Am J Transl Res 2025;17(7):5465-5474
www.ajtr.org /ISSN:1943-8141/AJTR0164573

Original Article

Off pump method of coronary artery bypass grafting enhances therapeutic efficacy and safety in elderly coronary heart disease patients

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Received March 17, 2025; Accepted July 9, 2025; Epub July 15, 2025; Published July 30, 2025

Abstract: Objective: To compare the therapeutic effects of off-pump versus conventional coronary artery bypass grafting (CABG) in elderly coronary heart disease (CHD) patients. Methods: This retrospective study analyzed 98 elderly CHD patients (47 conventional CABG, 51 off-pump CABG) treated between April 2019 and March 2021. Outcomes included intraoperative and postoperative indicators (distal anastomoses, mechanical ventilation time, hospital stay), graft patency, left ventricular function (LVEF, LVEDD), cardiac biomarkers (cTnI, CK, CK-MB), complication rates, 3-month quality of life (QoL), and long-term major adverse cardiovascular and cerebrovascular events (MACCE). Results: The two groups had similar distal anastomoses and graft patency rates ($P>0.05$). However, the off-pump group had shorter mechanical ventilation time and hospital stay than the conventional group (both $P<0.05$). LVEF and LVEDD showed no significant differences between the two group pre- and post-surgery. Cardiac biomarkers (cTnI, CK, CK-MB) increased postoperatively in both groups but were significantly lower in the off-pump group ($P<0.05$). The off-pump group had fewer complications, better QoL scores in social, mental, emotional, and overall health, and lower long-term MACCE incidence than the conventional group (all $P<0.05$). Conclusion: Off-pump CABG reduces surgical trauma, shortens recovery time, lowers complication rates, and improves QoL compared to conventional CABG, making it a preferable option for elderly CHD patients.

Keywords: Off-pump, cardiopulmonary bypass, CABG, elderly coronary heart disease, cardiac function

Introduction

Coronary heart disease (CHD) is a prevalent cardiovascular disorder characterized by coronary artery stenosis or occlusion due to atherosclerotic plaque formation, resulting in myocardial ischemia and subsequent cardiac dysfunction [1]. In China, the prevalence of CHD has shown a marked increase, particularly among elderly populations, making coronary artery bypass grafting (CABG) a crucial intervention for restoring myocardial perfusion and improving cardiac function in these patients [2]. CABG, a standard surgical treatment for CHD, involves the use of autologous arterial or venous grafts to bypass stenotic coronary segments, thereby reestablishing oxygenated blood flow to ischemic myocardium [3].

Contemporary CABG procedures primarily employ two techniques: conventional CABG (CCABG) and off-pump CABG (OPCABG) [4]. While CCABG provides optimal surgical exposure and anastomotic precision, establishing it as a gold standard, OPCABG has emerged as a valuable alternative for high-risk candidates due to its advantages in reducing the systemic inflammatory response and minimizing surgical trauma [5, 6]. Over recent decades, advances in surgical techniques and instrumentation have significantly expanded the clinical application of both CCABG and OPCABG [7, 8]. However, surgical selection requires careful consideration of relative merits, particularly for elderly patients who frequently present with multiple comorbidities including hypertension, diabetes mellitus, cerebrovascular disease, chronic pulmonary or renal insufficiency, and age-related organ dysfunction - all of which increase perioperative risks of bleeding, infection, and other complications [9, 10]. Notably, current evidence remains inconclusive regarding the safety profile of

https://doi.org/10.62347/VKEY9889

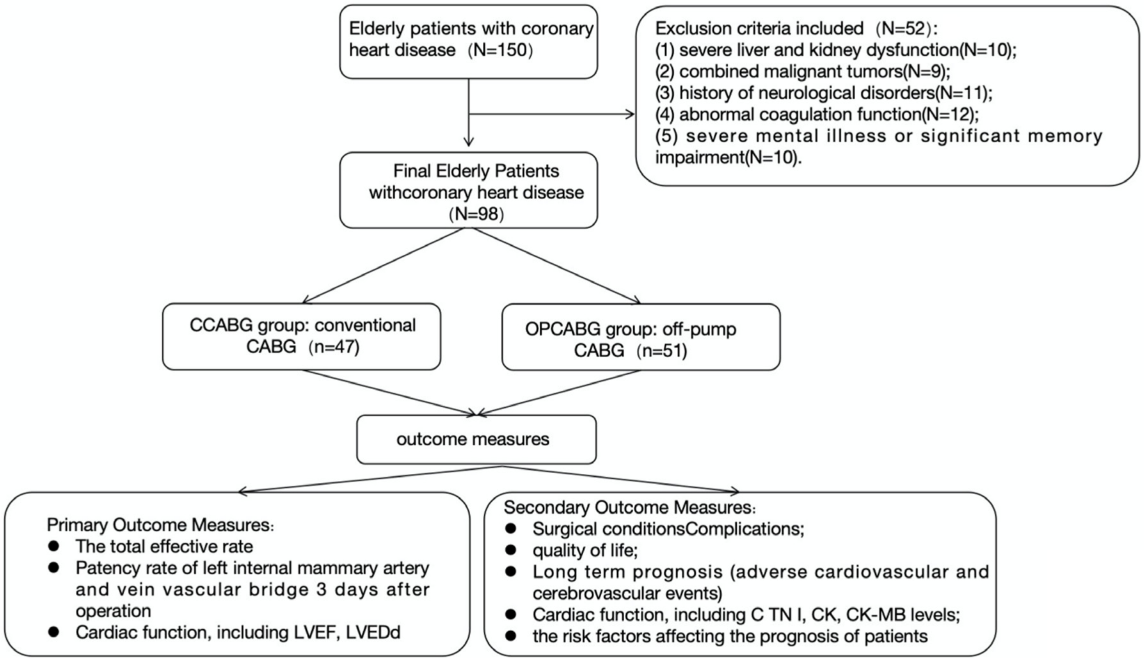

Figure 1. Flow chart of study design. OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting; LVEF: Left Ventricular Ejection Fraction; LVEDD: Left Ventricular End-Diastolic Diameter; cTn I: cardiac troponin I; CK: Creatine Kinase; CK-MB: Creatine Kinase-Myocardial Band.

OPCABG specifically for elderly CHD patients, as demonstrated by conflicting findings in the existing literature.

Based on the above, this study retrospectively analyzed the clinical data of 98 elderly patients with CHD to compare the efficacy of conventional CABG and off-pump CABG in elderly patients with CHD, so as to provide more reference for treatment selection.

Materials and methods

Case selection

The clinical data of 98 elderly patients with CHD admitted to Liaocheng People's Hospital from April 2019 to March 2021 were retrospectively analyzed. Among them, 47 patients who underwent conventional CABG were categorized as the conventional CABG (CCABG) group and 51 patients who underwent off-pump CABG as the off-pump CABG (OPCABG) group. This study was approved by the Ethics Committee of Liaocheng People's Hospital. A flow chart of study design is shown in **Figure 1**. The study was approved by the Liaocheng People's Hospital ethics committee and conformed to the Declaration of Helsinki.

Inclusion Criteria: Patients having a diagnosis of CHD confirmed by coronary angiography; aged ≥65 years; at least single coronary artery disease >70%; CABG was performed for the first time; with complete case data.

Exclusion Criteria: Patients with severe liver and kidney dysfunction; with malignant tumors; with a history of neurological disease; with coagulation abnormalities; with severe mental illness or significant memory impairment; refusal to cooperate with the study.

Data collection

All patients underwent endotracheal intubation, intravenous combined with general anesthesia, and median sternotomy; the internal mammary artery, radial artery, and great saphenous vein were freed as vascular grafts for future use. Electrocardiogram, pulse, oxygen saturation, nasopharyngeal temperature, central venous pressure, radial artery pressure and urine volume were routinely monitored.

CCABG group: Patients were treated with intravenous heparin 3.5 mg/kg for systemic heparinization. Cardiopulmonary bypass was established by catheterization of the ascending aorta and right atrium, the ascending aorta was blocked, myocardial protective solution and blood-containing cold cardioplegia were perfused, and ice chips were placed in the pericardial cavity for local cooling treatment. After cardiac arrest, the distal radial artery, the proximal great saphenous vein bridge and the coronary artery were anastomosed end-to-side. The temperature of nasopharyngeal cavity was maintained at about 31°C during the operation. Following the completion of distal anastomosis, the left anterior descending artery was anastomosed to the internal mammary artery, and the ascending aorta was then opened. When the patient's heart returned to pulsation, the ascending aorta was clamped to complete the vascular and aortic anastomosis.

OPCABG group: Patients were routinely given 100-200 U/kg dose of unfractionated heparin for intravenous injection, and prothrombin activation time was over 300 s. β-blockers were used to control heart rate, a midline incision was made at the sternum, the left internal mammary artery was freed. Papaverine saline was used to surround the standby. The pericardium was incised and suspended. The heart was fully exposed, pericardial traction was performed, and the target vessels on the lateral and posterior sides of the heart were exposed. Cardiac immobilizers were used adjunctively to immobilize the heart. The coronary artery was incised, the inflow thrombus was used to block the coronary anastomotic blood flow, and the anastomotic blood was dissipated by filtering high-pressure carbon dioxide. The distal end of the artery and the proximal end of the great saphenous vein bridge were anastomosed with the end-to-side anastomosis of the coronary arteries, and then part of the ascending aorta was clamped with a lateral clamp for proximal vascular anastomosis.

Both groups received conventional anti-infective therapy after operation.

Outcome measures

Primary outcome measures: (1) The treatment efficacy of the two groups of patients was evaluated, which was divided into cured (patients' cardiac function recovered without obvious index abnormalities and symptoms), markedly effective (patients' cardiac function basically recovered, abnormal indexes and symptoms improved), effective (patients' cardiac function improved, abnormal indexes and symptoms slightly improved) and ineffective (patients' cardiac function, abnormal indexes and symptoms did not significantly improve). Total effective rate (%) = (cured + markedly effective + effective) cases/total cases * 100. (2) Coronary angiography or coronary CT angiography was used to examine and compare the patency rate of left internal mammary artery and venous vascular bridge between the two groups 3 days after surgery. (3) Echocardiography was performed before and 3 months after operation in both groups, and cardiac function indicators, including left ventricular ejection fraction (LVEF) and left ventricular end diastolic diameter (LVEDD), was compared between the two groups.

Secondary outcome measures: (1) Intraoperative and postoperative conditions were recorded and compared between the two groups, including the number of distal anastomoses of venous bridge vessels, postoperative mechanical ventilation time, and hospital stay. (2) To evaluate patients' cardiac function, a DVIA2400 automatic biochemical analyzer (Siemens, Germany) was used to determine the levels of cardiac troponin I (cTn I), creatine kinase (CK) and creatine kinase isoenzyme (CK-MB) before and 3 days after operation in the two groups. (3) The occurrence of arrhythmia, atrial fibrillation, gastrointestinal reaction, and incision infection and other complications in the two groups were recorded and compared. (4) Three months after operation, the quality of life of the two groups was evaluated by using a 36-item short form health survey (SF-36), which included eight dimensions: physical pain, physical function, social function, mental function, physical function, overall vitality, emotional function and overall health. The total score of each dimension was 0-100 points, and the higher the score indicated the higher the life quality. (5) The long-term prognosis of the two patient groups was statistically analyzed and compared, including mortality, cerebrovascular events, myocardial infarction, heart failure, and cardiac-related rehospitalization.

Statistical analysis

SPSS 19.0 statistical software was used to analyze the data collected. The counted data were expressed as rate and percentage, and analyzed by Chi square test. The measured data were expressed as mean ± standard deviation and analyzed by student t test, paired t

Table 1. General information [n (%)]

Variable	OPCABG Group (n=51)	CCABG Group (n=47)	χ^2	P
Gender			0.008	0.993
Male	26 (50.98)	24 (51.06)		
Female	25 (49.02)	23 (48.94)		
Age (years)			0.001	0.980
≤69	24 (47.06)	22 (46.81)		
>69	27 (52.94)	25 (53.19)		
BMI (kg/m^2)			0.048	0.827
≤23	25 (49.02)	22 (46.81)		
>23	26 (50.98)	25 (53.19)		
Types of CHD			0.008	0.996
Stable angina	20 (39.22)	18 (38.30)		
Unstable angina	16 (31.37)	15 (31.91)		
Acute myocardial infarction	15 (29.41)	14 (29.79)		
Smoking history			0.258	0.611
Yes	30 (58.82)	30 (63.83)		
No	21 (41.18)	17 (36.17)		
Hypertension			0.097	0.756
Yes	31 (60.78)	30 (63.83)		
No	20 (39.22)	17 (36.17)		
Number of diseased vessels			0.007	0.997
1 Vessel	21 (41.18)	19 (40.43)		
2 Vessels	17 (33.33)	16 (34.04)		
3 Vessels	13 (25.49)	12 (25.53)		

BMI: Body Mass Index; CHD: Coronary heart disease; OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

Table 2. Comparison of curative effects between the two groups [n (%)]

Curative effect	OPCABG Group (n=51)	CCABG Group (n=47)	χ^2	P
Cure	10 (19.61)	4 (8.51)	-	-
Markedly effective	30 (58.82)	28 (59.57)	-	
Effective	8 (15.69)	7 (14.89)	-	-
Invalid	3 (5.88)	8 (17.02)	-	-
Total effective rate	48 (94.12)	39 (82.98)	3.046	0.081

OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

test or one-way analysis of variance followed by LSD test. A statistical difference was significant when P<0.05.

Results

General information comparison

This study included data of 50 male patients and 48 female patients, with the mean age of (69.35±1.12) years. Subjects were comparable due to insignificant differences in gender, age, Body Mass Index (BMI), types of CHD, smoking history, hypertension, and the number of diseased vessels (P>0.05, **Table 1**).

Therapeutic effects comparison

The OPCABG group demonstrated clinical outcomes of 10 cured cases, 30 markedly effective cases, 8 effective cases, and 3 invalid cases; while the CCABG group showed 4 cured cases, 28 markedly effective cases, 7 effective cases and 8 invalid cases. There was no significant difference in the therapeutic efficacy between the two groups (P>0.05, **Table 2**).

Table 3. Comparison of intraoperative and postoperative conditions between the two groups

Variable	OPCABG Group (n=51)	CCABG Group (n=47)	t	P
Number of distal anastomosis of venous grafts (pieces)	3.44±0.17	3.49±0.2	1.337	0.185
Postoperative mechanical ventilation time (h)	5.06±0.24	6.54±0.2	33.01	<0.001
Length of hospital stay (d)	10.13±0.2	13.55±0.23	78.71	<0.001

OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

Table 4. Comparison of vascular patency rate between the two groups

Variable	OPCABG Group (n=51)	CCABG Group (n=47)	χ^2	P
Patency rate of internal mammary artery bridge	50 (98.04)	44 (93.62)	1.222	0.269
Patency rate of venous graft	47 (92.16)	40 (85.11)	1.220	0.269

OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

Comparison of intraoperative and post-operative indicators

There was no significant difference in the number of distal anastomoses between the two groups (P>0.05), but the postoperative mechanical ventilation time and hospital stay in the off-pump group were shorter than those in the conventional group (P<0.05, **Table 3**).

Vascular patency rate assessment

There was no significant differences in the patency rate of internal mammary artery bridge and the patency rate of venous vascular bridge between the CCABG and the OPCABG group (P>0.05, **Table 4**).

Cardiac function evaluation

Before treatment, there was no significant difference in LVEF and LVEDD between the two groups (P>0.05). After treatment, these two indicators were still at similar levels in both groups (P>0.05, **Figure 2**).

There was no significant difference in the levels of cTnI, CK, or CK-MB between the two groups before surgery (P>0.05). Three days after treatment, the levels of above indicators were significantly increased in both groups compared with those before treatment, and the increase in CCABG group exceeded that in the OPCABG group (P<0.05, **Figure 3**).

Postoperative complications comparison

The incidence of complication in OPCABG group was 11.76%, which in the CCABG group was 34.04%. The incidence of postoperative complications in the OPCABG group was lower than that in its counterpart (P<0.05, **Table 5**).

Quality of life comparison

After operation, the OPCABG group made greater improvement in the five dimensions in terms of social function, mental function, overall vitality, emotional function and overall health compared to the CCABG group (P<0.05), yet no significant difference was observed between two groups in terms of three dimensions including body pain, role physical, or physical function (P>0.05). Details are in **Table 6**.

Long-term prognosis analysis

The mean follow-up duration for the patients was 1.6 years (range: 1-3 years). In the OPCABG group, the incidence of adverse cardiovascular event was 19.61%. In the CCABG group, the incidence of adverse cardiovascular event was 36.84%. The incidence of adverse cardiovascular events in the OPCABG group was significantly lower than that of the CCABG group (P<0.05, **Table 7**).

Univariate and multivariate analysis of prognostic factors

The prognosis was evaluated according to the incidence of postoperative adverse cardiovascular events, including 31 cases in the poor prognosis group and 67 cases in the good prognosis group. Univariate analysis showed that age, the number of diseased vessels, the incidence of complications, and coronary artery bypass grafting scheme were the factors affect-

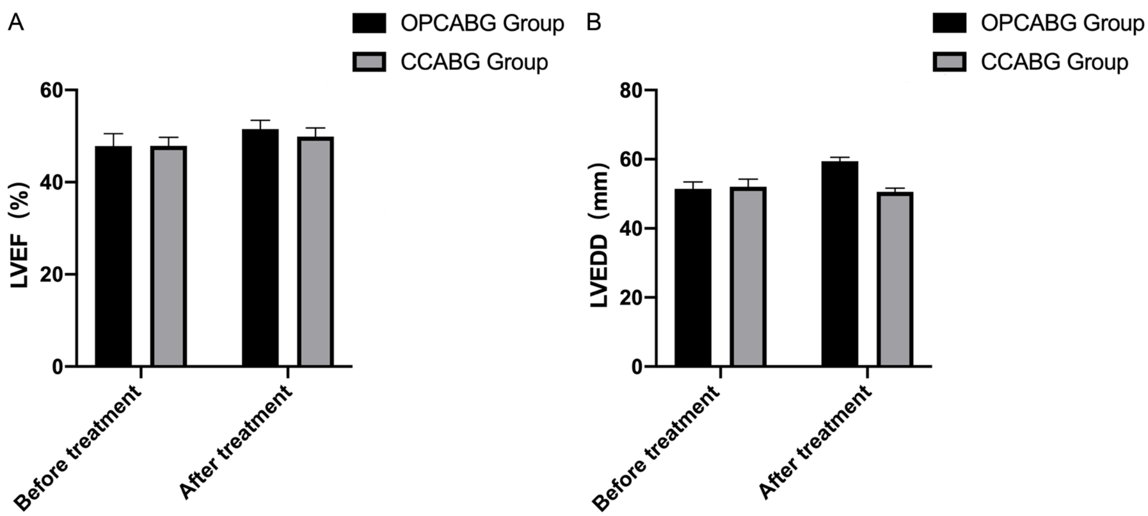

Figure 2. Comparison of cardiac function before and 3 months after surgery in the two groups. A: Comparison of LVEF before and after treatment in the two groups; B: LVEDD in the two groups before and after treatment. OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting; LVEF: Left Ventricular Ejection Fraction; LVEDD: Left Ventricular End-Diastolic Diameter.

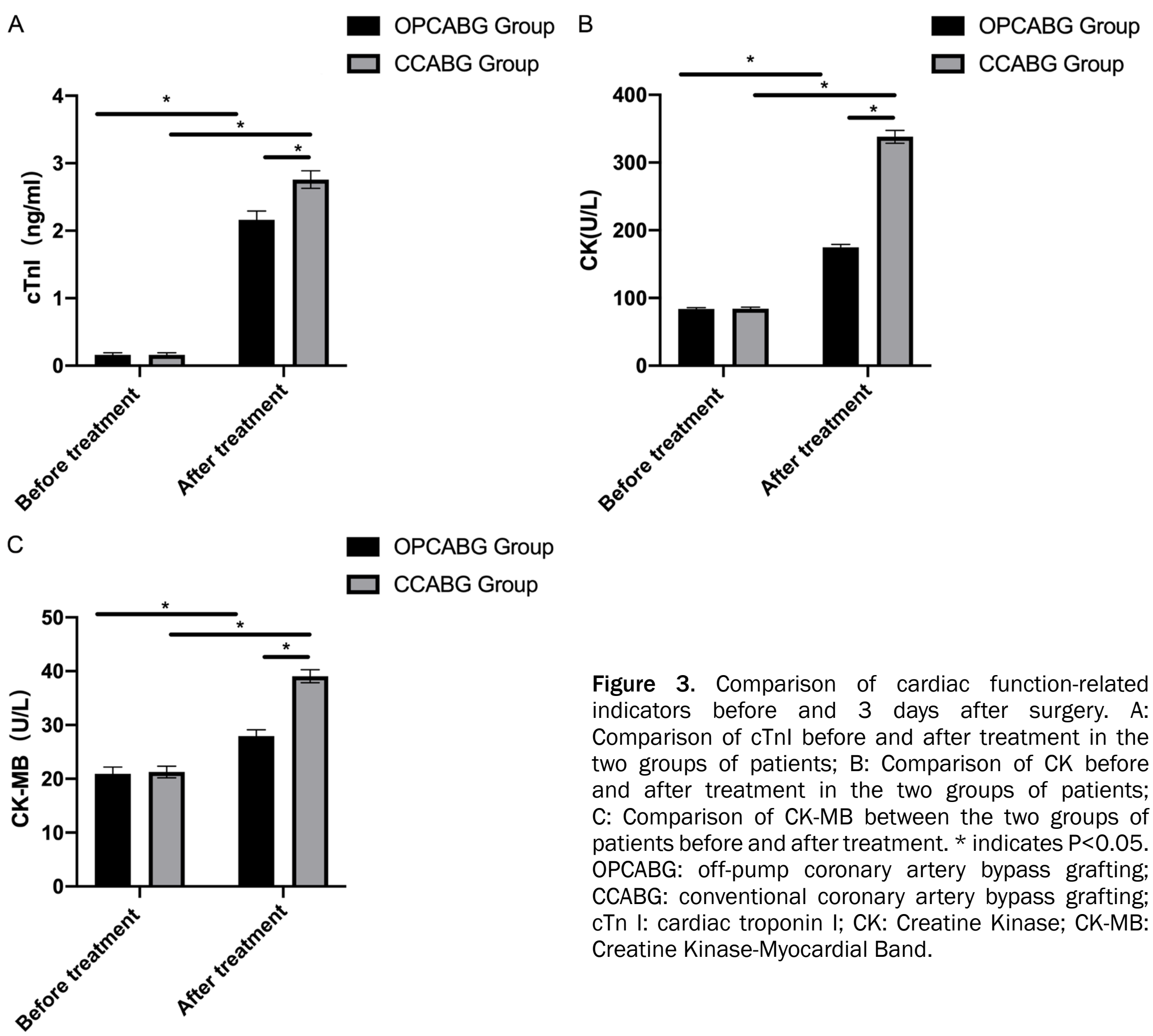

Figure 3. Comparison of cardiac function-related indicators before and 3 days after surgery. A: Comparison of cTnI before and after treatment in the two groups of patients; B: Comparison of CK before and after treatment in the two groups of patients; C: Comparison of CK-MB between the two groups of patients before and after treatment. * indicates $P<0.05$. OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting; cTn I: cardiac troponin I; CK: Creatine Kinase; CK-MB: Creatine Kinase-Myocardial Band.

Table 5. Comparison of postoperative complications after surgery [n (%)]

Variable	OPCABG Group (n=51)	CCABG Group (n=47)	χ^2	P
Arrhythmia	1 (1.96)	4 (8.51)	-	-
Atrial fibrillation	2 (3.92)	3 (6.38)	-	-
Gastrointestinal reactions	1 (1.96)	4 (8.51)	-	-
Wound infection	2 (3.92)	5 (10.64)	-	-
Complication rate	6 (11.76)	16 (34.04)	6.973	0.008

OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

Table 6. Comparison of quality of life between the two groups of patients 3 months after surgery

Dimension	OPCABG Group (n=51)	CCABG Group (n=47)	t	P
Body pain	65.91±2.12	66.23±2.4	0.070	0.485
Physiological function	56.3±2.13	56.45±2.31	0.335	0.738
Social function	73.5±2.45	66.7±2.04	14.86	<0.001
Mental function	70.89±2.1	64.42±2.13	15.13	<0.001
Role physical	66.32±2.33	66.00±2.23	0.693	0.490
Overall vitality	73.76±2.03	68.57±2.02	12.67	<0.001
Emotional function	63.52±2.61	53.93±2.37	18.99	<0.001
General health	79.25±2.3	73.07±2.56	12.59	<0.001

OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

Table 7. Comparison of long-term prognosis between the two patient groups [n (%)]

Variable	OPCABG Group (n=51)	CCABG Group (n=47)	χ^2	P
Mortality	1 (1.96)	3 (6.38)	-	-
Cerebrovascular events	3 (5.88)	4 (8.51)	-	-
Myocardial infarction	2 (3.92)	4 (8.51)	-	-
Heart failure	2 (3.92)	5 (10.64)	-	-
Cardiac-related rehospitalization	2 (3.92)	5 (10.64)		
Adverse cardiovascular event rate	10 (19.61)	21 (36.84)	3.907	0.048

OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

ing the prognosis of patients (**Table 8**). These variables were further included in the multivariate logistic regression analysis. The results showed that age, the number of diseased vessels and coronary artery bypass grafting scheme were independent risk factors affecting patient prognosis (**Table 9**).

Discussion

The optimal surgical approach for CABG - whether on-pump or off-pump - remains controversial in the medical literature, with limited clinical studies specifically comparing these two techniques. Our study found that the two methods has comparable numbers of distal venous graft anastomose, but off-pump approach shows significant advantages in terms of reduced postoperative mechanical ventilation duration and shorter hospital length of stay, suggesting superior recovery efficiency of off-pump CAGB for elderly CHD patients. These advantages may be attributed to avoidance of cardiopulmonary bypass-related complications, including central nervous system injury and pulmonary edema, which are known to prolong recovery [11]. Notably, off-pump CABG demonstrated significantly lower complication rates than the on-pump approach, reinforcing its safety profile. While on-pump CAGB provides optimal vascular exposure, it carries inherent risks of physiologic disturbances including systemic inflammatory response, myocardial ischemia-reperfusion injury, and cardiopulmonary bypass-induced mitochondrial damage from oxygen free radical production, all of which may

Table 8. Univariate analysis

Factor	Good prognosis group (n=67)	Poor prognosis group (n=31)	χ^2	P
Age			13.85	<0.001
≤69 (n=46)	40 (59.70)	6 (19.35)		
>69 (n=52)	27 (40.30)	25 (80.65)		
Smoking history			0.207	0.649
Yes (n=60)	40 (59.70)	20 (64.52)		
No (n=38)	27 (40.30)	11 (35.48)		
Number of diseased vessels			12.49	<0.001
1-2 (n=73)	57 (85.07)	16 (51.61)		
3 (n=25)	10 (14.93)	15 (48.39)		
Complications			6.887	0.009
Yes (n=22)	10 (14.93)	12 (38.71)		
No (n=76)	57 (85.07)	19 (61.29)		
Coronary artery bypass grafting			32.61	<0.001
OPCABG (n=51)	48 (71.64)	3 (9.68)		
CCABG (n=47)	19 (28.36)	28 (90.32)		

OPCABG: off-pump coronary artery bypass grafting; CCABG: conventional coronary artery bypass grafting.

Table 9. Multivariate analysis

Factor	B	S.E.	Wals	P	Exp (B)	95% C.I.	
						Lower limit	Upper limit
Age	1.864	0.735	6.428	0.011	0.155	0.037	7.255
Number of diseased vessels	2.072	0.777	7.107	0.008	7.944	1.731	6.457
Complications	0.193	0.858	0.260	0.610	1.549	0.288	8.331
Coronary artery bypass grafting	2.193	0.727	9.114	0.003	8.966	2.158	7.241

impair postoperative recovery [12, 13]. In contrast, off-pump CABG maintains circulatory stability without disrupting coagulation homeostasis, thereby minimizing systemic inflammatory response and ischemia-reperfusion injury while promoting faster recovery [14]. Importantly, our findings showed comparable graft patency rates between these two techniques, consistent with results from large-scale randomized trials [15], demonstrating equivalent patency rates regardless of coronary lesion location. These results collectively suggest that off-pump CABG offers distinct clinical advantages for elderly CHD patients without compromising graft efficacy.

Despite the comparable therapeutic outcomes, elderly CHD patients typically exhibit decreased physiological reserve and multiple comorbidities, rendering them higher-risk candidates for CABG, particularly those aged over 80 years [16]. Nevertheless, advanced age alone should not be considered an absolute contraindication for CABG. Currently, there are no universally established surgical indications for elderly patients, with decision-making primarily relying on individualized comprehensive assessment [17].

From a technical perspective, proponents of conventional on-pump CABG emphasize its ability to provide optimal surgical visualization through a bloodless field and stable anastomotic conditions, thereby facilitating procedural completion [18]. However, this approach is inherently more invasive and may adversely affect multiple organ systems. In contrast, off-pump CABG minimizes whole-body trauma, reduces the risk of multi-organ dysfunction, and accelerates postoperative recovery. These characteristics make off-pump CABG particularly advantageous for elderly patients, offering superior tolerability and distinct minimally invasive benefits [19]. Our results demonstrated no significant differences in cardiac function indicators before and after operation between the two surgical groups, suggesting that both techniques had comparable short-term effects on cardiac function in elderly CHD patients.

It is noteworthy that postoperative structural cardiac changes have traditionally served as important indicators for evaluating cardiac surgical outcomes [20]. In our study design, apart from the use of cardiopulmonary bypass, all other surgical procedures were standardized between groups. This method allowed us to specifically investigate whether off-pump CABG demonstrates equivalence or superiority to conventional techniques. Consequently, we incorporated perioperative myocardial injury assessment as a key outcome for evaluating short-term postoperative cardiac outcomes. Myocardial enzyme levels serve as crucial biochemical markers for quantifying myocardial damage, as they are released into circulation following cardiomyocyte injury [21]. Our data revealed that while both groups showed significant elevations in cTnI, CK, and CK-MB levels at postoperative day 3 compared to baseline values, these increases were substantially more pronounced in the CCABG group than in the OPCABG group. These findings suggest that off-pump CABG is associated with less severe myocardial injury, potentially attributable to its ability to circumvent ischemia-reperfusion injury [22].

Quality of life is increasingly recognized as a health indicator in clinical practice. CABG directly solves the reperfusion problem of coronary artery stenosis, reduces discomfort caused by the disease, and can promote postoperative recovery of patients, thereby achieving the goal of improving their quality of life [23]. We compared the quality of life 3 months after surgery between the two groups. The results showed that the five dimensions including social function, mental function, overall vitality, emotional function, and overall health of patients in the OPCABG group were significantly higher than those of patients in CCABG group, indicating that OPCABG was evidently superior to CCABG in postoperative rehabilitation.

In summary, off-pump CABG has the advantages of less surgical trauma, fewer postoperative complications, and faster rehabilitation than conventional on-pump CABG, which is conducive to improving the quality of life after surgery and is worthy of clinical application. However, this study also had some limitations. For example, due to the relatively small sample size, the results of the study need to be further verified. Secondly, for elderly patients with coronary heart disease, it remains to be seen whether it can screen out the population more suitable for off-pump CABG treatment through further risk stratification.

Disclosure of conflict of interest

None.

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