger than our study number of patients.

Concerning the mean flow in ml/min in group A (off-pump CABG) the mean flow in grafts was 45.7±3.1 ml/min while in group B (on-pump CABG) the mean flow in grafts was 47.7±3.5 ml/min, mean flow in grafts in ml/Min was significantly higher in group B (on-pump CABG), **Schmitz et al., (4)** also reported that graft flow in on pump CABG patients was higher than that in off pump CABG patients while **Zhuang et al., (1**) found no statistical difference about mean flow between off Pump CABG group and on pump CABG group.

Concerning the pulsatility index, in group A (off-pump CABG) the Mean ±SD was 1.9±0.18, while in group B (on-pump CABG) the Mean ±SD was 1.7±0.17, pulsatility index was significantly higher in group A (off-pump CABG), while **Zhuang et al., (1**) found no statistical difference about pulsatility index between off Pump CABG group and on pump CABG group.

Concerning the percentage of backward flow (% BF), in group A (off-pump CABG) the Mean ±SD was 2.1±0.21, while in group B (on-pump CABG) the Mean ±SD was 2.0±0.19, The percentage of backward flow (% BF) was significantly higher in group A (off-pump CABG), while **Zhuang et al., (1**) found no statistical difference about the percentage of backward flow between off Pump CABG group and on pump CABG group.

In terms of ventilator weaning, all patients in both groups required postoperative mechanical ventilation, and no patients were extubated in the operating room.In group A (off-pump CABG) mean ±SD 6.7±10.2, while in group B (on-pump CABG) mean ±SD 8.3±12.8, weaning from ventilator was significantly higher in group B (on-pump CABG), and this was comparable with the results of **Zhuang et al., (1**) and **Schmitz et al., (4)** .

Concerning blood transfusion in group A (off-pump) the percentage of intraoperative blood transfusion was 26.0% And the percentage of post operative blood transfusion was 34.0%, while in group B (on-pump) the percentage of intraoperative blood transfusion was 18.0 % And the percentage of post operative blood transfusion was 20.0%. There was no statistically significant difference between the two groups, which was comparable to the findings of **Zhuang et al., (1**) and **Schmitz et al., (4)**.

Regarding ECG ischemic changes in group A (off-pump) the percentage of ECG ischemic changes was 10.0%, while in group B (on-pump) the percentage of ECG ischemic changes was 8.0. There was no statistically significant difference between the two groups, which was comparable to the findings of **Zhuang et al., (1**) and **Schmitz et al., (4)**.

Concerning ICU stay in group A (off-pump) the Mean ±SD of ICU stay was 2.4±0.9, while in group B (on-pump) the Mean ±SD of ICU stay was 2.3±0.9. There was no statistically significant difference between the two groups, which was comparable to the findings of **Zhuang et al., (1**) and **Schmitz et al., (4)**.

Regarding hospital stays in group A (off-pump) the Mean ±SD of hospital stays was 6.7±1.8, while in group B (on-pump) the Mean ±SD of hospital stays was 7.1±1.0. There was no statistical significant difference between both groups, and this was comparable with the results of **Zhuang et al., (1**) and **Schmitz et al., (4)**.

Concerning mortality in group A (off-pump) the percentage of mortality was 4.0%, while in group B (on-pump) the percentage of mortality was 2.0%. There was no statistically significant difference between the two groups, which was comparable to the findings of **Zhuang et al., (1**) and **Schmitz et al., (4)**.

Conclusion

According to the findings of our study, we believe that transit time flow measurement is useful in clinical practice because it prompts surgeons to investigate the cause of poor graft flow, and off-pump coronary bypass surgery can achieve the same anastomosis as on-pump coronary bypass surgery. The surgeon's experience and expertise determine the outcome of off-pump coronary bypass surgery.

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