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Original Article

Efficacy of on-pump versus off-pump coronary artery bypass grafting in early-stage renal impairment without dialysis therapy

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Abstract

Background

Coronary artery disease is the most common of the cardiovascular diseases that can be treated with coronary artery bypass grafting (CABG) surgery, with either on-pump or off-pump technique. In this study, we aimed to compare the early results of isolated CABG, using on-pump and off-pump techniques, in patients with preoperative mild-to-moderate elevation of serum creatinine (1.6–2.5 mg/dl) level who did not require maintenance dialysis to support renal function.

Patients and methods

This prospective nonrandomized study included 60 patients who complained of symptoms of coronary artery disease and subsequently underwent myocardial revascularization at Cardiothoracic Surgery Department, Shebin El-Kom Teaching Hospital, Menoufia, Egypt, between June 2017 and August 2018.

Results

In group A (the on-pump group), the mean age was 73.40 ± 6.38 years, whereas in group B (the off-pump group), the mean age was 72.87 ± 9.62 years. The mean of total pump time was 112.40 ± 37.80 min and the mean of total ischemic time was 67.50 ± 24.18 min Regarding the operation time, the mean of on-pump CABG operation time was 234.60 ± 57.54 min, and 273.77 ± 43.07 min for the off-pump CABG operation, with statistically significant difference (P = 0.004). The mean time of ICU stay was 4.66 ± 3.36 days in the on-pump CABG and 3.70 ± 2.15 days in the off-pump CABG group, with no statistically significant difference between the two groups (P = 0.191).

Conclusion

Regarding postoperative renal dysfunction and need for dialysis, results were in favor of the off-pump technique. Renal function is better preserved in patients undergoing off-pump CABG than those undergoing on-pump CABG.

Keywords: Coronary artery disease, off-pump coronary artery bypass, on-pump coronary artery bypass grafting, renal impairment

Introduction

Ischemic heart disease (IHD) or coronary artery disease (CAD) is the most common of the cardiovascular diseases that is characterized by reduced blood supply to the heart owing to narrowing of coronary arteries because of accumulation of plaque in the arteries of the heart [1,2]. This disease can be treated with coronary artery bypass grafting (CABG) surgery. CABG has traditionally been applied with cardiopulmonary bypass (CPB) and an arrested heart [3]. The current development of cardiac stabilizers has made it possible to conduct the operation on the beating heart and thereby

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avoid cardiac arrest and CPB. Accordingly, it was hoped that complications seen after CABG could be reduced [4].

Off-pump coronary artery bypass (OPCAB) was popularized in the mid-1990s to decrease operative mortality and postoperative morbidity associated with the use of CPB, including neurologic complications, lung dysfunction, hemodynamic instability, global myocardial ischemia, systemic inflammatory response, and renal failure [5]. Other, theoretical or real, advantages of OPCAB over on-pump coronary artery bypass grafting (ONCAB) included less manipulation of the aortic root leading to a lower risk of perioperative stroke, less inflammation leading to less organ damage, and avoidance of myocardial injury caused by cardioplegic arrest and reperfusion [6]. However, several prospective randomized clinical trials comparing off-pump coronary artery bypass grafting (OPCAB) and on-pump coronary artery bypass grafting (ONCAB) in low-risk patients have not been able to demonstrate any significant reduction in mortality or significant postoperative complications [7–9]. In contrast, in most studies, patients undergoing OPCAB received fewer bypass grafts. Moreover, performing distal anastomoses on a moving field using a shunt to divert blood flow from the edges of the vessels presents less ideal conditions than the bloodless, stable conditions of ONCAB and concern was raised that graft patency might suffer [10].

In this study, we aimed to compare the early results of isolated CABG, using on-pump and off-pump, in patients with preoperative mild-to-moderate elevation of serum creatinine (1.6–2.5 mg/dl) level who did not require maintenance dialysis to support renal function. We examined if off-pump coronary revascularization offers a superior renal protection when compared with conventional coronary revascularization with CPB.

Patients and methods

Study design

All enrolled patients signed a consent form and the ethical approval was obtained from the ethical committee of Shebin El-Kom Teaching Hospital, Menoufia. This prospective nonrandomized study included 60 patients who complained of symptoms of CAD and subsequently underwent myocardial revascularization at Cardiothoracic Surgery Department, Shebin El-Kom Teaching Hospital, Menoufia, Egypt, between June 2017 and August 2018. Patients were allocated to either group according to the surgeon's preference as follows:

(1) Group A (the on-pump group): it included patients who underwent conventional myocardial revascularization by means of left internal mammary artery (LIMA) on left anterior descending (LAD) grafts plus additional saphenous vein graft interventions.
(2) Group B (the off-pump group): it included patients who underwent off-pump myocardial revascularization by means of LIMA on LAD grafts plus additional saphenous vein grafts.

The two groups were similar with respect to age, sex, and preoperative variables.

Inclusion criteria

Any patient subjected to isolated elective CABG, with preoperative mild-to-moderate elevation of serum creatinine levels between 1.6 and 2.5 mg/dl level, who did not require maintenance dialysis to support renal function was included. Moreover, we included all patients with (i) multivessel CAD, (ii) undergoing isolated on-pump (conventional) surgery, (iii) undergoing isolated off-pump (beating heart) surgery, and (iv) controlled risk factors, for example, hypertension, diabetes mellitus, hyperlipidemia, and smoking.

Exclusion criteria

Patients who had the following conditions were excluded: (a) normal serum creatinine levels, (b) single-vessel disease, (c) undergoing emergency surgery, (d) left ventricular ejection fraction less than 30%, (e) planned for OPCAB and reverted to on-pump owing to hemodynamic instability, and (f) undergoing redo-CABG.

Preoperative assessment

Preoperative stage of preparation/assessment included standard steps which started by careful and thorough history taking and clinical examination taking into consideration the patient's age, sex, and risk factors.

Laboratory studies

We evaluate all the following laboratory assessments: blood group and cross matching, complete blood count, electrolyte evaluation, kidney function tests (blood urea nitrogen/creatinine values), prothrombin time, international normalized ratio, activated partial thromboplastin time, liver function tests, blood sugar tests, and cardiac enzymes.

Imaging studies

Plain chest radiography, coronary angiography, transthoracic echocardiographic examination, and carotid duplex. Moreover, we evaluated other tests: 12-lead resting ECG and pulmonary functions tests (except in cases of left main stem lesions or equivalent).

Procedure of group A (on-pump technique)

We perform the CPB according the technique of John Gibbon. After routine aortic and right atrial cannulation is done using a common single atrial venous cannula pericardiotomy, a double-outlet cardioplegia cannula is inserted in the aortic root in all cases. CPB is carried out at 32°C in all cases. Intraoperative myocardial protection is achieved using antegrade single-dose high-volume cardioplegia (8°C). All distal anastomoses are constructed during one period of aortic cross-clamping. Venting of the heart is carried out through the same cardioplegia cannula double-line via the aortic root.

Regarding the distal anastomoses, we performed the distal anastomoses in the same sequence for all cases. Initially, the right coronary artery (RCA) is started followed by the posterior RCA branches, then the marginal branches of the circumflex artery,

and the diagonal branches of the LAD. The integrity of the grafts is carefully checked for flow manually and any possible leakage from the suture line before the LIMA is anastomosed to the LAD vessel as a final step in all patients. The distal anastomoses in all cases of separate CABG are done in an end-to-side fashion. In cases of sequential grafting, the most distal anastomosis is an end-to-side anastomosis and the following distal anastomoses are diamond-shaped (cross) or side-to-side anastomoses. Running polypropylene 7/0 sutures are used.

After the aorta is vented and the cross-clamp removed, fashioning of the proximal anastomoses is carried out, on the beating heart, aided with a vascular side-occlusion clamp after a hole is made by the scalpel and opened by a size 4.4/4.5 punch. All proximal anastomoses are made by running polypropylene 6/0 sutures.

Procedure of group B (the off-pump)

Performing the distal anastomoses is usually performed in the same sequence for all cases. Initially, the LIMA is anastomosed to the LAD vessel then the diagonal branches of the LAD, and then the RCA is started followed by the posterior RCA branches, then the marginal branches of the circumflex artery. The distal anastomoses in all cases of separate CABG are done in an end-to-side fashion. In cases of sequential grafting, the most distal anastomosis is an end-to-side anastomosis and the following distal anastomoses are diamond-shaped (cross) or side-to-side anastomoses. Running polypropylene 7/0 sutures are used. The proximal anastomoses were done as the same technique as for on-pump CABG.

Operative data and parameters

A record was made of the following: number and distribution of proximal and distal anastomoses, ischemic time, total CPB time, any occurrence of surgical problems necessitating the reinstitution of CPB, need for intraoperative inotropic support, intraoperative mean arterial blood pressure and central venous pressure, and any incident of hemodynamic instability during the procedure especially in group B.

Postoperative follow-up

A standard record of postoperative data was applied. A record was made of the following: kidney function tests (blood urea, serum creatinine, creatinine clearance, and a 24-h urine collection for the estimation of albuminuria level), ICU stay, mechanical ventilator support and if it was prolonged, mean hospital stay, hospital mortality defined as those deaths occurring within 30 days of the procedure or any mortality occurring within the same period of hospitalization, and operative morbidity defined as all complications beginning within 30 days of operation.

Statistical analysis

Data were analyzed by Microsoft Office 2010 and statistical package for social science, version 22 (IBM SPSS Inc. for Windows, version 22). Parametric data were expressed as mean ± SD, and nonparametric data were expressed as number and percentage of the total. Determining the extent that a single observed series of proportions differs from a theoretical or expected distribution was done using the χ^2-test. *P* value less than 0.05 is considered significant.

Results

Demographic data

In group A (the on-pump group), the mean age was 73.40 ± 6.38 years, whereas in group B (the off-pump), the mean age was 72.87 ± 9.62 years. All demographic data and baseline characteristics are summarized in Table 1.

Analysis of the preoperative abdominal and pelvic ultrasound (U/S) shows that there are 5 (16.6%) patients with chronic renal insufficiency in the ONCAB and two (6.6%) patients in the OPCAB group. In ONCAB, there are two (6.6%) patients with diabetic nephropathy, whereas in the OPCAB, there are eight (26.67%) patients.

Operative data

The mean of total pump time was 112.40 ± 37.80 min and the mean of total ischemic time was 67.50 ± 24.18 min. Regarding the operation time, the mean of ONCAB operation time 234.60 ± 57.54 min, and 273.77 ± 43.07 min for the OPCAB operation, with statistically significant difference ($P = 0.004$). The number of patients who need intra-aortic balloon pump was three patients in ONCAB and two patients in the OPCAB. Moreover, the number of patients who need inotropes was 29 (96.67%) in the ONCAB and 27 (90%) in the OPCAB group.

Postoperative data

The mean time of ICU stay 4.66 ± 3.36 days in the ONCAB and 3.70 ± 2.15 days in the OPCAB group, with no statistically significant difference between the two groups ($P = 0.191$). In terms of the medical parameters, Table 2 compares between the two groups before and after the operation.

Discussion

In this study, we compared the early results of isolated CABG, using on-pump and off-pump, in patients with preoperative mild-to-moderate elevation of serum creatinine (1.6–2.5 mg/dl)

Table 1: The demographic data

Demographic data	ONCAB (*n*=30)	OPCAB (*n*=30)	*P*
Age (years)	73.40±6.38	72.87±9.62	0.801
Weight (kg)	83.13±12.68	79.47±8.92	0.201
Male	25 (83.33)	23 (76.67)	-
Smoking	8 (26.67)	9 (30)	-
Hypertension	27 (90)	24 (80)	-
Diabetes mellitus	18 (60)	18 (60)	-
Dyslipidemia	22 (73.3)	22 (73.3)	-
Previous MI	14 (46.6)	10 (30.3)	-
Recent MI	6 (20)	0 (0)	-

Data were presented as mean±SD and *n* (%). MI, myocardial infarction; ONCAB, on-pump coronary artery bypass grafting; OPCAB, off-pump coronary artery bypass grafting.

Table 2: Comparison between preoperative and postoperative laboratory data among the on-pump and off-pump groups

	Pre-ONCAB	Post-ONCAB	Pre-OPCAB	Post-OPCAB	*P*[a]	*P*[b]	*P*[c]
Hemoglobin (g/dl)	12.57±1.43	9.42±1.1	12.92±1.21	10.35±0.89	0.001	0.001	0.006
Creatinine kinase-MB (U/I)	22.20±7.27	45.61±24.07	22.27±6.95	45.27±27.78	0.001	0.001	0.960
Troponin (U/I)	0.76±1.64	5.26±4.87	0.07±0.08	1.77±1.48	0.001	0.001	0.007
Random glucose testing (mg/dl)	117.40±32.02	157.43±57.27	115.87±64.87	135.73±39.81	0.001	0.007	0.095
Alanine transaminase (U/I)	27.03±10.90	27.63±16.74	30.90±10.77	31.73±12.09	0.617	0.639	0.282
Aspartate transaminase (U/I)	26.20±9.43	65.4±35.19	27.90±7.47	59.83±32.98	0.001	0.001	0.530
Total bilirubin (mg/dl)	0.63±0.34	0.78±0.46	0.74±0.26	0.92±0.29	0.458	0.001	0.289
Potassium (mmol/l)	4.47±0.40	5.22±0.62	4.79±0.51	5.06±0.38	0.001	0.012	0.236
Sodium (mmol/l)	142.53±2.96	146.4±4.61	140.97±3.86	144.8±5.67	0.001	0.003	0.235
Chloride (mmol/l)	103.40±4.08	109.93±4.73	101.80±4.80	110.67±5.36	0.001	0.001	0.577
Magnesium (mmol/dl)	0.98±0.17	1.32±0.3	1.01±0.29	1.22±0.25	0.001	0.004	0.170
Blood urea nitrogen (mg/dl)	35.77±16.58	49.0±15.36	31.20±12.07	32.5±15.43	0.001	0.430	0.001
Creatinine (mg/dl)	1.87±0.24	2.62±0.87	1.87±0.22	1.98±0.66	0.001	0.317	0.002
Creatinine clearance (ml/min)	41.43±8.63	30.87±11.04	40.41±9.48	39.84±13.68	0.001	0.686	0.012
Albuminuria (g/24 h)	1.36±1.18	1.07±0.828	1.33±1.20	1.32±1.23	0.001	0.926	0.370
Mean ejection fraction (%)	40±13	-	52±9	-	-	-	0.002
Systolic blood pressure (mmHg)	114.83±11.33	125±16.74	111.83±7.48	128±11.96	0.010	0.001	0.595
Diastolic blood pressure (mmHg)	58.67±8.30	57.67±8.17	60.67±8.17	63.67±8.92	0.632	0.144	0.009
Heart rate (beats/min)	88.37±9.72	90.87±11.81	72.27±11.04	84.23±7.82	0.285	0.001	0.016
Central venous pressure (mmHg)	11.0±2.68	10.17±4.44	10.07±3.14	9.33±3.2	0.215	0.296	0.408

ONCAB, on-pump coronary artery bypass grafting; OPCAB, off-pump coronary artery bypass grafting. [a]*P* value between pre-ONCAB and post-ONCAB. [b]*P* value between pre-OPCAB and post-OPCAB. [c]*P* value between post-ONCAB and post-OPCAB.

level who did not require maintenance dialysis to support renal function. We examined if off-pump coronary revascularization offers a superior renal protection when compared with conventional coronary revascularization with CPB. There was no significant difference in the mean ± SD of age among the on-pump group (73.40 ± 6.38) when compared with that of the off-pump group (72.87 ± 9.62) ($P = 0.801$).

Age has consistently predicted mortality after CABG, with advancing age associated with higher mortality. Assuming that age less than 65 years carries a relative risk of 1, it was found that the relative risk increased to 2.07 for patients between 65 and 74 years old and to 3.84 for those older than 75 years [11]. Despite this increased short-term risk of mortality after CABG treatment, long-term results remain encouraging. When patients less than 50 years of age are compared with those 70 years and older, and are matched by age to a population that did not undergo CABG, the older patients experience a longer hospitalization and higher hospital mortality, although their long-term survival more closely matches the general population compared with their younger counterparts [12,13]. Although elderly patients face an increased likelihood of morbidity after CABG and a particularly high incidence of stroke compared with the general population, age itself should not exclude a patient from being offered treatment with CABG, assuming that there is no prohibitive comorbidity. A careful quality-of-life and longevity assessment should be made in the oldest age groups [14,15].

In the on-pump, the percentage of female sex was 16.67%, whereas in the off-pump, the percentage was 23.33% in relation to male sex, which dominate in both studies (in on-pump 83.3% and in off-pump 76.7%). The higher percentage of male sex can be attributed to the fact that the ratio of men with IHD needing a CABG procedure is still higher; as will be discussed later, female sex carries an independent mortality risk, but overall, men are more prone to IHD than women. The number of patients with previous myocardial infarction in the on-pump group is greater than that of the off-pump group as infarcted patients will have lower contractility (ejection fraction), so surgeons prefer to do them on-pump. Hammar *et al.*[16] reported that when age and body surface area were taken into account, the relative operative risk between men and women became similar. Others have also found no differences in operative mortality, total postoperative morbidity, and ICU length of stay [17]. Comparable findings were reported for coronary bypass surgery in black male and female patients.

Smoking is the single most important cause of preventable premature mortality in the USA [18]. There is strong evidence from the Coronary Artery Surgery Study that smoking cessation after coronary bypass is rewarded by less recurrent angina, improved function, fewer hospital admissions, maintenance of employment, and improved survival (84% survival for quitters versus 68% for persistent smokers at 10 years for those randomized to operation) ($P = 0.018$) [19].

Hypertension is one of the most prevalent and powerful contributors to cardiovascular diseases, the leading cause of death in the USA. There is, on average, a 20 mmHg systolic and 10 mmHg diastolic increment increase in blood pressure from age 30 to 65 years. Isolated systolic hypertension is the dominant variety. There is no evidence of a decline in the prevalence of hypertension over four decades despite improvements in its

detection and treatment [20]. Hypertension contributes to all of the major atherosclerotic cardiovascular disease outcomes increasing risk, on average, two- to three-fold. Some studies reported that there may be a relationship between CPB and cancer progression such as melanoma and lung cancer [21,22].

In our study, we achieved strict control of preoperative blood sugar (fasting value: 100–120 mg and postprandial: 180–200 mg) preoperatively by insulin shots and postoperatively by using continuous intravenous insulin infusion in diabetic patients of both groups. This protocol was also adopted by many surgical groups in different surgical centers. Measurement of glycosylated hemoglobin 1 (HbA_{1c}) and admission of patients with levels less than 6% for the operation, and delaying the operation if HbA_{1c} of at least 6% is recommended. As HbA_{1c} of at least 6% was associated with an increased risk of postoperative superficial sternal wound infections and a trend for higher mediastinitis rate and significantly higher mortality 3 years after CABG [23,24].

CABG surgery in elderly patients with diabetes (age ≥ 65 years) has been reported to result in a reduction in mortality of 44% in Coronary Artery Surgery Study. The relative survival benefit of CABG versus medical therapy was comparable in patients with and without diabetes [25]. Nevertheless, a study from Sweden has indicated that patients with diabetes of all ages have a mortality rate during the 2-year period after CABG that is about twice that of patients without diabetes. Thirty-day mortality after CABG was 6.7% in patients with diabetes, and subsequent mortality between day 30 and 2 years was 7.8% compared with 3% and 3.6%, respectively, in patients without diabetes [26].

Analysis of the preoperative abdominal and pelvic U/S shows there was no statistically significant difference between the two groups as 10 patients had normal U/S examination result in both groups. As for the other findings, these are not considered to be risk factors for renal impairment postoperatively as U/S of the kidneys is a useful screening tool for kidney stones, cysts, and masses [27]. It can assess complications of obstructive kidneys stones. It provides useful information when a patient is in renal failure or if there is blood found in the urine. It can also provide information for those experiencing repeated urinary tract infections. However, it is not considered a renal function test.

The more prolonged total time of surgery in the OPCAB group can be attributed to the relatively more difficult technical demands of the technique and the fact that before every anastomosis there is some time needed to stabilize the heart without compromising the hemodynamics [28]. The ratio of use of intra-aortic balloon pump in both groups is higher than the other studies owing to the small studied group in comparison with the other studies. There is no statistically significant difference in ICU stay between the on-pump group and off-pump group in our study. Moreover, we noted that our ICU stay is much longer than other studies; this is owing to our ICU protocol of patient discharge [29].

In most of the reviewed studies including ours, renal function is better preserved in patients undergoing off-pump CABG than those undergoing on-pump CABG. Moreover, its notable that, in our study, there is higher percentage of patients who developed primary renal disease requiring dialysis postoperatively than in the other different studies, especially in the on-pump group, but this is expected as the criteria of inclusion for all our patients were 'patients with preoperative renal impairment (serum creatinine: 1.6–2.5 mg/dl),' but some of these studies included patients with normal serum creatinine preoperatively and measured the affection beyond normal renal function, and as we mentioned before, the preoperative renal impairment is considered by itself a risk factor for postoperative renal dysfunction [30,31]. Acute changes in renal function after CABG surgery are not well understood and incompletely characterized, and represent a challenging clinical problem [32].

Conclusion

Analysis of postoperative results showed no correlation between findings in abdominopelvic U/S and postoperative renal impairment. Cleveland Clinic Foundation Acute Renal Failure Scoring System does not take in consideration the various pathophysiological parameters of the CPB. Throughout the literature, there is a strong agreement that multiple risk factors (preoperative, intraoperative, and postoperative) and multiple pathological and physiological factors interact together to affect the kidney functions. Regarding postoperative renal dysfunction and need for dialysis, results were in favor of the off-pump technique. Renal function is better preserved in patients undergoing off-pump CABG than those undergoing on-pump CABG.

Recommendations

General measures to prevent renal dysfunction after cardiac surgery should be utilized in all patients with special attention to those with preoperative renal dysfunction. Ultimately, a successful therapy will utilize strategies that target these multiple pathways. This integrated strategy would target hemodynamic, inflammatory, and oxidative pathways and act at the points of proximal cellular injury. CPB offers an attractive model to study these pathways, because the timing of the insult is known and potentially modifiable.

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Conflicts of interest

There are no conflicts of interest.

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