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Comparable survival over an extended follow-up after on-pump versus off-pump coronary artery bypass grafting: a propensity score-matched cohort

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Provisional Title: Comparable survival over an extended follow-up after on-pump versus off-pump coronary artery bypass grafting. A propensity score-matched cohort.

Running Title: Comparable outcomes following Off-Pump vs On-Pump CABG

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Abstract

Background

Long-term survival following off-pump coronary artery bypass grafting (OPCAB) compared with conventional on-pump coronary artery bypass grafting (ONCAB) remains uncertain. Randomised trials and meta-analyses up to 5–10 years after procedures have demonstrated either no significant differences or modest disadvantages of OPCAB, particularly regarding completeness of revascularisation and late mortality. However, comparative data extending up to 20 years after procedure are scarce. Thus, very-long-term outcomes after ONCAB versus OPCAB in a propensity score-matched cohort were evaluated.

Methods

Consecutive adults undergoing isolated primary coronary artery bypass grafting between 1999 and 2016 at a single cardiac surgery centre were retrospectively identified. Patients undergoing isolated OPCAB or ONCAB procedures were included and matched in a 1:2 ratio using clinically relevant preoperative variables. The primary outcome was overall survival in the matched cohort analysed using Cox proportional hazards regression.

Results

During the study period, 2,935 patients underwent isolated primary coronary artery bypass grafting (CABG), of whom 2,496 (85.0%) underwent ONCAB and 439 (15.0%) OPCAB procedures. Median survival time was 13.7 years (95% CI 13.2–14.2) and median follow-up was 12.3 years (interquartile range 8.0–17.1, maximum 23.9 years). The matched cohort consisted of 402 OPCAB patients matched to 804 ONCAB patients. Median survival time was 12.4 years (95% CI 11.9–13.2) in ONCAB and 12.6 years (95% CI 11.5–13.8) in OPCAB patients. Overall survival did not differ significantly between the groups (HR 0.95, 95% CI 0.82–1.11; ONCAB as reference). No significant differences were observed in the cumulative incidence of cardiovascular mortality.

Conclusion

In this propensity score-matched cohort with follow-up extending up to 20 years, ONCAB and OPCAB were associated with comparable long-term survival and cardiovascular mortality. These findings support an individualised approach to operative technique selection based on patient characteristics and surgical expertise.

Key Words: coronary artery bypass grafting; cardiopulmonary bypass; off-pump surgery; cardiothoracic surgery; cardiac surgery

Background

Coronary artery disease accounts for approximately 13% of all deaths and remains the leading cause of death globally [1]. Coronary artery bypass grafting (CABG) is an established surgical treatment for multivessel coronary artery disease. CABG can be performed either with cardiopulmonary bypass (on-pump CABG, ONCAB) or without it (off-pump CABG, OPCAB). The conventional ONCAB technique facilitates easier cardiac manipulation compared with the OPCAB approach. Long-term series report 15–22-year survival rates of approximately 20–33% after CABG, reflecting both the progression of underlying disease and the aging of the surgical population [2].

OPCAB technique was designed to avoid cardiopulmonary bypass (CPB) and cardioplegic arrest, with the aim of reducing systemic inflammatory response, neurologic injury, renal dysfunction and other CPB-related complications [3, 4]. However, OPCAB is technically demanding and may be associated with fewer distal anastomoses and higher rates of incomplete revascularisation, potentially compromising long-term graft patency and survival [5–9].

Contemporary guidelines do not recommend either technique as superior, but in a heavily calcified aorta, OPCAB with the “aortic no-touch” technique is reasonable [10, 11]. Several randomised and observational studies have reported either no difference between the techniques or a modest advantage for ONCAB [4, 7, 8, 12–15]. Very-long-term comparative data extending up to 20 years remains limited, particularly in low-volume centres. Large, randomised trials have generally demonstrated no short-term survival benefit of OPCAB and, in some cases, have suggested worse mid-term outcomes [4, 8, 16, 17]. OPCAB has also been associated with inferior outcomes in low-volume settings [18]. Meta-analyses of randomised and observational studies have shown either no difference or slightly higher long-term mortality with OPCAB, especially in lower-volume centres [12–14, 19–21]. In contrast, high-volume OPCAB centres have reported comparable or even favourable long-term survival when complete revascularisation is achieved [7, 18, 22].

Many previous observational studies relied on conventional multivariable adjustment, whereas few have applied propensity score methodologies with extended long-term follow-up. Therefore, outcomes were compared up to 20 years after ONCAB and OPCAB in a single-centre cohort using propensity score matching to balance baseline characteristics. Survival after OPCAB was hypothesised to be comparable with ONCAB.

Methods

A retrospective single-centre study was conducted using propensity score matching to compare outcomes between the treatment groups. Patients were identified from the prospectively maintained institutional cardiac surgery database including all CABG patients between 1999 and 2016. Follow-up data were collected

retrospectively. Mortality data were collected from the national registry and were unavailable for 178 patients; thus, these patients were excluded. Complete-case analysis was used because the overall extent of missing data was limited. Concomitant valve, aortic, or other major cardiac procedures (n=468) and redo surgeries (n=146) were excluded. The study was approved by the institutional review board with a waiver of individual informed consent due to the retrospective nature of the study. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [23].

The choice between ONCAB and OPCAB was left to the discretion of the attending surgeon, based on patient risk profile, coronary anatomy and intraoperative considerations. Intraoperative transoesophageal ultrasound and epi-aortic ultrasound were routinely used. ONCAB procedures were performed via median sternotomy with standard institution-specific protocols for CPB, aortic cannulation and cardioplegic arrest. Myocardial protection was achieved using tepid blood cardioplegia. Most commonly, cardiac arrest was achieved via an antegrade potassium-magnesium bolus, followed by continuous retrograde blood cardioplegia via coronary sinus for the remainder of the procedure. After completion of distal anastomoses, grafts were perfused with the same cardioplegic solution.

OPCAB procedures were also performed via median sternotomy using mechanical stabilisers and positioning devices. Intracoronary shunts were used at the surgeon's discretion. Haemodynamic stability was maintained via volume loading, vasoactive support and temporary pacing as needed. The left internal thoracic artery (LITA) was the preferred conduit for the left anterior descending artery (LAD) in both groups. Additional arterial conduits, including the right internal thoracic artery (RITA), radial artery and saphenous vein grafts were used as clinically indicated.

Perioperative clinical variables including age, sex, body surface area, diabetes mellitus, prior myocardial infarction, renal function, chronic obstructive pulmonary disease, peripheral arterial disease, cerebrovascular disease and EuroSCORE II [24], in addition to 30-day perioperative outcomes, were prospectively recorded in the institutional database.

Analyses were performed using R version 4.4.3 [1] with the MatchIt, cobalt, survival and cmprsk packages. A two-sided p-value <0.05 was considered statistically significant. Comparisons of perioperative characteristics between OPCAB and ONCAB were made using the Wilcoxon rank-sum test for continuous variables and Pearson's chi-squared test or Fisher's exact test for categorical variables. Continuous data are presented as medians with interquartile ranges and categorical data as counts with percentages.

Propensity score matching was used to reduce selection bias and estimate the average treatment effect of different operative techniques on outcomes. Only patients with complete covariate data were included in the matched analysis; thus, 37 OPCAB patients and 373 ONCAB patients were excluded before matching. Nearest neighbour pair matching was used in a 1:2 ratio (OPCAB:ONCAB) without

replacement and with no calliper restriction. The propensity score was calculated with a logistic regression model including 14 clinically selected preoperative covariates listed in Figure 1. Intraoperative and postoperative variables were considered post-treatment mediators rather than baseline confounders and were therefore excluded from matching. Balance was assessed using absolute standardised mean differences and was visualised with a Love plot (Figure 1, supplementary material). Complete case analysis was used because missing data was limited and considered unlikely to materially affect the findings.

The primary outcome was overall survival from the date of surgery. Patients were followed until January 2024. Kaplan–Meier estimates were used to derive survival curves and median survival times, with comparisons between groups performed using the log-rank test. In addition, univariate Cox proportional hazards models were fitted to obtain hazard ratios (HR) and 95% confidence intervals (CI). Proportional hazards assumption was evaluated using Schoenfeld residuals. All outcome analyses were conducted with the propensity score-matched cohort.

Cardiovascular mortality, with non-cardiovascular death treated as a competing risk, was analysed as a secondary outcome. Cumulative incidence functions were plotted and compared using Gray's test and cumulative incidence at a fixed 10-year time-point was additionally reported. A Fine–Gray competing risks regression model was used and results are reported as sub-distribution HRs with corresponding CIs. Cardiovascular death was defined as I00–I99 of the International Classification of Diseases, 10th Revision, coded as the primary cause of death on death certificates. Early (30-day) post-operative outcomes including all-cause mortality, reoperation, deep sternal wound infection (DSWI), intra-aortic balloon pump (IABP) use, need for haemodialysis and length of hospital stay (LOS) were analysed as secondary endpoints.

Results

All patients

During the study period, a total of 2,935 patients underwent isolated primary CABG, of whom 2,496 (85.0%) received ONCAB and 439 (15.0%) OPCAB. The annual number of OPCAB procedures ranged from 6 to 62, with a median of 22 per year (supplementary material). Overall median follow-up time was 12.3 years (IQR 8.0–17.1, maximum 24.9 years). During follow-up, 1,953 patients (67%) died, including 258 (59%) in the OPCAB group and 1,695 (68%) in the ONCAB group. Cardiovascular deaths occurred in 896 ONCAB patients (35.9%) and 117 OPCAB patients (26.7%). In the overall cohort, the median survival time was 13.8 years (95% CI 13.4–14.4) for ONCAB and 12.8 years (95% CI 11.9–14.0) for OPCAB.

Matched patients

A total of 402 OPCAB patients were matched to 804 ONCAB patients. Adequate post-matching covariate balance was achieved (Figure 1, Table 1, supplementary material).

The median number of distal anastomoses was four in the ONCAB group and three in OPCAB group (p<0.001). The ONCAB group also had more distal venous and arterial anastomoses. Internal thoracic artery (ITA) usage did not statistically differ between the two groups (p=0.093). Among ONCAB patients, median CPB time was 95 minutes and aortic cross clamp (ACC) time 74 minutes (Table 2). Thirty-day mortality was low and did not differ significantly between ONCAB and OPCAB patients (1.7% vs 0.5%, p=0.5). Rates of perioperative myocardial infarction, stroke, reoperation for bleeding, postoperative atrial fibrillation (POAF), IABP, DSWI, pneumonia and renal replacement therapy did not statistically significantly differ between groups. Peak blood creatinine and troponin T (TnT) levels were statistically higher in the ONCAB group (Table 3).

The median follow-up time was 11.5 years in the ONCAB group (IQR 7.7–16.3, maximum 23.9 years) and 10.9 years in the OPCAB group (IQR 7.3–14.0 years, maximum 23.8 years). The median survival time was 12.4 years (95% CI 11.9–13.2) in the ONCAB group and 12.6 years (95% CI 11.5–13.8) in the OPCAB group. Overall survival did not differ significantly between the groups (log-rank test, p=0.51) (Figure 2). In the Cox proportional hazards model, the HR for all-cause mortality was 0.95 (95% CI 0.82–1.11), with ONCAB as the reference group (Table 4). The Schoenfeld residual test indicated evidence of non-proportionality for operative technique, driven mainly by the end of follow-up when few patients remained at risk (p = 0.0225, supplementary figure). Cardiovascular death occurred in 271 ONCAB patients (33.7%) and in 106 OPCAB patients (26.4%) during follow-up. The cumulative incidence of cardiovascular death at 10 years was 18% (95% CI 16%–21%) in the ONCAB group and 19% (95% CI 15%–23%) in the OPCAB group. No significant difference in the cumulative incidence of cardiovascular death was observed between the groups (Gray's test, p-value = 0.3). The sub-distribution HR for cardiovascular death was 0.85 (95% CI 0.68–1.07) with ONCAB as the reference (Figure 3).

Discussion

In this single-centre propensity score-matched analysis with up to 20 years of follow-up, no significant difference was observed in either all-cause mortality or early post-operative complications between patients undergoing on-pump and off-pump CABG. Propensity score matching was used to mitigate confounding factors by indication and aimed to isolate the independent effect of surgical technique on survival. Our study adds to the existing literature by providing data from a real-world cohort, extending beyond the follow-up of most prior randomised trials [4, 9, 16, 17]. Furthermore, our findings suggest that equal long-term outcomes for both ONCAB and OPCAB can be achieved in a low-volume centre.

Our findings are consistent with the longest randomised trials reporting up to 20 years of follow-up [25], as well as a meta-analysis of 10-year follow-up data [21]. Large, registry-based and single-centre series have associated OPCAB with both similar and worse long-term survival [7, 8, 12, 22]. Both observational studies and randomised trials have suggested inferior outcomes in OPCAB technique, particularly in lower-volume settings [9, 16, 17]. Incomplete revascularisation, which is more frequent with OPCAB, has been identified as a key determinant of inferior long-term survival [9]. High-volume OPCAB centres have demonstrated equal long-term outcomes between the techniques when anastomotic quality and graft number are optimised [7, 22]. Our study shows that similar principles may be applicable in a smaller unit as well.

The theoretical advantages of OPCAB relate primarily to the avoidance of CPB-related systemic inflammation, embolic burden and end-organ dysfunction [3, 4]. These benefits may be particularly relevant in high-risk patients, such as the elderly or those with major aortic calcification or severe comorbidities. However, off-pump surgery is not suitable for all patients, as it presents technical challenges with potential trade-offs in graft number, target selection, or anastomotic quality [5, 6, 8]. This was observed in our study as the lower number of anastomoses conducted in the OPCAB patients. Also, differences were not observed in post-operative complications between the techniques. This finding may contradict the theoretical harm of CPB but may have resulted from optimal and individualised selection of patients to different procedures by the Heart Team.

Taken together with prior randomised and observational evidence, our findings support OPCAB as a viable alternative long-term revascularisation strategy when performed by experienced surgeons for appropriately selected patients. Attention should be paid to graft selection, distal anastomotic quality and completeness of revascularisation. The choice between ONCAB and OPCAB is then guided by a Heart Team-based approach considering individual patient risk profiles as well as coronary and aortic anatomy. Future research should focus on identifying patient subgroups most likely to benefit from OPCAB and reassessing the relative impact of surgical technique in the context of modern CPB and surgical techniques. Further studies could focus on how new surgical findings could be paired with other modern medical therapies addressing coronary artery disease.

Several limitations should be acknowledged. Firstly, this was a single-centre, observational study. Despite the use of propensity score matching, residual confounding cannot be excluded. Unmeasured factors such as coronary target quality, frailty, surgeon-specific decision-making, surgeon experience and patient selection may have influenced both treatment allocation and outcomes. These factors may have led to treating easier anatomies with OPCAB. Alternatively, aortic calcification may have been overrepresented in the OPCAB group. SYNTAX score or other standardised methods for describing the number of lesions were not available for our analyses. This makes it more challenging to address whether complete

revascularisation was achieved. Secondly, surgical practise evolved over the prolonged inclusion period and included advances in medical therapy, graft selection and perioperative management. Although matching reduced baseline imbalances, secular trends may still have affected outcomes. Exclusion of patients with missing mortality or covariate data may have introduced selection bias, and residual bias related to missing data cannot be excluded. Thirdly, our findings may not be generalisable to centres with different case-mix profiles or operative expertise. The principal strengths of our study include the comprehensive long-term follow-up obtained from the national registry and the extensive, prospectively maintained institutional cardiac surgery database.

In conclusion, survival up to 20 years was comparable between ONCAB and OPCAB in this single-centre, low-volume setting.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The reported research has been conducted in an ethical and responsible manner and is in full compliance with all relevant codes of experimentation and legislation. The patient right to a separate written permission was waived by the ethical board's decision due to the retrospective nature of the study. Additional approval from a separate ethics board was not required for this retrospective study. Study permission was received from the local ethics board of the Vaasa Central Hospital: ÖVPH/1192/13.01/2025. Clinical trial number: not applicable.

Availability of data and materials

The data supporting the findings of this study are stored at Vaasa Central Hospital. These restricted data are not publicly available and were used under license for the current study. These data are, however, available from the authors upon reasonable request and with permission of the Finnish Social and Health Data Permit Authority Findata.

Competing interests

The authors report no conflicts of interests.

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AI disclosure

ChatGPT 5.2 (OpenAI) was used for language editing to improve grammar and clarity.

Authors' contributions

AP: Conceptualisation, methodology, writing the original draft, data validation.

PR: Writing, review and editing, administrative support.

JOW: Writing, review and editing, data acquisition, conceptualisation and administration of the institutional cardiac surgery registry.

MH: Formal analysis, data validation, methodological oversight, writing the original draft.

All authors contributed to the interpretation of the data, critically revised the manuscript, approved the final version for publication and agree to be accountable for all aspects of the work, ensuring the accuracy and integrity of the published material.

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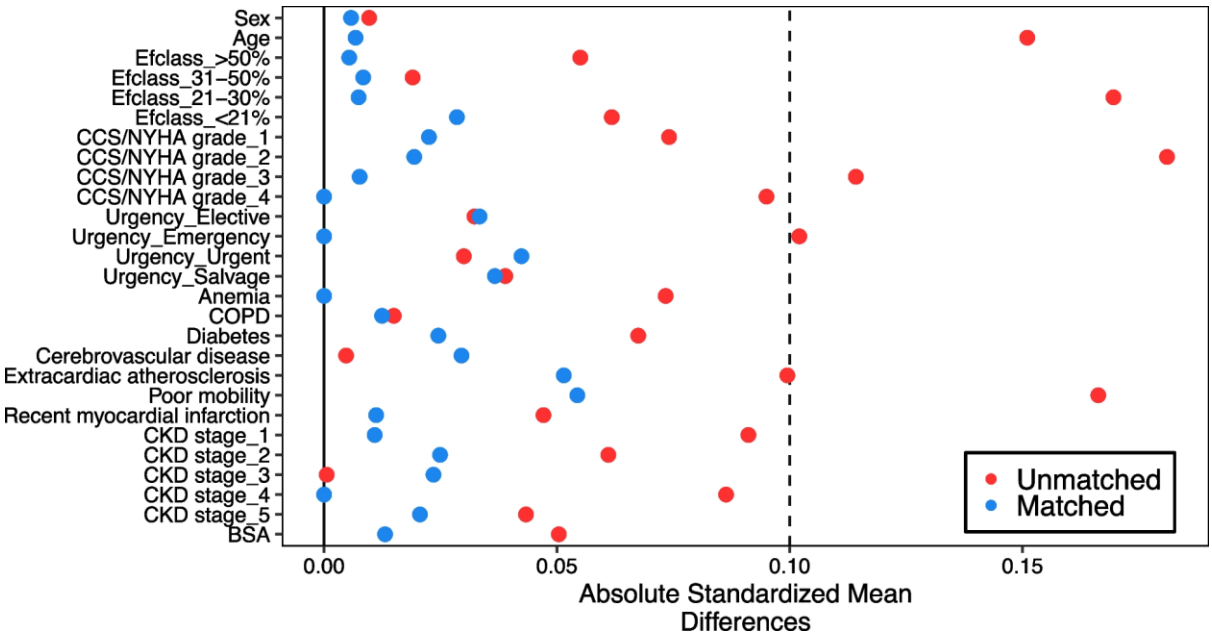
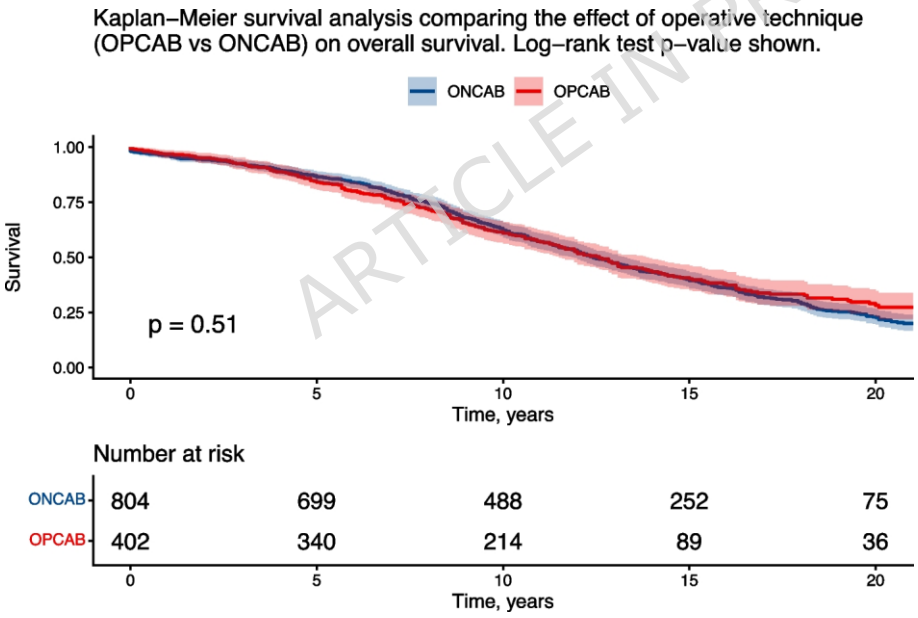
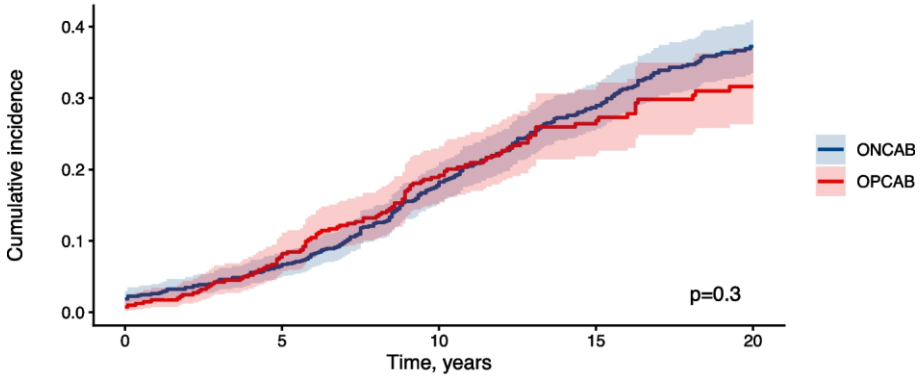




Cumulative incidence of cardiovascular mortality according to operative technique (OPCAB vs ONCAB). Gray's test p–value shown.



ONCAB					
At Risk	804	699	488	252	75
Events	15	54	145	221	264
OPCAB					
At Risk	402	340	214	89	36
Events	3	33	75	97	106

Table 1

	Unmatched				
Characteristic	**ONCAB** N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402
Age, years	68 (30–89)	70 (38–90)	0.026	70 (30–87)	70 (38–90)
Sex, female	620 (25%)	105 (24%)	0.7	200 (25%)	99 (25%)
Euroscore II	1.48 (0.95–2.59)	1.46 (0.94–2.79)	0.6	1.58 (0.98, –2.83)	1.46 (0.98, –2.81)
NYHA			0.024		
1	76 (4.2%)	23 (6.6%)		37 (6.2%)	20 (6.1%)
2	486 (27%)	112 (32%)		199 (33%)	105 (32%)
3	815 (45%)	135 (38%)		241 (40%)	128 (39%)
4	446 (24%)	81 (23%)		120 (20%)	73 (22%)
Missing data	673	88		207	76
CCS			<0.001		
1	94 (4.0%)	26 (6.1%)		43 (5.6%)	23 (5.9%)
2	556 (23%)	137 (32%)		253 (33%)	129 (33%)
3	1,014 (43%)	155 (37%)		279 (36%)	144 (37%)
4	704 (30%)	105 (25%)		190 (25%)	96 (24%)

Characteristic	Unmatched				
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402
Missing data	128	16		39	10
Diabetes	536 (21%)	85 (19%)	0.3	164 (20%)	78 (19%)
Cerebrovascular disease	248 (9.9%)	43 (9.8%)	>0.9	71 (8.8%)	39 (9.7%)
COPD	248 (9.9%)	47 (11%)	0.7	79 (9.8%)	41 (10%)
Extracardiac atherosclerosis	230 (9.2%)	57 (13%)	0.018	115 (14%)	51 (13%)
Poor mobility	29 (1.2%)	16 (3.6%)	<0.001	25 (3.1%)	16 (4.0%)
Recent MI	684 (27%)	113 (26%)	0.5	214 (27%)	105 (26%)
LV function			0.047		
>50%	1,608 (68%)	295 (70%)		570 (71%)	284 (71%)
31-50%	639 (27%)	115 (27%)		217 (27%)	110 (27%)
21-30%	108 (4.5%)	8 (1.9%)		11 (1.4%)	6 (1.5%)
<21%	24 (1.0%)	2 (0.5%)		6 (0.7%)	2 (0.5%)
Missing data	117	19			
Glomerular filtration rate	80 (66–92)	80 (65–91)	0.2	78 (64–91)	80 (65–91)

	Unmatched				
Characteristic	**ONCAB** N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402
Missing data	231	11			
Anaemia	459 (18%)	95 (22%)	0.13	176 (22%)	88 (22%)
Missing data	9	0			

Age is reported as mean (minimum–maximum), and all other continuous variables as median (Q1–Q3). Categorical variables are summarized as n (%). Between-group comparisons were conducted using the Wilcoxon rank-sum test for continuous variables

and either Pearson's chi-square test or Fisher's exact test for categorical variables, where appropriate. Comparisons are not applicable for matched patients with matched variables. ONCAB: On-pump coronary artery bypass grafting, OPCAB: Off-pump coronary artery bypass grafting, NYHA: The New York Heart association classification, CCS: The Canadien Cardiovascular Society classification, COPD: Chronic obstructive pulmonary disease, Recent MI: Myocardial infarction during the previous 90 days, LV function: Left ventricle ejection fraction.

TABLE 2 ***Intraoperative factors***

Characteristic	Unmatched			Matched		
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402	**p-value**
Urgency			0.7			0.7
Elective	1,819 (73%)	321 (73%)		600 (75%)	294 (73%)	
Emergent	17 (0.7%)	2 (0.5%)		0 (0%)	0 (0%)	
Urgent	638 (26%)	110 (25%)		191 (24%)	103 (26%)	
Salvage	22 (0.9%)	6 (1.4%)		13 (1.6%)	5 (1.2%)	
CPB time	96 (80–113)	NA	NA	95 (79–112)	NA	NA
Missing data	3	NA		2	NA	
ACC time	75 (60–90)	NA	NA	75 (59–89)	NA	NA
Missing data	3	NA		3	NA	
Distal anastomoses	4 (3–5)	3 (2–3)	<0.001	4 (3–5)	3 (2–3)	<0.001
Missing data	4	1				
Venous distal anastomoses	3 (2–4)	1 (1–2)	<0.001	3 (2–4)	1 (1–2)	<0.001
Missing data	7	3		3	1	
Arterial grafts	1 (1–2)	1 (1–1)	<0.001	1 (1–1)	1 (1–1)	<0.001

TABLE 2 ***Intraoperative factors***

Characteristic	Unmatched			Matched		
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402	**p-value**
Missing data	5	4				
ITA usage			<0.001			0.040
No	162 (6.5%)	35 (8.2%)		69 (8.6%)	43 (11%)	
LITA	1,937 (78%)	359 (84%)		655 (81%)	334 (83%)	
RITA	29 (1.2%)	4 (0.9%)		3 (0.4%)	3 (0.7%)	
BITA	354 (14%)	27 (6.4%)		77 (9.6%)	22 (5.5%)	
Missing data	14	14		0	0	
Intraoperative allogenic blood products			<0.001			<0.001
0	1,960 (79%)	395 (90%)		635 (79%)	361 (90%)	
1-2	405 (16%)	31 (7.1%)		131 (16%)	29 (7.2%)	
3-4	99 (4.0%)	9 (2.1%)		27 (3.4%)	8 (2.0%)	
>4	32 (1.3%)	4 (0.9%)		11 (1.4%)	4 (1.0%)	
Intraoperative bleeding	350 (300–500)	300 (200–400)	<0.001	300 (280–400)	300 (200–400)	<0.001
Missing data	3	0		2	0	

TABLE 2 ***Intraoperative factors***

Characteristic	Unmatched			Matched		
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402	**p-value**

Continuous variables are reported as median (Q1–Q3). Categorical variables are summarized as n (%). Between-group comparisons were conducted using the Wilcoxon rank-sum test for continuous variables and either Pearson's chi-square test or Fisher's exact test for categorical variables, where appropriate. ONCAB: On-pump coronary artery bypass grafting, OPCAB: Off-pump coronary artery bypass grafting, CPB: cardio-pulmonary bypass, ACC: aortic cross clamp, ITA: internal thoracic artery, LITA: left internal thoracic artery, RITA: right internal thoracic artery, BITA: bilateral thoracic artery

TABLE 3 Post-operative outcomes

Characteristic	Unmatched			Matched		
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402	**p-value**
Bleeding from drains	500 (360–690)	600 (450–850)	<0.001	520 (370–690)	598 (450–810)	<0.001
Missing data	4	0		3	0	
Haemoglobin at discharge (g/l)	102 (94–112)	108 (98–117)	<0.001	103 (95–113)	108 (98–117)	<0.001
Missing data	27	1		8	0	
Reoperation (any cause)	117 (4.7%)	24 (5.5%)	0.6	42 (5.2%)	21 (5.2%)	>0.9
Missing data	2	0		2	0	
Reoperation (due to bleeding)	69 (2.8%)	14 (3.2%)	0.7	26 (3.2%)	11 (2.7%)	0.8
Missing data	2	0		2	0	
LOS (days)	6.00 (5.00–8.00)	7.00 (5.00–8.00)	0.5	7.00 (5.00–8.00)	7.00 (5.00–8.00)	>0.9
Missing data	19	1		8	1	
ICU time (days)	1.00 (1.00–1.00)	1.00 (1.00–1.00)	0.6	1.00 (1.00–1.00)	1.00 (1.00–1.00)	0.7
Missing data	4	0		3	0	

TABLE 3 Post-operative outcomes

Characteristic	Unmatched			Matched		
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402	**p-value**
Extubation time (hours)	5.50 (4.50–7.00)	5.00 (4.00–6.50)	<0.001	5.50 (4.50–7.00)	5.00 (4.00–6.50)	0.001
Missing data	15	1		6	1	
30-day mortality	35 (1.4%)	2 (0.5%)	0.2	14 (1.7%)	2 (0.5%)	0.13
Cerebral infarction	57 (2.3%)	8 (1.8%)	0.7	18 (2.3%)	6 (1.5%)	0.5
Missing data	4	0		4	0	
TIA	19 (0.8%)	0 (0%)	0.10	5 (0.6%)	0 (0%)	0.2
Missing data	4	0		4	0	
AMI	39 (1.6%)	8 (1.8%)	0.9	15 (1.9%)	6 (1.5%)	0.8
Missing data	7	0		3	0	
Pneumonia	159 (6.4%)	19 (4.3%)	0.12	57 (7.1%)	17 (4.2%)	0.065
Missing data	4	0		4	0	
DSWI	30 (1.2%)	4 (0.9%)	0.8	9 (1.1%)	4 (1.0%)	>0.9
Missing data	1	0		1	0	
Delirium	255 (10%)	42 (9.6%)	0.7	95 (12%)	37 (9.2%)	0.2

TABLE 3 Post-operative outcomes

Characteristic	Unmatched			Matched		
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402	**p-value**
Missing data	5	0		4	0	
Atrial fibrillation	987 (41%)	162 (39%)	0.4	335 (43%)	153 (40%)	0.3
Missing data	90	21		27	19	
Dialysis	26 (1.0%)	3 (0.7%)	0.6	13 (1.6%)	2 (0.5%)	0.2
Missing data	4	2		4	2	
IABP	27 (1.1%)	4 (0.9%)	>0.9	8 (1.0%)	3 (0.7%)	0.8
Missing data	1	0		1	0	
TnT (ng/l)	350 (240–530)	100 (60–230)	<0.001	350 (240–530)	100 (60–224)	<0.001
Missing data	871	83		226	67	
Creatinine (µmol/l)	89 (76–107)	87 (73–108)	0.081	91 (77–111)	86 (72–107)	0.003
Missing data	241	11		7	0	
CRP (mg/l)	200 (157–243)	195 (146–255)	0.6	202 (161–247)	196 (148–255)	0.4
Missing data	42	1		13	0	

Data from the first 30-days after operation. Continuous variables are reported as median (Q1–Q3). Categorical variables are summarized as n (%). Between-group comparisons were conducted using the Wilcoxon rank-sum test for continuous variables and either Pearson's chi-square test or Fisher's exact test for categorical variables, where appropriate. ONCAB: On-pump

TABLE 3 Post-operative outcomes

Characteristic	Unmatched			Matched		
	ONCAB N = 2,496	**OPCAB** N = 439	**p-value**	**ONCAB** N = 804	**OPCAB** N = 402	**p-value**

coronary artery bypass grafting, OPCAB: Off-pump coronary artery bypass grafting, LOS: length of hospital stay, ICU: intensive care unit, TIA: Transient ischaemic attack, AMI: Acute myocardial infarction, DSWI: Deep sternal wound infection, IABP: Intra-aortic balloon pump, TnT: Troponin-T level, CRP: C-reactive protein

Table 4. Univariate Cox Proportional Hazards Models for Death as the Outcome.

	Unmatched				Matched			
Characteristic	**N**	**HR**	**95% CI**	**p-value**	**N**	**HR**	**95% CI**	**p-value**
	2,935				1,206			
ONCAB		—	—			—	—	
OPCAB		1.05	0.92–1.20	0.5		0.95	0.82–1.11	0.5
Sex	2,935				1,206			
Male		—	—			—	—	
Female		1.21	1.09–1.34	<0.001		1.24	1.06–1.45	0.007
CCS	2,791				1,157			
1		—	—			—	—	
2		0.99	0.75–1.30	>0.9		0.94	0.65–1.37	0.8
3		1.31	1.00–1.71	0.047		1.34	0.93–1.92	0.12
4		1.56	1.19–2.05	0.001		1.65	1.14–2.39	0.008
NYHA	2,174				923			
1		—	—			—	—	
2		0.92	0.69–1.24	0.6		0.93	0.63–1.38	0.7
3		1.36	1.02–1.80	0.033		1.45	0.99–2.13	0.057
4		1.52	1.14–2.04	0.004		1.76	1.18–2.62	0.005
LV function	2,799				1,206			
>50%		—	—			—	—	
31-50%		1.41	1.28–1.56	<0.001		1.47	1.26–1.71	<0.001
21-30%		2.85	2.34–3.47	<0.001		2.93	1.78–4.83	<0.001
<21%		3.54	2.38–5.27	<0.001		2.78	1.32–5.87	0.007
Diabetes	2,935				1,206			
No		—	—			—	—	
Yes		1.71	1.55–1.90	<0.001		1.56	1.32–1.84	<0.001

		Unmatched				Matched		
Characteristic	**N**	**HR**	**95% CI**	**p-value**	**N**	**HR**	**95% CI**	**p-value**
COPD	2,935				1,206			
No		—	—			—	—	
Yes		1.83	1.60–2.09	<0.001		2.07	1.69–2.55	<0.001
Poor mobility	2,935				1,206			
No		—	—			—	—	
Yes		1.97	1.43–2.70	<0.001		1.79	1.28–2.51	<0.001
Extracardiac arteriopathy	2,935				1,206			
No		—	—			—	—	
Yes		2.24	1.96–2.57	<0.001		2.04	1.69–2.45	<0.001
Renal impairment	2,693				1,206			
Stage 1		—	—			—	—	
Stage 2		1.58	1.41–1.77	<0.001		1.57	1.31–1.88	<0.001
Stage 3		3.32	2.89–3.82	<0.001		3.08	2.49–3.81	<0.001
Stage 4		11.4	7.34–17.8	<0.001		9.82	5.99–16.1	<0.001
Stage 5		3.14	1.40–7.03	0.005		2.07	0.77–5.60	0.15
Recent MI	2,935				1,206			
No		—	—			—	—	
Yes		1.30	1.18–1.43	<0.001		1.33	1.14–1.55	<0.001

Cox Proportional Hazards Models for Death as the Outcome. CI: Confidence Interval, HR: Hazard Ratio, ONCAB: On-pump coronary artery bypass grafting, OPCAB: Off-pump coronary artery bypass grafting, NYHA: The New York Heart association classification, CCS: The Canadien Cardiovascular Society classification, COPD: Chronic obstructive pulmonary disease, Recent MI: Myocardial infarction during the previous 90 days.