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Association Between Obesity and Early Outcomes After Minimally Invasive Coronary Artery Bypass Surgery: A Propensity Score-Matched Study

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Abstract

Background: The impact of obesity on outcomes following minimally invasive direct coronary artery bypass (MIDCAB) and multivessel MIDCAB (MV-MIDCAB) remains incompletely understood. Methods: This retrospective, single-centre analysis included 383 patients with available body mass index (BMI) data: 275 non-obese patients (BMI < 30 kg/m^2) and 108 obese patients (BMI ≥ 30 kg/m^2). Propensity score matching based on available preoperative covariates yielded 105 matched pairs. Baseline balance was assessed using standardized mean differences (SMDs). Results: Multivessel MIDCAB was performed in 41.9% of obese and 44.8% of non-obese patients ($p = 0.755$), while complete revascularization was achieved in 32.4% and 33.3%, respectively ($p = 1.000$). Acute kidney injury occurred in 6.7% of obese and 3.8% of non-obese patients ($p = 0.549$), while postoperative delirium occurred in 8.7% and 5.7%, respectively ($p = 0.581$). Wound infection was documented in 3 obese patients (2.9%) and 1 non-obese patient (1.0%; risk difference, 1.9 percentage points; approximate 95% confidence interval [CI], −1.8 to 5.7; exact paired $p = 0.625$). In-hospital mortality occurred in 1 obese patient and no non-obese patients (risk difference, 1.0 percentage point; approximate 95% CI, −0.9 to 2.8; exact paired $p = 1.000$). Conclusions: No statistically significant differences in early outcomes were detected.

Keywords: multivessel MIDCAB; coronary artery bypass grafting; left minithoracotomy; thoracoscopic internal mammary artery harvesting; obesity

1. Introduction

Coronary artery bypass grafting (CABG) remains the gold-standard surgical procedure for patients with advanced coronary artery disease (CAD) [1]. Minimally invasive direct coronary artery bypass (MIDCAB) represents an evolution in surgical technique, particularly for patients with stenosis of the left anterior descending (LAD) artery [2]. The MIDCAB procedure is associated with a reduced duration of in-hospital stay, a lower incidence of wound healing complications, and a decreased need for blood transfusion [3]. Multivessel MIDCAB, performed via left anterior thoracotomy, further advances minimally invasive techniques for patients with multivessel coronary artery disease [4].

The prevalence of obesity has increased significantly over the past few decades [5]. Obesity is linked to chronic inflammation, which might exacerbate the atherosclerotic burden on the coronary arteries [6]. The association between obesity and adverse outcomes in patients undergoing CABG has been the subject of considerable debate [7]. Conversely,

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some studies have reported poorer outcomes following CABG in obese patients when compared to those of normal weight [8]. Furthermore, other authors demonstrated that obesity was associated with higher morbidity and mortality in patients undergoing CABG, particularly in those with reduced ejection fraction [1]. Additionally, obese patients have been found to experience a significantly higher rate of deep sternal wound infections compared to their non-obese counterparts following bypass surgery [9]. Moreover, obesity has been implicated in reduced graft patency post-CABG [10]. However, several studies have reported comparable outcomes between obese and non-obese patients after CABG [11]. Other research has even suggested improved outcomes in obese patients with regard to postoperative myocardial infarction, stroke, and acute kidney injury [12]. These counter-intuitive findings in obese patients following bypass surgery have been described as the obesity paradox [13].

The impact of obesity on outcomes in patients undergoing MIDCAB or multivessel MIDCAB remains unclear. Consequently, the aim of this study was to assess the influence of obesity on clinical outcomes in patients who have undergone either MIDCAB or multivessel MIDCAB procedures.

2. Materials and Methods

2.1. Study Population

A retrospective, single-centre database analysis was performed using the MIDCAB database from University Hospital Bonn (Figure 1). The database comprised 390 records with operation dates ranging from 3 January 2022 to 2 January 2025. One record was excluded because of missing body mass index (BMI) data, and six records were excluded because previous cardiac surgery was documented as present, resulting in an analytic cohort of 383 patients. Because the available database did not permit independent verification of every original exclusion criterion, reconstruction of the analytic cohort may have introduced selection bias. Of these, 275 patients had a BMI < 30 kg/m^2 and 108 had a BMI ≥ 30 kg/m^2.

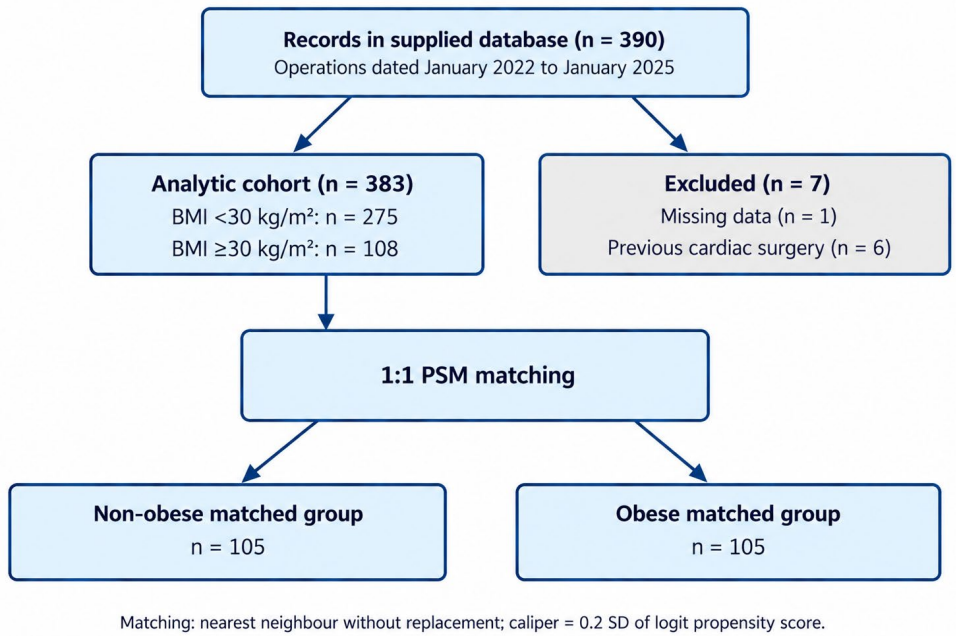

Figure 1. Cohort flow for the database-based re-analysis. BMI, body mass index; PSM, propensity score matching.

Patients were classified as non-obese (BMI < 30 kg/m^2) or obese (BMI ≥ 30 kg/m^2). A logistic-regression propensity score was estimated using available preoperative variables:

age, sex, diabetes mellitus, insulin-dependent diabetes, hypertension, hyperlipidemia, pulmonary hypertension, peripheral vascular disease, chronic renal insufficiency, COPD, prior stroke, obstructive sleep apnea, preoperative ejection fraction, elective surgery, urgent surgery, and coronary disease extent. Missing covariate values were imputed using the median of the corresponding variable before propensity-score matching. One-to-one nearest-neighbour matching without replacement was performed using a caliper of 0.2 standard deviations of the logit propensity score, with optimal assignment of matched pairs based on propensity-score distance. The procedure yielded 105 matched pairs; three obese and 170 non-obese patients were unmatched. Standardized mean differences (SMDs) were calculated before and after matching.

The MV-MIDCAB technique facilitates revascularization of all coronary territories. Prior to surgery, each patient underwent a comprehensive preoperative evaluation by an interdisciplinary heart team to determine which coronary vessels would be addressed surgically. In selected cases, a hybrid revascularization approach was planned in collaboration with referring cardiologists. For these patients, the left coronary system was revascularized surgically using the MV-MIDCAB technique, while the right coronary artery was treated through percutaneous coronary intervention (PCI), which could be performed either before or after surgery, depending on the clinical circumstances.

The timing of PCI and MV-MIDCAB was carefully considered, particularly in relation to dual antiplatelet therapy (DAPT). In urgent cases, surgery was carried out while the patient was on aspirin (100 mg daily) and clopidogrel (75 mg daily). For elective procedures, surgery was typically postponed for six weeks, after which it was performed with aspirin monotherapy (100 mg daily).

The original clinical workflow included bilateral subclavian artery duplex ultrasonography and non-contrast thoracic CT to assess anatomy.

2.2. Surgical Procedure

The MIDCAB technique has been previously described in detail [14]. All patients were positioned dorsally with the left hemithorax elevated by 20° to 30°. Double-lumen endotracheal intubation was routinely performed. The left internal mammary artery (IMA) and/or right IMA were harvested using either a conventional or thoracoscopic approach. The great saphenous vein was likewise harvested via conventional or thoracoscopic methods. Systemic heparinization was administered prior to opening the pericardium.

Following this, target coronary vessels—left anterior descending artery (LAD), ramus diagonalis (RD), ramus intermedius (RIM), circumflex artery (RCX), and/or right coronary artery (RCA)—were identified using a vacuum-assisted tissue stabilizer (Octopus Evolution, Medtronic, Minneapolis, MN, USA). All anastomoses were performed using an off-pump technique. Intracoronary shunts (Medtronic, Minneapolis, MN, USA) were employed when necessary.

Grafts—including the right IMA and/or great saphenous vein—were anastomosed to the left IMA in a T-graft configuration. Following completion of the bypass procedure, graft flow was assessed via intraoperative ultrasound. Protamine was administered at a 1:1 ratio to heparin to achieve reversal. Finally, drainage of both the pericardial and left pleural cavities was established.

2.3. Ethics

This retrospective data analysis was reviewed and approved by the Ethics Committee of the Medical Faculty of the University of Bonn, Germany (reference number 2026-438-BO; protocol number 2026-06). Based on the submitted study documents, the Ethics Committee raised no ethical or legal objections to the conduct of the study. The study was conducted

in accordance with the principles of the Declaration of Helsinki and applicable national regulations. The requirement for informed consent was not applicable.

Clinical and procedural data were extracted from the institutional MIDCAB database at University Hospital Bonn. The available database contained perioperative and in-hospital variables.

2.4. Primary and Secondary Outcomes

The primary outcome was all-cause in-hospital mortality. Secondary outcomes included postoperative stroke, bleeding requiring rethoracotomy, wound infection, acute kidney injury, dialysis, postoperative delirium, resuscitation, low cardiac output, and VA-ECMO use.

2.5. Statistical Analysis

Continuous variables are summarized as median (minimum–maximum), except HbA1c, which is summarized as mean ± standard deviation. Categorical variables are reported as counts and percentages using the number of non-missing observations as the denominator. Propensity scores were estimated by logistic regression using the prespecified available covariates listed above; missing covariate values were median-imputed before matching. One-to-one nearest-neighbour matching without replacement used optimal assignment of matched pairs based on propensity-score distance and a caliper of 0.2 standard deviations of the logit propensity score. Covariate balance was evaluated using absolute SMDs; an absolute SMD < 0.10 was considered a conventional balance target. Before matching, independent-group comparisons used two-sided Fisher exact tests for sparse categorical data and two-sided chi-square tests otherwise; continuous variables were compared using two-sided Mann–Whitney U tests. In the matched cohort, binary outcomes were compared using exact two-sided McNemar tests on complete matched pairs; continuous variables were compared using paired Wilcoxon signed-rank tests. Risk differences are reported with approximate Wald 95% confidence intervals based on paired discordances. Analyses were performed using IBM SPSS Statistics for Windows, version 31.0.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Preoperative Characteristics

The analysis included 383 patients (275 non-obese and 108 obese), of whom 105 matched pairs were identified using 1:1 propensity score matching (Table 1, Figure 2). Before matching, obesity was associated with higher rates of diabetes mellitus (39.8% vs. 23.3%; SMD = −0.361), insulin-dependent diabetes (16.7% vs. 6.5%; SMD = −0.319), obstructive sleep apnea (11.3% vs. 4.0%; SMD = −0.158), and arterial hypertension (90.7% vs. 82.9%; SMD = −0.232), as well as higher mean HbA1c levels (6.2 ± 1.2% vs. 5.8 ± 1.0%; SMD = −0.381). After matching, imbalances in diabetes mellitus, insulin-dependent diabetes, and male sex were attenuated; however, residual imbalance remained for HbA1c, hyperlipidemia, varicose veins, pulmonary embolism, obstructive sleep apnea, COPD, and preoperative dialysis (absolute SMD > 0.10 for each).

Table 1. Preoperative characteristics before and after propensity-score matching.

Variable	Non-Obese n = 275	Obese n = 108	SMD Before	Non-Obese n = 105	Obese n = 105	SMD After
Age (years), median (min–max)	66.0 (39.0–89.0)	64.5 (35.0–82.0)	0.132	64.0 (39.0–83.0)	65.0 (35.0–82.0)	−0.092
BMI (kg/m^2), median (min–max)	25.7 (17.1–29.9)	33.0 (30.0–57.1)	—	25.7 (17.1–29.9)	33.3 (30.0–57.1)	—
Male sex, n (%)	232 (84.4%)	85 (78.7%)	−0.146	86 (81.9%)	83 (79.0%)	−0.072
EuroSCORE II (%), median (min–max)	1.2 (0.5–10.2)	1.2 (0.5–8.7)	−0.007	1.2 (0.5–10.1)	1.2 (0.5–8.7)	0.017
Previous stroke, n (%)	12 (4.4%)	3 (2.8%)	0.086	2 (1.9%)	2 (1.9%)	0.001
Diabetes mellitus, n (%)	64 (23.3%)	43 (39.8%)	−0.361	37 (35.2%)	40 (38.1%)	−0.059
Insulin-dependent diabetes, n (%)	18 (6.5%)	18 (16.7%)	−0.319	16 (15.2%)	16 (15.2%)	0.000
HbA1c (%), mean ± SD	5.8 ± 1.0	6.2 ± 1.2	−0.381	5.9 ± 1.1	6.2 ± 1.2	−0.198
Arterial hypertension, n (%)	228 (82.9%)	98 (90.7%)	−0.232	97 (92.4%)	95 (90.5%)	0.068
Pulmonary hypertension, n (%)	2 (0.7%)	2 (1.9%)	−0.099	2 (1.9%)	2 (1.9%)	0.000
Hyperlipidemia, n (%)	220 (80.3%)	91 (84.3%)	−0.004	83 (79.0%)	88 (83.8%)	−0.122
Peripheral vascular disease, n (%)	27 (9.8%)	9 (8.4%)	0.049	10 (9.5%)	9 (8.7%)	0.030
Varicose veins, n (%)	29 (10.6%)	15 (14.0%)	−0.104	9 (8.6%)	15 (14.4%)	−0.183
Deep vein thrombosis, n (%)	3 (1.1%)	0 (0.0%)	0.148	0 (0.0%)	0 (0.0%)	0.000
Pulmonary embolism, n (%)	1 (0.4%)	1 (0.9%)	−0.070	0 (0.0%)	1 (1.0%)	−0.138
Obstructive sleep apnea, n (%)	11 (4.0%)	12 (11.3%)	−0.158	7 (6.7%)	12 (11.5%)	−0.169
COPD, n (%)	14 (5.1%)	9 (8.3%)	−0.129	10 (9.5%)	7 (6.7%)	0.104
Atrial fibrillation, n (%)	25 (9.1%)	8 (7.5%)	0.060	10 (9.6%)	8 (7.7%)	0.068
Preoperative dialysis, n (%)	2 (0.7%)	1 (0.9%)	−0.022	0 (0.0%)	1 (1.0%)	−0.138
Chronic renal insufficiency, n (%)	20 (7.3%)	8 (7.5%)	−0.010	9 (8.6%)	8 (7.8%)	0.029
Preoperative LVEF (%), median (min–max)	55.0 (0.5–80.0)	55.0 (30.0–70.0)	−0.028	55.0 (25.0–80.0)	55.0 (30.0–70.0)	0.075

SMD, standardized mean difference; PSM, propensity score matching; DM, diabetes mellitus; COPD, chronic obstructive pulmonary disease. BMI defines the exposure groups and is therefore shown descriptively but not used as a matching-balance SMD. HbA1c values > 20% were treated as implausible unit-entry errors and excluded from HbA1c summaries.

3.2. Intraoperative Characteristics

Procedural characteristics are summarized in Table 2. Before matching, no statistically significant differences were observed between groups. Multivessel MIDCAB, complete revascularization, T-graft use, and aortic no-touch techniques showed comparable frequencies, while median operative time was similar (182.5 vs. 185.0 min; $p = 0.620$). After matching, procedural characteristics remained broadly comparable, with no statistically significant between-group differences. Multivessel MIDCAB was performed in 41.9% of obese and 44.8% of non-obese patients ($p = 0.755$), and complete revascularization was achieved in 32.4% and 33.3%, respectively ($p = 1.000$). T-graft use was less frequent among

obese patients (33.3% vs. 40.0%; $p = 0.324$), as was the use of two IMA grafts (6.7% vs. 14.3%; $p = 0.134$). Median operative time was 182.0 versus 190.0 min ($p = 0.885$).

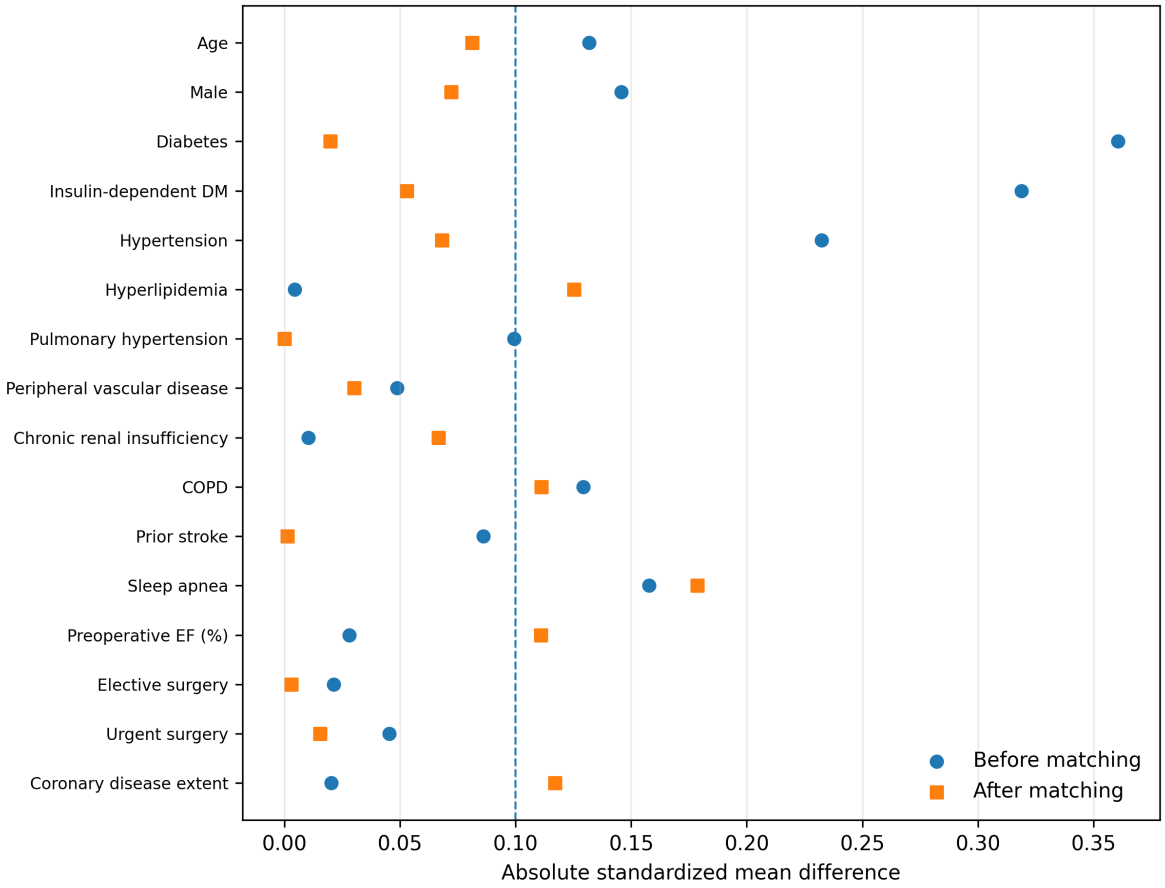

Figure 2. Love plot showing absolute SMDs before and after matching. The vertical reference line indicates |SMD| = 0.10.

Table 2. Procedural characteristics before and after propensity-score matching.

Variable	Non-Obese n = 275	Obese n = 108	*p* Before	Non-Obese n = 105	Obese n = 105	*p* Matched
Previous PCI, n (%)	70 (25.6%)	28 (26.7%)	0.839	30 (28.6%)	26 (25.5%)	0.771
Left main stenosis, n (%)	67 (24.8%)	24 (22.9%)	0.691	26 (25.7%)	22 (21.6%)	0.405
Elective surgery, n (%)	156 (56.7%)	59 (55.7%)	0.851	60 (57.1%)	59 (57.3%)	1.000
Urgent surgery, n (%)	108 (39.3%)	44 (41.5%)	0.690	41 (39.0%)	41 (39.8%)	1.000
Emergency surgery, n (%)	38 (13.8%)	17 (15.7%)	0.629	11 (10.5%)	15 (14.3%)	0.557
NSTEMI, n (%)	44 (16.1%)	22 (20.4%)	0.315	15 (14.4%)	20 (19.0%)	0.473
STEMI, n (%)	7 (2.5%)	7 (6.5%)	0.065	4 (3.8%)	6 (5.7%)	0.754
Multivessel MIDCAB, n (%)	132 (48.0%)	47 (43.5%)	0.429	47 (44.8%)	44 (41.9%)	0.755
Complete revascularization, n (%)	94 (34.2%)	36 (33.3%)	0.875	35 (33.3%)	34 (32.4%)	1.000
Aortic no-touch technique, n (%)	207 (75.5%)	88 (81.5%)	0.213	82 (78.8%)	85 (81.0%)	0.720
Conversion to CPB, n (%)	4 (1.5%)	2 (1.9%)	0.676	2 (1.9%)	2 (1.9%)	1.000
Use of two IMA grafts, n (%)	33 (12.0%)	9 (8.3%)	0.301	15 (14.3%)	7 (6.7%)	0.134

Table 2. *Cont.*

Variable	Non-Obese n = 275	Obese n = 108	*p* Before	Non-Obese n = 105	Obese n = 105	*p* Matched
Total arterial revascularization, n (%)	72 (30.5%)	26 (28.3%)	0.690	30 (34.1%)	24 (27.0%)	0.728
T-graft technique, n (%)	113 (41.1%)	38 (35.2%)	0.287	42 (40.0%)	35 (33.3%)	0.324
Endoscopic vein harvesting, n (%)	20 (7.3%)	10 (9.3%)	0.499	6 (5.7%)	9 (8.7%)	0.424
Thoracoscopic IMA preparation, n (%)	96 (35.0%)	42 (39.3%)	0.442	40 (38.1%)	39 (37.5%)	1.000
Temporary pacer, n (%)	4 (1.5%)	2 (1.9%)	0.676	3 (2.9%)	2 (1.9%)	1.000
Catecholamine use, n (%)	168 (61.1%)	68 (63.0%)	0.815	61 (58.1%)	65 (61.9%)	0.659
Operation time (min), median (min–max)	185.0 (79.0–370.0)	182.5 (111.0–348.0)	0.620	190.0 (100.0–364.0)	182.0 (111.0–348.0)	0.885

PCI, percutaneous coronary intervention; LMCA, left main coronary artery; NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction; MIDCAB, minimally invasive direct coronary artery bypass; CPB, cardiopulmonary bypass; IMA, internal mammary artery.

3.3. Postoperative Outcomes

Postoperative outcomes before and after propensity score matching are summarized in Table 3. Before matching, no statistically significant differences were observed between groups. Acute kidney injury (6.5% vs. 3.6%; $p = 0.216$), postoperative delirium (9.4% vs. 8.4%; $p = 0.747$), dialysis (2.8% vs. 1.5%; $p = 0.409$), and wound infection (2.8% vs. 1.5%; $p = 0.406$) were numerically more frequent in obese patients. Median ICU stay was 1 day in both groups ($p = 0.266$), and in-hospital mortality was rare (0.9% vs. 0%; $p = 0.280$). After matching, no statistically significant differences were detected in the reported postoperative outcomes. Acute kidney injury occurred in 6.7% of obese versus 3.8% of non-obese patients ($p = 0.549$), while delirium occurred in 8.7% versus 5.7% ($p = 0.581$). Wound infection was recorded in 2.9% versus 1.0% (risk difference, +1.9 percentage points; approximate 95% CI, −1.8 to 5.7; exact McNemar $p = 0.625$). Other complications, including stroke, resuscitation, rethoracotomy for bleeding, and VA-ECMO use, were uncommon. Median ICU stay remained 1 day in both groups ($p = 0.195$), and in-hospital mortality occurred in one obese patient and no non-obese patients (risk difference, +1.0 percentage point; approximate 95% CI, −0.9 to 2.8; exact McNemar $p = 1.000$).

Table 3. Postoperative outcomes before and after propensity-score matching.

Outcome	Non-Obese n = 275	Obese n = 108	*p* Before	Non-Obese n = 105	Obese n = 105	Matched RD (95% CI); *p*
Stroke, n (%)	2 (0.7%)	0 (0.0%)	1.000	1 (1.0%)	0 (0.0%)	−1.0 pp (−2.8, +0.9); $p = 1.000$; n = 105
Postoperative delirium, n (%)	23 (8.4%)	10 (9.4%)	0.747	6 (5.7%)	9 (8.7%)	+2.9 pp (−3.9, +9.8); $p = 0.581$; n = 103
Resuscitation with ROSC, n (%)	3 (1.1%)	1 (0.9%)	1.000	2 (1.9%)	1 (1.0%)	−1.0 pp (−4.2, +2.3); $p = 1.000$; n = 105
Low cardiac output, n (%)	2 (0.7%)	0 (0.0%)	1.000	1 (1.0%)	0 (0.0%)	−1.0 pp (−2.9, +0.9); $p = 1.000$; n = 101
Acute kidney injury, n (%)	10 (3.6%)	7 (6.5%)	0.216	4 (3.8%)	7 (6.7%)	+2.9 pp (−3.3, +9.1); $p = 0.549$; n = 104

Table 3. *Cont.*

Outcome	Non-Obese n = 275	Obese n = 108	*p* Before	Non-Obese n = 105	Obese n = 105	Matched RD (95% CI); *p*
Postoperative dialysis, n (%)	4 (1.5%)	3 (2.8%)	0.409	1 (1.0%)	3 (2.9%)	+1.9 pp (−1.8, +5.6); $p = 0.625$; n = 105
Wound infection, n (%)	4 (1.5%)	3 (2.8%)	0.406	1 (1.0%)	3 (2.9%)	+1.9 pp (−1.8, +5.7); $p = 0.625$; n = 103
Bleeding requiring rethoracotomy, n (%)	3 (1.1%)	2 (1.9%)	0.623	3 (2.9%)	2 (1.9%)	−1.0 pp (−5.2, +3.3); $p = 1.000$; n = 103
VA-ECMO use, n (%)	1 (0.4%)	1 (0.9%)	0.487	1 (1.0%)	1 (1.0%)	+0.0 pp (−2.7, +2.7); $p = 1.000$; n = 104
ECMO weaning, n (%)	1 (0.4%)	0 (0.0%)	1.000	1 (1.0%)	0 (0.0%)	−1.0 pp (−2.8, +0.9); $p = 1.000$; n = 104
ICU stay (days), median (min–max)	1.0 (0.0–56.0)	1.0 (1.0–15.0)	0.266	1.0 (0.0–56.0)	1.0 (1.0–15.0)	Paired $p = 0.195$
In-hospital mortality, n (%)	0 (0.0%)	1 (0.9%)	0.280	0 (0.0%)	1 (1.0%)	+1.0 pp (−0.9, +2.8); $p = 1.000$; n = 104

VA-ECMO, veno-arterial extracorporeal membrane oxygenation; ICU, intensive care unit.

4. Discussion

The association between obesity and outcomes after coronary artery bypass grafting (CABG) remains complex. Previous studies of conventional CABG have reported heterogeneous associations between body mass index (BMI) and perioperative and long-term outcomes, ranging from comparable results to increased morbidity in specific obesity classes [5,7,8,11,14]. The so-called "obesity paradox" has also been described in patients with coronary artery disease and surgical populations [13,15]. However, apparently protective associations in observational studies may reflect differences in age, frailty, nutritional status, disease severity, smoking, comorbidity burden, and patient selection rather than a direct beneficial effect of excess adiposity [15,16]. These findings highlight the importance of careful risk adjustment and cautious interpretation of observational comparisons.

Evidence regarding the influence of obesity specifically on outcomes after minimally invasive direct coronary artery bypass (MIDCAB) and multivessel MIDCAB (MV-MIDCAB) remains limited, although previous studies support the feasibility of these approaches in appropriately selected patients [2–4,14,17,18]. Current revascularization guidance emphasizes individualized decision-making by the multidisciplinary Heart Team, taking into account coronary anatomy, clinical risk, patient characteristics, procedural feasibility, and the likelihood of achieving appropriate revascularization [18]. In the present cohort, MV-MIDCAB, T-graft use, and complete revascularization were numerically less frequent among obese patients after propensity score matching. These differences may reflect patient selection and procedural planning; however, the available data do not allow their underlying reasons to be determined. Factors such as target-vessel anatomy, technical exposure, thoracic wall characteristics, conduit quality, and the potential role of hybrid percutaneous coronary intervention (PCI) were not sufficiently characterized. Accordingly, these procedural differences should be regarded as potential sources of residual confounding rather than evidence of a direct effect of obesity on operative strategy [18].

Propensity score matching can improve comparability with respect to measured baseline covariates, but its effectiveness depends on the quality of the available data, the specification of the propensity score model, and the resulting covariate balance. Standardized mean differences (SMDs) are recommended for assessing baseline balance because they quantify differences in covariate distributions without relying on sample-size-dependent significance tests [19]. In the present study, several covariates remained above the conven-

tional absolute SMD threshold of 0.10 after matching. These residual imbalances indicate that comparability between groups was incomplete and that residual confounding may have influenced the observed associations. Furthermore, propensity score methods cannot eliminate confounding by unmeasured factors, including incompletely characterized anatomical, technical, and clinical determinants of procedural selection [20].

Obesity has been associated with wound complications following conventional CABG, particularly deep sternal wound infection after median sternotomy [9,20–25]. Nevertheless, findings from conventional CABG cannot be directly extrapolated to MIDCAB, which involves different access routes and incision patterns. In the present matched cohort, wound infections were recorded in three obese patients and one non-obese patient, with no statistically significant difference detected by exact paired testing. Given the very small number of events, the absence of statistical significance should not be interpreted as evidence of equivalent infection risk. Postoperative infection is a multifactorial outcome, and the available data did not consistently characterize the anatomical site, depth, diagnostic criteria, timing, microbiology, treatment, or need for surgical debridement. Infections diagnosed after discharge may also not have been systematically captured. Recent cardiac-surgery research has investigated inflammatory markers as potential predictors of postoperative infections, illustrating the complexity of infection risk assessment; however, such findings do not establish a specific association between obesity and wound infection after MIDCAB [23–25]. Consequently, the numerical difference observed in our cohort should be interpreted cautiously and requires confirmation in larger studies with standardized infection definitions and follow-up [25].

BMI is a readily available measure but provides only a limited characterization of adiposity because it does not distinguish fat mass from skeletal muscle or other fat-free mass. Moreover, BMI does not reflect visceral or epicardial fat distribution [6,25–30]. Recent CABG-specific research has investigated fat-mass and fat-free-mass indices as potentially more informative predictors of postoperative morbidity, although further validation is required before their routine use in clinical risk assessment [31–33]. In the present study, BMI was dichotomized at 30 kg/m^2, grouping patients with overweight and potentially underweight patients within the non-obese category while precluding separate analyses of obesity classes. This approach may have obscured clinically relevant differences across the BMI spectrum. Future investigations should consider separate BMI categories and, where feasible, additional anthropometric or validated body-composition measures [33].

5. Study Limitations

First, this was a retrospective, single-centre study, and the analytic cohort was reconstructed from the available institutional database. Not all original exclusion criteria could be independently verified, creating the possibility of selection bias. Second, although propensity score matching improved comparability, residual imbalances persisted and unmeasured confounding cannot be excluded. Third, the matched cohort was relatively small, and several postoperative outcomes occurred infrequently. Consequently, effect estimates were imprecise, and approximate confidence intervals for paired risk differences should be interpreted with particular caution. Fourth, procedural heterogeneity and incomplete information on operative strategy, hybrid PCI, and wound-infection characteristics may have introduced additional bias. Fifth, BMI-based classification did not permit differentiation of obesity classes or body composition. Finally, the absence of systematic long-term follow-up precluded assessment of long-term clinical outcomes.

6. Conclusions

In this retrospective cohort of patients undergoing MIDCAB or MV-MIDCAB, no statistically significant differences were detected in early postoperative outcomes between obese and non-obese patients after propensity score matching.

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