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Clinical Study

Postoperative Tachyarrhythmias: On-Pump versus Off-Pump Coronary Artery Bypass Grafting

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Objective. Tachyarrhythmias, after coronary artery bypass graft (CABG) surgery, develop in 11%–40% of patients. Surgery technique (on-pump or off-pump) might affect incidence of post-CABG tachyarrhythmias. *Methods*. The study included 60 patients undergoing CABG (≥2 grafts) with left ventricle ejection fraction (LV EF) >40%. Patients were divided into two groups equally: group A (on-pump) and group B (off-pump). Patients were subjected to electrocardiographic monitoring (7 days postoperatively), transthoracic echocardiography, with recording of surgical details and complications. *Results*. Data collected between December 2012 and May 2013 showed no significant difference between two groups regarding incidence of postoperative tachyarrhythmias with statistically significant higher incidence of supraventricular tachycardia in group B ($P < 0.05$) and a trend towards higher incidence of atrial fibrillation in group A. Patients who developed postoperative tachyarrhythmias in group A showed higher prevalence of family history of coronary artery disease and higher incidence of postoperative chest infections ($P < 0.05$), while those in group B showed higher mean LV EF (pre- and postoperatively) ($P < 0.05$). Data were statistically described in terms of mean ± standard deviation. Comparison of numerical and categorical variables was done using Student's t- and Chi-square tests, respectively. *Conclusion*. Adopting off-pump CABG technique is not associated with less incidence of post-operative tachyarrhythmias, as compared to on-pump technique.

1. Introduction

Surgery for coronary artery disease is known as coronary artery bypass graft (CABG) surgery. It was first performed in 1967 by Kolesov and is still the leading heart operation performed today [1]. Surgeons use cardiopulmonary bypass machine (also known as the heart-lung machine) for on-pump CABG [2]. Complications of on-pump CABG, especially stroke and decrease in higher mental functions, spurred the development of off-pump technique [1]. Up to 30% of patients develop atrial fibrillation (Af) after CABG, mostly benign and self-terminating. Postoperative arrhythmias are associated with prolonged hospital stay, hemodynamic instability, and thromboembolism [3]. The primary goal of off-pump CABG surgery is to provide an equally comprehensive operation as the conventional operation. Patient selection plays an important role in success of off-pump CABG (OPCAB). Patients with poor ejection fraction, cardiomegaly, cardiogenic shock or malignant arrhythmias are at high risk for OPCAB [4].

2. Methods

2.1. Study Design and Data Collection. Sixty patients referred to cardiothoracic surgery department and planned for elective CABG were prospectively enrolled between December 2012 and May 2013. Patients were considered eligible for inclusion if they were undergoing first time CABG (planned for ≥2 grafts), with preoperative transthoracic echocardiography (TTE) showing left ventricle ejection fraction (LV EF) >40%, left atrial anteroposterior diameter <40 mm, and left ventricular end diastolic dimension (LVEDD) <57 mm. Patients with history of chronic tachyarrhythmias, myocardial infarction in the previous six weeks, coronary stenting, electrolyte imbalance (pre- or postoperative), on oral antiplatelets for the last two weeks before enrollment,

undergoing concomitant valve replacement, redo, or emergency CABG surgery, were excluded. Before inclusion, informed written consent was obtained after explanation of study protocol that was approved by our local institutional human research committee as it conforms to the ethical guidelines of the 1975 Declaration of Helsinki, as revised in 2008. Patients were randomly (1 : 1 randomization) assigned to undergo either on-pump CABG (group A) or off-pump CABG (group B).

All patients were subjected to history taking, clinical examination, 12-lead electrocardiogram (ECG) preoperatively and for seven days postoperatively (in addition to continuous ECG monitoring), TTE (pre- and postoperatively), and recording of surgical details including intra- and postoperative (7 days) complications (e.g., sepsis, tamponade, etc.).

2.2. Twelve-Lead ECG. To identify patients who develop tachyarrhythmias, it was done preoperatively and for 7 days postoperatively. Moreover, patients were continuously monitored for rhythm changes.

2.3. Transthoracic Echocardiography. TTE images were obtained using General Electric Vivid 7 cardiac ultrasound machine (General Electric, Horten, Norway). A 2.5 MHz phased array probe was used for image acquisition in patients acquiring the left lateral position. Images were digitized in cine-loop format and saved for subsequent analysis. Views were analyzed by a single echocardiographer employing the software program of the echocardiography machine and blinded to patients' randomization. Echocardiographic assessment was done preoperatively and on the first day postoperatively with recording of LV EF in apical four-chamber view by modified Simpson's method, LVEDD, and left atria anteroposterior diameter using m-mode acquisition in parasternal views, in addition to other routine TTE measurements.

2.4. Surgical Data. All operations were performed by surgeons well experienced in both on-pump and off-pump techniques. Operators were blinded to the study protocol, as well. All surgical details were documented using anesthesia sheets and surgeons remarks with special emphasis on perioperative complications and number of grafts.

2.5. Postoperative Complications. Patients were followed up postoperatively for seven days with documentation of complications including tamponade, chest infections, prolonged intubation, stroke, high drain bleeding (>1000 cm^3 in the 1st 6 hours postoperatively), and sepsis.

2.6. Statistics. Data were statistically described in terms of mean ± standard deviation (± SD). Comparison of numerical variables between the study groups was done using Student's t-test. For comparing categorical data, Chi-square test was performed. P values were used to describe significance. All statistical calculations were done using Statistical Package for Social Sciences (SPSS for Windows) software (version 15.0, SPSS Inc., Chicago, IL, USA).

Table 1: Baseline characteristics of the two individual study groups.

Item	Group (A) (n = 30)	Group (B) (n = 30)	P value*
Age (years)	59.53 ± 9.45	57.07 ± 9.1	>0.05
Number of grafts	2.9 ± 0.75	2.67 ± 0.47	>0.05
Diabetes mellitus	23 (76.7)	22 (73.3)	>0.05
Hypertension	25 (83.3)	26 (86.7)	>0.05
Smoking	13 (43.3)	13 (43.3)	>0.05
Dyslipidemia	21 (70)	17 (56.7)	>0.05
Family history of CAD	8 (26.7)	11 (36.7)	>0.05
LA AP diameter (mm)	34.8 ± 2.9	33.7 ± 2.9	>0.05
LVEDD (mm)	52.9 ± 4.2	51 ± 4.48	>0.05
LVESD (mm)	41.04 ± 4.4	42 ± 5.5	>0.05
LV EF (%)	54 ± 7.6	55 ± 7.4	>0.05

Data are presented as mean ± SD and number (percentage).
*Chi-square test and Student's t-test.
CAD: coronary artery disease; LA AP diameter: left atrium anteroposterior diameter; LVEDD: left ventricular end diastolic dimension; LVESD: left ventricular end systolic dimension; LV EF: left ventricle ejection fraction (Simpson's).

3. Results

A total of sixty consecutive patients undergoing first time CABG (planned for ≥2 grafts) were prospectively enrolled in the current study, which comprises 30 patients randomly assigned to undergo on-pump CABG (group A) and 30 patients assigned to undergo off-pump CABG (group B). The study population included 39 male patients (65%) with a mean age of 58.3 ± 9.3 years. Group A included 18 (60%) male patients with a mean age of 59.53 ± 9.45 years, while group B included 21 (70%) male patients with a mean age of 57.07 ± 9.1 years. The two individual groups were statistically matched regarding age, gender, risk factors for coronary ischemia, number of grafts used and preoperative TTE data, as shown in Table 1.

3.1. Group A versus Group B. Postoperative comparative data between both study groups are shown in Table 2. Group A patients showed statistically significant higher incidence of postoperative chest infections and high drain bleeding, while group B patients showed higher mean LV EF. More patients in group B developed postoperative tachyarrhythmias. However, this numerical finding did not reach statistical significance.

3.2. Group A. No statistically significant difference was found between patients who developed postoperative tachyarrhythmias [n = 3 (10%), 2 (66.7%) male patients] and those who did not develop postoperative tachyarrhythmias [n = 27 (90%), 16 (59.3%) male patients], regarding age, gender, risk factors distribution, number of grafts used, TTE data, or incidence of other postoperative complications. These data are shown in Table 3.

Table 2: Postoperative data of the two individual study groups.

Item	Group (A) (n = 30)	Group (B) (n = 30)	P value*
LA AP diameter (mm)	34.8 ± 2.9	33.8 ± 2.9	>0.05
LVEDD (mm)	53.3 ± 4.4	50.6 ± 4.5	>0.05
LVESD (mm)	42.6 ± 3.5	42.08 ± 4.3	>0.05
LV EF (%)	48.9 ± 7.6	54 ± 6.8	**<0.001**
Tachyarrhythmias	3 (10)	5 (16.7)	>0.05
Tamponade	7 (23.3)	2 (6.7)	>0.05
Chest infection	15 (50)	7 (23.3)	**<0.05**
Prolonged intubation	4 (13.3)	2 (6.7)	>0.05
Cerebrovascular stroke	3 (10)	4 (13.3)	>0.05
High drain bleeding	7 (23.3)	1 (3.3)	**<0.05**
Sepsis	10 (33.3)	5 (16.7)	>0.05

Data are presented as mean ± SD and number (percentage).
*Chi-square test and Student's t-test.
CAD: coronary artery disease; LA AP diameter: left atrium anteroposterior diameter; LVEDD: left ventricular end diastolic dimension; LVESD: left ventricular end systolic dimension; LV EF: left ventricle ejection fraction (Simpson's).
P < **0.001** = statistically highly significant.
P < **0.05** = statistically significant.

3.3. Group B. No statistically significant difference was found between patients who developed postoperative tachyarrhythmias [n = 5 (16.7%), 4 (80%) male patients] and those who did not develop postoperative tachyarrhythmias [n = 25 (83.3%), 17 (68%) males], regarding age, gender, risk factors distribution, number of grafts used, TTE data, or incidence of other postoperative complications. These data are shown in Table 4.

3.4. Patients with Postoperative Tachyarrhythmias. Results showed that eight patients (13.3%) developed postoperative tachyarrhythmias among the whole study population. Three (37.5%) of them belong to group A, while five patients (62.5%) belong to group B. Regarding group A, all of the three patients developed Af, while in group B one (20%) patient developed Af, two (40%) patients developed supraventricular tachycardia (SVT), one (20%) patient developed atrial flutter, and one (20%) patient developed ventricular fibrillation (VF). Group B patients showed statistically significant higher incidence of SVT. There was no significant difference between patients who developed postoperative tachyarrhythmias in both study groups regarding age, gender, number of grafts. Regarding distribution of risk factors of CAD, group A patients showed statistically significant higher prevalence of family history of CAD. Regarding postoperative complications other than tachyarrhythmias, group A patients showed statistically significant higher incidence of postoperative chest infections. Regarding TTE data, group B patients showed statistically significant higher LV EF (pre- and postoperatively). None of the patients who developed postoperative tachyarrhythmias in both groups suffered from prolonged intubation or high drain bleeding. These data are shown in Table 5.

4. Discussion

4.1. Postoperative Tachyarrhythmias. The present study was conducted to evaluate the incidence of tachyarrhythmias after CABG, comparing two surgical techniques, that is, on-pump versus off-pump. The studied population included 39 male patients (65%) and 21 female patients (35%) with a mean age of 58.30 ± 9.3 years.

Results showed that incidence of tachyarrhythmias after CABG in both groups combined was 13.3%. 50% of them developed Af. Regarding the on-pump group (group A), incidence of postoperative tachyarrhythmias was 10% while in the off-pump group (group B) it was 16.7%. However, this did not reach statistical significance. All patients belonging to group A who developed postoperative tachyarrhythmias showed Af, while 20% of cases who developed tachyarrhythmias in group B developed Af with no statistical significant difference but a trend towards higher incidence of Af after on-pump CABG. Regarding group B; 40% of patients developed SVT with statistically significant higher incidence in comparison to group A patients, 20% developed atrial flutter and 20% developed VF. Results showed also that patients belonging to group B, including those who developed postoperative tachyarrhythmias, showed significantly higher postoperative LV systolic function. It seemed that higher LV EF was not protective against postoperative tachyarrhythmias.

A prior study showed concordant results with the present study results although it included larger number of patients. It compared on-pump versus off-pump CABG patients with no significant difference between both groups regarding distribution of risk factors for CAD (hypertension, diabetes, positive family history of CAD, and dyslipidemia) and reported no significant difference between both groups regarding incidence of postoperative tachyarrhythmias but a trend towards higher incidence of Af among on-pump CABG group of patients. This was upon short term followup [4]. Another study showed that higher incidence of post-CABG tachyarrhythmias especially Af was significantly associated with older age. However, it showed no statistically significant difference between both CABG techniques regarding incidence of postoperative Af upon short term followup as shown in our study results [5].

Post-off-pump atrial tachyarrhythmias were recorded in 13.3% (4 patients) of patients belonging to group B in the current study. Another study reported higher incidence, that is, 22%, but it included patients with prior history of atrial tachyarrhythmias. This might lead to different results [6]. Results of several meta-analyses stated that off-pump CABG was significantly associated with decreased incidence of postoperative tachyarrhythmias, especially Af [7–9]. On the other hand, a prior study including 138 CABG patients concluded that on-pump CABG was significantly associated with decreased incidence of Af [10]. We have to mention that various studies reported different results regarding incidence of postoperative tachyarrhythmias upon comparing on-pump and off-pump techniques. Results might be influenced by criteria or number of patients enrolled, in addition to surgeons' experience especially regarding off-pump CABG technique.

Table 3: Comparative data between patients who developed and patients who did not develop postoperative tachyarrhythmias among on-pump CABG group.

Item	Patients with no tachyarrhythmias (n = 27)	Patients with tachyarrhythmias (n = 3)	P value*
Age (years)	59.4 ± 9.3	59.6 ± 9.6	>0.05
Number of grafts	2.93 ± 0.35	2.67 ± 0.42	>0.05
Cross-clamping time (min.)	82.4 ± 12	81.6 ± 17.5	>0.05
Diabetes mellitus	21 (77.8)	2 (66.7)	>0.05
Hypertension	23 (85.2)	2 (66.7)	>0.05
Smoking	10 (37)	3 (100)	>0.05
Dyslipidemia	19 (70.4)	2 (66.7)	>0.05
Family history of CAD	6 (22.2)	2 (66.7)	>0.05
Pre-CABG			
LA AP diameter (mm)	35 ± 3.1	33.6 ± 1.5	>0.05
LVEDD (mm)	52.6 ± 4.3	55.3 ± 2	>0.05
LVESD (mm)	41 ± 3.4	42 ± 2.5	>0.05
LV EF (%)	54 ± 2.6	49.6 ± 2	>0.05
Post-CABG			
LA AP diameter (mm)	35 ± 3.1	33.6 ± 1.5	>0.05
LVEDD (mm)	53 ± 4.5	55.6 ± 2.3	>0.05
LVESD (mm)	42 ± 1.5	42.04 ± 2.3	>0.05
LV EF (%)	54.4 ± 7.9	49 ± 1	>0.05
Tamponade	6 (22.2)	1 (33.3)	>0.05
Chest infection	13 (48)	2 (66.7)	>0.05
Prolonged intubation	4 (14.8)	0	>0.05
Cerebrovascular stroke	3 (11.1)	0	>0.05
High drain bleeding	7 (26)	0	>0.05
Sepsis	9 (33.3)	1 (33.3)	>0.05

Data are presented as mean ± SD and number (percentage).
*Chi-square test and Student's t-test.
CAD: coronary artery disease; LA AP diameter: left atrium anteroposterior diameter; LVEDD: left ventricular end diastolic dimension; LVESD: left ventricular end systolic dimension; LV EF: left ventricle ejection fraction (Simpson's).

Many other studies agreed with our results that stated that incidence of post-CABG ventricular tachyarrhythmias is relatively rare but still the most serious [11, 12]. A prior retrospective study stated that off-pump technique is considered protective against ventricular tachyarrhythmias. However, this statement did not reach statistical significance [13]. On the other hand, the only patient in the present study who developed ventricular tachycardia belonged to the off-pump CABG group. But we have to highlight the relatively small number of patients enrolled in our study.

It is worth mentioning that patients enrolled in our study did not receive any form of prophylaxis against occurrence of postoperative tachyarrhythmias. It was shown by many studies that pre-, intra- and postoperative prophylaxis using Metoprolol [14], Verapamil [15], Digoxin and Propranolol [16], Landiolol and Bisoprolol [17], or statins [18] could be effective.

In the present study, patients with LA anteroposterior diameter measuring >40 mm and LV EF <40% were excluded. There was no statistically significant difference between patients who developed and who did not develop postoperative tachyarrhythmias regarding both parameters (pre- and postoperative) in both study groups. A prior study stated that incidence of post-CABG Af was associated with preoperatively higher LA volumes lower LV EF. However, this study included patients with preoperative LA anteroposterior diameters measuring >40 mm and LV EF <40% [19]. We hypothesized that Af is more common among patients undergoing on-pump CABG and it is still the commonest arrhythmia encountered after CABG as illustrated through our work. We tried to exclude the well-known precipitating factor of Af, that is, LA enlargement, which means excluding the element of electric remodeling as much as possible, but still Af is the commonest.

4.2. Other Postoperative Complications. In the current study, incidence of postoperative chest infections and high drain bleeding was significantly higher among on-pump CABG group of patients. On the other hand, there was no significant difference regarding incidence of other postoperative complications including cerebrovascular stroke between both study groups. It is worth mentioning that majority of patients who

Table 4: Comparative data between patients who developed and patients who did not develop postoperative tachyarrhythmias among off-pump CABG group.

Item	Patients with no tachyarrhythmias (n = 25)	Patients with tachyarrhythmias (n = 5)	P value*
Age (years)	57 ± 8.9	56.8 ± 11.3	>0.05
Number of grafts	2.64 ± 0.32	2.8 ± 0.79	>0.05
Diabetes mellitus	19 (76)	3 (60)	>0.05
Hypertension	23 (92)	3 (60)	>0.05
Smoking	11 (44)	2 (40)	>0.05
Dyslipidemia	16 (64)	1 (20)	>0.05
Family history of CAD	11 (44)	0	>0.05
Pre-CABG			
LA AP diameter (mm)	33.7 ± 3	33.8 ± 2.5	>0.05
LVEDD (mm)	50.6 ± 3.9	52.6 ± 6.8	>0.05
LVESD (mm)	40 ± 2.4	41 ± 4.5	>0.05
LV EF (%)	51.5 ± 7.1	55.2 ± 7.5	>0.05
Post-CABG			
LA AP diameter (mm)	33.7 ± 3	33.8 ± 2.5	>0.05
LVEDD (mm)	50.3 ± 4.1	52.2 ± 6.6	>0.05
LVESD (mm)	41 ± 1.5	41.4 ± 2.2	>0.05
LV EF (%)	51.2 ± 7	54.3 ± 5.6	>0.05
Tamponade	2 (8)	0	>0.05
Chest infection	7 (28)	0	>0.05
Prolonged intubation	2 (8)	0	>0.05
Cerebrovascular stroke	3 (12)	1 (20)	>0.05
High drain bleeding	1 (4)	0	>0.05
Sepsis	4 (16)	1 (20)	>0.05

Data are presented as mean ± SD and number (percentage).
*Chi-square test and Student's t-test.
CAD: coronary artery disease; LA AP diameter: left atrium anteroposterior diameter; LVEDD: left ventricular end diastolic dimension; LVESD: left ventricular end systolic dimension; LV EF: left ventricle ejection fraction (Simpson's).

developed postoperative stroke in our study belonged to the off-pump group.

Similarly, a meta-analysis (37 randomized trials) reported no significant differences between both CABG techniques regarding incidence of postoperative stroke, with decreased incidence of postoperative chest infections among off-pump CABG group of patients [7]. Several studies that also excluded emergency CABG also reported no difference between both CABG techniques regarding stroke incidence [10, 20, 21]. Recently, this was also confirmed again in another study enrolling patients aged ≥75 years old undergoing elective first time CABG. There was no significant difference between on-pump and off-pump CABG with regard to the composite outcome of death, stroke, myocardial infarction, repeat revascularization, or new renal-replacement therapy within 30 days and within 12 months after surgery [22].

However, a prior study and meta-analysis showed that off-pump CABG was associated with lower rate of stroke incidence, even with long term followup postoperatively [23, 24]. We hypothesized from the resulted data that higher incidence of Af (which was not statistically significant) in group A was accompanied by significantly occurring postoperative chest infections. Moreover, incidence of Af was higher among patients with lower LV EF that is, group A.

Count of blood products for transfusion was not included in our methodology. A recent study stated that transfusion of blood products after CABG has a strong, dose-dependent association with the risk of stroke [25]. Hetastarch was not used as an artificial colloid intraoperatively in the present study owing to previous data suggesting its association with high risk of bleeding manifested by increased postoperative transfusion requirements and high drain bleeding during the first hours. This is considered for both on-pump and off-pump CABG [26].

5. Conclusion

Study results showed no significant difference between on-pump CABG and off-pump CABG surgery regarding incidence of postoperative tachyarrhythmias, with statistically significant higher incidence of SVT among off-pump group of patients and a trend towards higher incidence of atrial fibrillation among on-pump group of patients. On-pump group showed significantly higher incidence of postoperative

Table 5: Comparative data between patients who developed post-operative tachyarrhythmias in both study groups.

Item	Group (A) (n = 3)	Group (B) (n = 5)	P value*
Age (years)	59.6 ± 9.6	56.8 ± 11.3	>0.05
Number of grafts	2.67 ± 0.6	2.8 ± 04	>0.05
Diabetes mellitus	2 (66.7)	3 (60)	>0.05
Hypertension	2 (66.7)	3 (60)	>0.05
Smoking	3 (100)	2 (40)	>0.05
Dyslipidemia	2 (66.7)	1 (20)	>0.05
Family history of CAD	2 (66.7)	0	<**0.05**
Pre-CABG			
LA AP diameter (mm)	33.6 ± 1.5	33.8 ± 2.5	>0.05
LVEDD (mm)	55.3 ± 2	52.6 ± 6.8	>0.05
LVESD (mm)	41.03 ± 4	42.01 ± 5	>0.05
LV EF (%)	49.6 ± 2	55.2 ± 7.5	<**0.05**
Post-CABG			
LA AP diameter (mm)	33.6 ± 1.5	34 ± 2.6	>0.05
LVEDD (mm)	55.6 ± 2.3	52.2 ± 6.6	>0.05
LVESD (mm)	42 ± 3.1	42.02 ± 2.3	>0.05
LV EF (%)	49 ± 1	54.3 ± 5.6	<**0.05**
Tamponade	1 (33.3)	0	>0.05
Chest infection	2 (66.7)	0	<**0.05**
Cerebrovascular stroke	0	1 (20)	>0.05
Sepsis	1 (33.3)	1 (20)	>0.05

Data are presented as mean ± SD and number (percentage).
*Chi-square test and Student's t-test.
CAD: coronary artery disease; LA AP diameter: left atrium anteroposterior diameter; LVEDD: left ventricular end diastolic dimension; LVESD: left ventricular end systolic dimension; LV EF: left ventricle ejection fraction (Simpson's).
P < **0.05** = statistically significant.

chest infection and high drain bleeding. Off-pump group showed significantly higher LV EF (pre- and postoperatively).

5.1. Limitations of the Study. The data presented in our study only apply for patients defined by inclusion and exclusion criteria. This is a single-centre study with a small sample size of the cohort, so larger sample studies still needed to explore the multifactorial etiology of post-CABG tachyarrhythmias. Also, the study lacks the proper postoperative follow up period that can allow further tracking of postoperative tachyarrhythmias and other complications as well. Need for blood transfusion products and inotropic support was not included in study methodology. Both can affect the incidence of postoperative complications including tachyarrhythmias. Also, we did not go through many surgical details.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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