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Article

Obesity Does Not Affect Major Outcomes in Robotic Coronary Surgery

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Abstract

Background: Robotic-assisted coronary surgery is gaining attraction as an alternative to traditional open-heart procedures, offering potential benefits such as decreased mortality rates, shorter hospital stays, and reduced complications. This study aimed to investigate the outcomes of robotic-assisted coronary surgery, focusing particularly on the impact of obesity. **Methods**: A total of 210 consecutive patients underwent robotic-assisted coronary surgery over an eight-year period at a single institution. Patients were categorized based on body mass index (BMI), distinguishing between obese (BMI $\geq$30 kg/m^2) and non-obese (BMI $<$30 kg/m^2) groups. The analysis encompassed preoperative characteristics, operative factors, and postoperative outcomes. **Results**: Comparisons between obese and non-obese patients revealed similar preoperative comorbidities. However, the operation time was prolonged in the obese group ($p = 0.03$). Major cardiac and cerebrovascular events, along with overall complications, displayed no significant disparities between the groups. Notably, superficial wound infections were more prevalent among obese patients ($p = 0.03$). Importantly, intensive care unit and hospital stay times were comparable between the two groups. **Conclusion**: Robotic-assisted coronary surgery demonstrates its potential as a viable alternative to conventional open-heart procedures, offering benefits such as reduced mortality rates, shorter hospital stays, and minimized perioperative complications. This study's findings underscore the feasibility and safety of this approach, with outcomes comparable between obese and non-obese patients.

Keywords

obesity; coronary artery bypass grafting; robotic-assisted surgery; minimally invasive surgery

Introduction

Robotic cardiac surgery has emerged as a promising alternative to conventional open-heart surgery. Its increasing popularity is associated with reduced mortality rates, shorter hospital stays, and fewer perioperative complications [1–3]. Surprisingly, during the last 4 years, robotic-assisted cardiac surgery has increased by 600%, from 0.06% to 0.4% [4]. This increase shows a growing recognition of its benefits. The scope of cardiac operations suitable to robotic assistance has grown significantly, including mitral valve surgery, tricuspid valve repair, arrhythmia surgery, intracardiac tumor excision, and congenital heart defect repair. Robotic technology has enabled these intricate interventions to be performed safely and with enhanced precision.

Coronary artery bypass grafting (CABG) accounts for approximately 50% of all robotic cardiac procedures [4,5]. This adaptable approach may be used on multivessel and single-vessel coronary disease patients. Furthermore, combined with percutaneous coronary interventions, it can be selectively included in hybrid revascularization approaches. The careful selection of patients for robotic coronary surgery significantly impacts the overall outcomes. While robotic coronary surgery has several advantages, there are some instances that traditional approach is still preferred. Notably, patients who are unable to tolerate single-lung ventilation, those who have hemodynamic instability, and those with reduced left ventricular function are often considered unsuitable candidates for robotic surgery.

Several studies have investigated the correlation between obesity and minimally invasive cardiac surgery. Notably, obese patients may benefit from these minimally invasive techniques, potentially avoiding sternal complications while maintaining a comparable risk of mortality and morbidity as standard treatments [6,7]. However, the correlation between obesity and robotic coronary surgery is unknown and requires further evaluation. By analyzing the outcomes associated with obesity in the context of robotic coronary surgery, the present study aims to contribute to this understudied area.

Methods

This study used a retrospective observational design. The study lasted from January 2015 to March 2023, and 210 patients received robotic-assisted coronary surgery at our medical institution, consecutively. This patient cohort included individuals with both single-vessel and multivessel coronary artery disease. All patients underwent left internal mammary artery (LIMA) harvesting using the DaVinci robotic system, with exposure facilitated by a left anterior thoracotomy. Subsequently, single-vessel or multivessel coronary anastomoses were performed. The surgical procedures were carried out either with or without cardiopulmonary bypass. Each patient had comprehensive preoperative, intraoperative, and postoperative data recorded. The primary study endpoint aimed to assess the impact of obesity on surgical outcomes in patients undergoing robotic coronary surgery and secondary study endpoints were to evaluate specific perioperative complications, such as cardiac events, length of hospital stay, and wound infections. Patients were monitored during their hospital stay, and postoperative data were recorded. Longer-term follow-up data, including outcomes beyond the immediate postoperative period, were not included to the study. The study for this paper has obtained ethical approval from the hospital's local ethics committee (Ethical Approval Reference Number: 2023.06.70) to ensure compliance with ethical guidelines and standards in accordance with the principles outlined in the Declaration of Helsinki.

Patient categorization was based on the World Health Organization (WHO) body mass index (BMI) classification system, wherein individuals with a BMI of 18.5–24.9 kg/m^2 were classified as normal weight, those with a BMI of 25.0–29.9 kg/m^2 were classified as overweight, and those with a BMI of 30.0 kg/m^2 or higher were classified as obese. For the analytical purposes of our study, the patient cohort was divided into two different groups: those classified as obese (BMI of $\geq$30 kg/m^2) and those classified as nonobese (BMI of $<$30 kg/m^2).

Surgical Technique

The LIMA was harvested using the Da Vinci® Si™ system (Intuitive Surgical, Sunnyvale, CA, USA) after a double-lumen endotracheal tube was inserted and the patient was properly positioned. This procedure involved establishing three ports through the second (7 mm), fourth (12 mm), and sixth (7 mm) intercostal spaces. An intrathoracic pressure of 10 mmHg was achieved by infusing carbon dioxide into the pleural cavity. After LIMA was harvested with a pedicle, the Da Vinci® system was removed from the operative setting, and the ports were removed. A 6-cm muscle-sparing left anterior thoracotomy was performed. Heparin (Poliparin, Polifarma, Istanbul, Turkey) was administered, with an activated clotting time of 300 in off-pump patients and 480 in on-pump patients. Cannulation of the right internal jugular vein, right femoral artery, and right femoral vein was performed in cases where the patient was undergoing on-pump surgery in line with techniques previously described in our previous studies [8,9]. The diastolic arrest was achieved using a Chitwood® DeBakey Clamp (Scanlan International Inc., St. Paul, MN, USA) via the second intercostal space. Coronary anastomoses are performed under direct vision. Commencing with the distal coronary anastomosis, 7/0–8/0 polypropylene sutures (Surgipro II, Covidien, Mansfield, MA, USA) were used. Subsequently, the proximal anastomosis of the saphenous vein graft was performed with an aortic side clamp and 6/0 polypropylene sutures (Surgipro II, Covidien, Mansfield, MA, USA).

Statistics

The statistical analysis was conducted using IBM SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Continuous data were presented as mean $\pm$ standard deviation or median with interquartile range (IQR). The Kolmogorov–Smirnov test was used to assess the normality of the distribution. When the data exhibited a normal distribution, the Student t-test was used to analyze. For non-normally distributed data, the Mann–Whitney U test was used. Categorical data were represented using counts and frequencies. Data analysis was conducted using the Chi-square or Fisher exact tests for categorical data. A significance level of $p < 0.05$ was considered statistically significant.

Results

The mean age of the entire cohort was 56.70 $\pm$ 9.58 years, with 180 (85.7%) patients being male. The mean BMI for the entire cohort was 28.62 $\pm$ 4.29 kg/m^2. The obese group had a mean BMI of 33.79 $\pm$ 3.71 kg/m^2, whereas the nonobese group had a mean BMI of 26.59 $\pm$ 2.37 kg/m^2. Both groups were statistically identical in terms of age, gender distribution, comorbidities, such as chronic obstructive pulmonary disease, diabetes mellitus, active smoking, renal failure, cerebrovascular disease, previous percutaneous coronary intervention, and ejection fraction. A comprehensive overview of preoperative characteristics can be found in Table 1.

Within our cohort, 155 (73.8%) patients underwent single-vessel bypass procedures, whereas 55 (26.2%) patients underwent multivessel bypass surgeries. One hundred forty (66.7%) patients underwent off-pump procedures, with 20 (9.5%) patients necessitating conversion to sternotomy for various reasons. Our previous study analyzed predictors and causes for conversion to ster-

Table 1. Preoperative data of the patients.

	Obese patients (BMI ≥30 kg/m^2)	Non obese patients (BMI <30 kg/m^2)	*p* value
	(60)	(150)	
	N (%) & Mean ± SD	N (%) & Mean ± SD	
Age, years	55.45 ± 9.53	57.20 ± 9.60	0.33
Male	54 (90.0%)	126 (84.0%)	0.59
BMI (kg/m^2)	33.8 ± 3.7	26.6 ± 2.4	<0.001*
COPD	18 (30.0%)	37 (24.7%)	0.42
Active smoker	21 (35.0%)	64 (42.6%)	0.38
Diabetes mellitus	21 (35.0%)	49 (32.7%)	0.74
Hypertension	48 (78.3%)	103 (68.7 %)	0.16
Dyslipidemia	40 (66.7%)	87 (58.0%)	0.24
Renal failure	3 (5.0%)	3 (2.6%)	0.41
Cerebrovascular disease	1 (1.7%)	5 (3.3%)	0.51
Previous PCI	14 (23.3%)	41 (27.3%)	0.55
Preoperative creatinine (mg/dL)	1.11 ± 0.68	1.08 ± 0.61	0.46
EF, %	54.4 ± 8.0	54.7 ± 8.6	0.83

BMI, Body mass index; COPD, Chronic obstructive pulmonary disease; EF, ejection fraction; PCI, percutaneous coronary intervention. *: Statistically significant.

Table 2. Operative data of the patients.

	All patients	Obese patients (BMI ≥30 kg/m^2)	Non obese patients (BMI <30 kg/m^2)	*p* value
	(210)	(60)	(150)	
	N (%) & Mean ± SD	N (%) & Mean ± SD	N (%) & Mean ± SD	
Single-vessel bypass	155 (73.8%)	48 (80.0%)	107 (71.3%)	0.19
Off-pump surgery	140 (66.7%)	43 (71.7%)	97 (64.7%)	0.33
Conversion to sternotomy	20 (9.5%)	6 (10.0%)	14 (9.3%)	0.95
Operation time, min	290.77 ± 50.16	303.27 ± 51.11	285.17 ± 50.06	0.03*
CPB time, min	71.85 ± 27.19	77.88 ± 27.94	70.29 ± 27.24	0.48
AC time, min	39.26 ± 20.57	36.00 ± 19.46	40.04 ± 21.14	0.67

AC, Aortic Cross-clamp; CPB, cardiopulmonary bypass. *: Statistically significant.

notomy in robotic and minimally invasive coronary bypass patients [10]. The mean overall operation time was 290.77 ± 50.16 min, with a statistically significant difference between obese and nonobese patients (303.27 ± 51.11 and 285.17 ± 50.06, respectively; $p = 0.03$). However, no significant differences in cardiopulmonary bypass time and aortic cross-clamp time were observed between the two groups, as shown in Table 2.

The mortality rate in our cohort remained at 0%. Notably, there were no significant differences in new-onset atrial fibrillation, postoperative renal failure, postoperative cerebrovascular events, postoperative myocardial infarctions, reexploration rates, and prolonged inotropic use between obese and nonobese patients. Deep wound infections were not observed in our cohort. However, it is worth noting that superficial wound infections were more common in the obese group than in the nonobese group ($p = 0.03$). There were no differences between the two patient groups in terms of intensive care unit and hospital stay time (Table 3).

Discussion

Obesity has become a global epidemic, with its prevalence showing a consistent upward trajectory in recent decades [11]. Obesity has long been known as a risk factor for cardiovascular diseases, particularly coronary artery disease [12]. However, a phenomenon known as the "obesity paradox" defies conventional expectations, positing that individuals with cardiovascular disease who are overweight or obese have better outcomes than their normal-weight counterparts [13,14]. Oreopoulos *et al*. [15] conducted a previous meta-analysis that overweight and obese patients undergoing coronary revascularization exhibited comparable or reduced short- and long-term mortality rates.

Due to the small size of study samples and variations in baseline patient characteristics, elucidating the underlying causes of the "obesity paradox" reported in patients undergoing coronary artery bypass grafting (CABG) is challenging. To address this phenomenon, multiple theories have emerged in the scientific literature. One well-known

Table 3. Postoperative data of the patients.

	All patients	Obese patients (BMI ≥30 kg/m^2)	Non-obese patients (BMI <30 kg/m^2)	*p* value
		N (%) & Median (IQR1-IQR3)	N (%) & Median (IQR1-IQR3)	
	(210)	(60)	(150)	
Operative mortality	0	0 (0.0)	0 (0.0)	NA
New onset atrial fibrillation	30 (14.3%)	9 (15.0%)	21 (14.0%)	0.85
Acute renal failure	2 (1.0%)	0 (0.0%)	2 (1.3%)	0.36
Re-exploration	15 (7.1%)	5 (8.3%)	10 (6.7%)	0.67
Prolonged inotrope use (>24 h)	5 (2.4%)	2 (3.3%)	3 (2.0%)	0.56
Postoperative MI	5 (2.4%)	0 (0.0%)	5 (3.3%)	0.15
Postoperative cerebrovascular event	5 (2.4%)	0 (0.0%)	5 (3.3%)	0.15
Superficial wound infections	6 (2.9%)	4 (6.7%)	2 (1.3%)	0.03*
Deep wound infections	0 (0.0%)	0 (0.0%)	0 (0.0%)	NA
ICU stay, days	1 [1–1]	1 [1–1]	1 [1–1]	0.58
Hospital stay, days	5 [4–6]	5 [4–6]	5 [4.0–5.25]	0.82

BMI, Body mass index; ICU, Intensive Care Unit; MI, Myocardial Infarction; NA, Not applicable; *, Statistically significant.

theory revolves around the presence of selection bias. As Rubinshtein *et al*. [16] point out, the tendency of obese patients to undergo revascularization procedures at an earlier age may introduce a bias in patient selection. Additionally, there is a difference in treatment options among obese patients, who are more likely to receive percutaneous coronary interventions and less likely to undergo coronary artery bypass grafting (CABG). The lack of randomization in treatment allocation adds to this complexity. A secondary consideration pertains to the significant differences in risk profiles among patients in various studies. These discrepancies highlight the contrasting comorbidity patterns between individuals of normal weight and those who are overweight or obese. The higher prevalence of comorbid medical conditions in normal-weight patients may significantly impact study outcomes, contributing to the apparent "obesity paradox".

The relationship between obesity and minimally invasive coronary artery bypass grafting (MICS) techniques remains relatively unexplored; a recent study by Liu *et al*. [17] examined obese and nonobese subgroups within MICS. The authors classified the obese subgroup as having a BMI >28 kg/m^2, corresponding to the typical obesity range for the Chinese population. Their findings revealed no statistically significant differences in intensive care unit duration, thoracic drainage volume 24-h postsurgery, hospital stay, and major adverse cardiac and cerebrovascular events. The conclusion drawn was that, according to the data, obesity is not a contraindication for using minimally invasive coronary bypass procedures among experienced surgeons [17].

Robot-assisted coronary artery bypass surgery has developed as an innovative substitute for traditional coronary artery bypass grafting, with a recent surge in popularity. This advanced technique poses significant technical challenges for surgeons, necessitating a steep learning curve to achieve mastery [18,19]. From the patient's standpoint, it improves quality of life, reduces intensive care unit durations and hospital stays, and facilitates a swift reintegration into the workforce. This method has proven its credibility as a safe and reliable procedure capable of addressing single-vessel coronary artery disease and more complex multivessel coronary artery disease patients [20–22].

There has been little research on obesity in robotic-assisted minimally invasive direct coronary artery bypass grafting (MIDCAB) and endoscopic coronary artery bypass grafting (TECAB). Wiedemann *et al*. [23] examined 127 patients undergoing the arrested heart TECAB procedure. The results showed no increase in operative time or intraoperative or postoperative complications for overweight and obese patients compared with those of normal weight individuals. Similarly, Vassiliades *et al*. [24] study found no statistically significant difference between different BMI groups in 30-day mortality, conversion to sternotomy, transfusion rates, or various complications encompassing wound, pulmonary, neurological, and myocardial. Kitahara *et al*. [7] conducted a retrospective single-center study on 486 patients who underwent robotic cardiac surgery, 54% of whom had coronary procedures. They observed that the morbidly obese group had comparable morbidity and mortality rates after robotic cardiac surgery compared with the nonobese cohort.

Using an off-pump approach, Hemli *et al*. [25] explored robotic-assisted MIDCAB in 110 consecutive patients. Their findings revealed that obese patients experienced a longer mean time for harvesting the left internal mammary artery (LIMA) than nonobese patients, leading to a longer overall operative duration. Despite these variations, there were no significant differences in mortality or morbidity between the obese and nonobese patient groups [25].

No mortality was observed within the entirety of our study cohort. Our study revealed that obese and nonobese patients exhibited comparable preoperative comorbidities.

Notably, the duration of the surgical procedure was longer in obese patients, which is consistent with the results of Hemli *et al*. [25]. Moreover, there were no significant differences between the groups in terms of major cardiac and cerebrovascular events and overall complications. It was shown that superficial wound infections at the thoracotomy site or femoral cannulation site were statistically more common in obese patients than in nonobese patients.

Obesity is a well-known risk factor for surgical site infections after coronary artery bypass grafting surgery [26,27]. The increased complexity and prolonged duration of the procedure lead to concerns, such as decreased tissue oxygenation and hyperglycemia, all related to an increased risk of surgical site infections. Notably, obese patients in our study had longer operative times, which may lead to an increased incidence of superficial wound infections. In our study, where patients underwent sternal-sparing surgery, it is not surprising that we did not observe cases of mediastinitis. However, the correlation between obesity and superficial wound infections is consistent with previous research findings [28].

Despite the valuable insights gained from our study, several limitations should be considered. The single-center retrospective design of the study includes inherent biases that may affect the generalizability of the findings. The small sample size could potentially limit the robustness of the statistical analyses and the ability to identify subtle differences. Larger cohorts may be required to provide more definitive conclusions. While practical, the World Health Organization (WHO) BMI classification may not adequately represent the heterogeneity within the obese population. Furthermore, the lack of randomization and the absence of long-term follow-up data limit our ability to establish causal relationships and assess outcome durability. Long-term follow-up data could provide insights into the durability of outcomes and the potential for late complications related to robotic-assisted coronary surgery.

Our study suggests several future directions. These include assessing long-term patient outcomes and quality of life from a patient's perspective, investigating the wound complication spectrum, and supporting multicenter larger studies. These efforts aim to improve patient care and related outcomes for all patients undergoing robotic coronary surgery.

Conclusion

In conclusion, our study highlights the safety and efficacy of robotic-assisted coronary surgery across a diverse patient cohort. Despite the longer operation time reported in obese patients, major cardiac and cerebrovascular events, and overall complications, no significant differences were found between obese and nonobese individuals. Notably, the absence of mortality reaffirms the positive outcomes of this technique.

Availability of Data and Materials

Data used to support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

EY, MG, MB and ÜA designed the study. ZMD, MB and EK collected and analyzed the data and interpreted the results. MB, EK, MG and ZMD contributed to the literature review, preparation of the manuscript and revision. ÜA, EK and EY conducted a control and critical review of the manuscript. All authors contributed to editorial changes in the article. All authors have read and approved the final version of the manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study for this paper has obtained ethical approval from the hospital's local ethics committee (Ethical Approval Reference Number: 2023.06.70) to ensure compliance with ethical guidelines and standards in accordance with the principles outlined in the Declaration of Helsinki. A written informed consent was obtained from each patient.

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Conflict of Interest

The authors declare no conflict of interest.

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