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The Cardiothoracic Surgeon

RESEARCH

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Risk of sternal wound infection in bilateral skeletonized internal thoracic artery in coronary artery bypass grafting: a propensity score matching analysis

Willem Hendrik te Gussinklo[1*†], Christian Burgard[1†], Joshua Jahn[1], Gabriele Romano[1], Matthias Karck[1], Rawa Arif[1] and Bashar Dib[1]

Abstract

Background A growing body of evidence shows that choosing an arterial graft as a second graft for coronary artery bypass grafting (CABG), has a superior patency and a survival benefit when compared to a saphenous vein graft (SVG). However, surgeons are wary to utilize the right internal mammary artery (RIMA), because of concerns of sternal wound infections (SWI). This study aims to evaluate the risk of SWI in bilateral internal mammary artery (BIMA) usage while performing skeletonized harvesting.

Methods Between January 2020 and July 2023, 1785 consecutive patients suffering from coronary artery disease (CAD) underwent a CABG operation at our hospital. Propensity score matching was performed where 259 single internal mammary artery (SIMA) patients were compared to 259 BIMA patients. We assessed sternal wound infections, and performed univariate and multivariate analysis identifying risk factors for SWI.

Results There were six (1.2%) wound infections, evenly divided between SIMA ($n=3$, 1.2%) and BIMA ($n=3$, 1.2%) groups. Multivariate testing showed female gender (OR: 3.21, 95%CI: 1.58–6.55, $p=0.001$), diabetes (OR: 3.07, 95%CI: 1.42–6.61, $p=0.004$, NYHA class ≥ 3 (OR: 2.38, 95%CI: 1.09–5.20, $p=0.029$) and postoperative delirium (OR: 1.92, 95%CI: 1.29–2.85, $p=0.001$) to be significant risk factors for SWI. BIMA grafting was not confirmed as an independent risk factor for SWI (OR: 0.66, 95%CI: 0.19–2.27, $p=0.506$).

Conclusion This study shows that skeletonized BIMA grafting does not increase the risk of SWI. Female gender, diabetes, NYHA ≥ 3 and postoperative delirium did increase the risk for a sternal wound infection.

Keywords Coronary artery disease, Coronary artery bypass grafting, Arterial revascularization, Bilateral internal mammary arteries, Sternal wound infection

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Background

When patients with coronary artery disease (CAD) verified in coronary angiogram (CAG), already managed with lifestyle advice and optimal medical therapy, are still experiencing symptoms, or are at a high risk of acute coronary syndrome (ACS) a coronary revascularization strategy should be considered [1]. And when the patient has three vessel disease (3VD) or a left main (LM) stenosis, a coronary artery bypass grafting (CABG) operation is the preferred treatment [2]. Next, selecting the appropriate grafts for CABG is a critical decision in cardiac surgery. The left internal mammary artery (LIMA) stands out as the preferred graft for CABG, particularly for grafting the left anterior descending (LAD) coronary artery in every patient with CAD and LAD stenosis. Studies have consistently demonstrated superior patency and a survival benefit of LIMA over saphenous vein grafts [3]. When harvesting the internal mammary artery (IMA) there are the skeletonized and pedicled technique which can be performed [4]. While the use of LIMA is widely accepted in CABG operations, the selection of the secondary graft remains a subject of debate. The saphenous vein graft (SVG) is commonly chosen as the second graft due to its ease of use and the low complication rates during harvest. However, despite its popularity, SVGs have shown a high failure rate of up to 60% after ten years [5]. A widely accepted alternative to SVGs is the right internal mammary artery (RIMA). Retrospective studies have indicated a survival benefit with the use of arterial grafts, both in short- and long-term survival [6–8]. However, bilateral internal mammary artery (BIMA) is only performed in 4% of the cases, particularly because it leads to a longer operation time, but also mainly because of concerns about poor wound healing [9].

One of the largest disadvantages of BIMA grafting are sternal wound infections. Multiple studies illustrate increased rates of sternal wound infection (SWI) after BIMA [10, 11]. Conversely, recent studies show contrasting results, indicating comparable rates of SWI between BIMA and single internal mammary artery (SIMA) patients, when performing the skeletonized technique [12]. This study aims to evaluate the risk of sternal wound infection in BIMA with skeletonized harvesting.

Methods

In this monocentric and retrospective study, patients who underwent isolated CABG for coronary heart disease were identified at University Hospital Heidelberg, Germany. Patients with perioperative history of resuscitation, Minimally Invasive Direct Coronary Artery Bypass (MIDCAB), complete venous revascularization and emergency operation were excluded from this study. All the remaining patients underwent a median sternotomy with the use of at least one IMA for bypass grafting.

The study collective was divided into two groups: patients with BIMA received skeletonized LIMA and RIMA bypass grafting and if needed, additional grafts for example with SVG or the radial artery. The control group received only one skeletonized LIMA, also if needed with additional venous or radial artery grafting.

The primary endpoint of the study was the occurrence of sternal wound infection (SWI). SWI was categorized as either superficial or deep infection. Superficial infections involved the skin, subcutaneous tissue or prestern-al fat, whereas deep infections involved the sternum, mediastinum or muscle tissue including osteitis, osteomyelitis or mediastinitis. Microbiological cultures were obtained from the wound site to support the diagnosis. The secondary endpoints included postoperative outcomes such as ICU length of stay, cumulative drainage volume, re-exploration for bleeding, postoperative delirium, cerebrovascular events, postoperative dialysis, and in-hospital mortality. Postoperative surveillance for sternal wound infection included the index hospitalization and routine clinical follow-up at approximately 30 and 180 days after surgery. Additional cases were identified through readmission records and outpatient postoperative assessment.

The study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the local institutional ethics committee of Heidelberg University Hospital. Due to the retrospective nature of the study, the requirement for individual patient consent was waived.

Data were initially entered into a Microsoft Excel (Microsoft Corp) spreadsheet and then transferred to a SPSS (IBM®SPSS®29, Chicago, IL, USA) file for data description and analysis. Baseline characteristics, perioperative data, the incidence of postoperative wound infection and postoperative data were collected. Univariate and multivariate regression analysis was performed to identify risk factors for sternal wound infection. Propensity scores were estimated using a logistic regression model based on the following covariates: sex, age, body mass index, diabetes, active smoking, previous cardiac surgery, obstructive lung disease, peripheral arterial disease, and dialysis. Patients were matched using 1:1 nearest-neighbor matching with a caliper of 0.05 without replacement.

Surgical technique

All procedures were performed via median sternotomy. Bone wax was routinely applied according to institutional practice, whereas topical antibiotic agents (e.g., vancomycin) were not used. The internal mammary arteries were harvested using a skeletonized technique in all patients, predominantly with monopolar electrocautery. In cases of bilateral internal mammary artery (BIMA) grafting,

the right internal mammary artery (RIMA) was typically anastomosed end-to-side to the in situ left internal mammary artery (LIMA), forming a composite Y-graft configuration. Coronary artery bypass grafting was performed predominantly using cardiopulmonary bypass with cardioplegic cardiac arrest, whereas off-pump CABG was carried out in selected cases at the surgeon's discretion. Additional grafts, when required, were performed using saphenous vein grafts or the radial artery. Sternal closure was performed using stainless steel wires according to standard institutional practice. The subcutaneous tissue was closed in layers using a resorbable Vicryl 1 – 0 suture. In the majority of cases, the skin was closed using a resorbable intracutaneous 4 – 0 suture, while skin staples were used in selected cases depending on surgeon preference. Perioperative antibiotic prophylaxis consisted of cefuroxime administered according to institutional standards. Glycemic control was achieved by maintaining euglycemia using short-acting insulin during the perioperative period. After removal of chest drains and clinical stabilization, patients with diabetes were transitioned back to antidiabetic therapy, targeting blood glucose levels below 200 mg/dL.

Results

Between January 2020 and July 2023, 1785 consecutive patients suffering from CAD underwent a CABG operation at the Heidelberg University Hospital and were included in the analysis. After applying the exclusion criteria; patients who were resuscitated peri-operatively ($n=62$), patients not receiving a sternotomy ($n=52$), patients not receiving internal mammary grafting ($n=88$) and emergency operations ($n=390$) a total of 1193 patients remained. Among the included patients, 925 (77.5%) patients received SIMA grafting and 268 (22.5%) patients received BIMA grafting. However, the patients in these two groups showed big discrepancies in for example age (SIMA: 68.9 ± 8.6 vs. BIMA: 62.4 ± 8.7, $p<0.001$), body mass index (BMI) (SIMA: 24.5 ± 4.5 vs. BIMA: 24.4 ± 4.0 $p=0.003$), diabetes (SIMA: 44.6% vs. BIMA: 24.8%, $p<0.001$) and peripheral arterial disease (SIMA: 14.7% vs. BIMA: 8.6%, $p=0.009$). Which led us to believe we had to perform a propensity score matching (PSM) to be able to correctly compare the SIMA and BIMA groups. A PSM was performed with a calliper of 0.05 on 9 variables: sex, age, BMI, diabetes, active smoking, previous cardiac surgery, obstructive lung disease, peripheral arterial disease and dialysis. After PSM 9 cases could not be matched and were excluded, which left us with 259 matched cases. Baseline patients' characteristics are shown in Table 1.

Perioperative findings

In the perioperative data significant differences in the operation time between the cohorts could be observed (SIMA: 253 ± 61 min. vs. BIMA: 292 ± 52 min, $p<0.001$). This disparity can be attributed to the additional time required for the preparation of both mammary arteries for BIMA grafting and the sewing of the composite graft. Furthermore, the duration of aortic cross-clamping was longer, although not significantly, in BIMA patients compared to SIMA patients (SIMA: 66 ± 43 min. vs. BIMA: 71 ± 21 min., $p<0.083$), likely due to the increased complexity associated anastomosing multiple arterial grafts. Perioperative data is shown in Table 2.

Table 1 Baseline characteristics after propensity score matching

	Total ($n=518$)	**SIMA ($n=259$)**	**BIMA ($n=259$)**	***p*-value**
Age (years)	63.6 ± 8.5	64.2 ± 8.8	63.0 ± 8.2	0.102
Sex (male)	89.6% ($n=464$)	89.2% ($n=231$)	90% ($n=233$)	0.774
BMI	24.4 ± 4.0	24.30 ± 4.1	24.5 ± 4.0	0.590
Dyslipidaemia	78.6% ($n=407$)	75.7% ($n=196$)	81.5% ($n=211$)	0.108
Hypertension	85.7% ($n=444$)	86.5% ($n=224$)	84.9% ($n=220$)	0.615
Diabetes	24.9% ($n=129$)	25.1% ($n=65$)	24.7% ($n=64$)	0.919
Active smoking	23.4% ($n=121$)	21.6% ($n=56$)	25.1% ($n=65$)	0.350
Peripheral artery disease	8.7% ($n=45$)	8.5% ($n=22$)	8.9% ($n=23$)	0.876
Dialysis (chronic renal failure)	0.2% ($n=1$)	0% ($n=0$)	0.4% ($n=1$)	1.000
Obstructive lung disease	14.9% ($n=77$)	15.1% ($n=39$)	14.7% ($n=38$)	0.902
Previous cardiac surgery	0.8% ($n=4$)	1.2% ($n=3$)	0.4% ($n=1$)	0.405
NYHA class ≥ 3	33.6% ($n=174$)	25.1% ($n=65$)	42.1% ($n=109$)	< 0.001
Left ventricular ejection fraction (EF in %) preoperatively				< 0.001
EF > 50%	82.2% ($n=426$)	89.2% ($n=231$)	75.3% ($n=195$)	
EF 31–50%	16.0% ($n=83$)	9.7% ($n=25$)	22.4% ($n=58$)	
EF 21–30%	1.0% ($n=5$)	0.4% ($n=1$)	1.5% ($n=4$)	
EF ≤ 20%	0.6% ($n=3$)	0.4% ($n=1$)	0.8% ($n=2$)	

Table 2 Perioperative data

	Total (*n* = 518)	SIMA (*n* = 259)	BIMA (*n* = 259)	*p*-value
Operation time (min.)	272 ± 60	253 ± 61	292 ± 51	< 0.001
Cardiopulmonary bypass time (min.)	108 ± 45	110 ± 56	106 ± 31	0.363
Aortic x-clamp time (min.)	69 ± 34	66 ± 43	71 ± 21	0.083
Off-pump CABG	3.5% (*n* = 18)	3.1% (*n* = 8)	3.9% (*n* = 10)	0.631
Postoperative RBC transfusion [mL]	304,6 ± 700,1	267,6 ± 436,8	341,7 ± 888,1	0,229
Postoperative FFP transfusion [mL]	113,7 ± 553,9	94,5 ± 392,3	133,0 ± 678,4	0,430
Postoperative platelet transfusion [mL]	117,2 ± 327,4	94,4 ± 237,7	140,1 ± 396,5	0,112

Table 3 Primary outcome

	Total (*n* = 518)	SIMA (*n* = 259)	BIMA (*n* = 259)	*p*-value
Wound infection	1.2% (*n* = 6)	1.2% (*n* = 3)	1.2% (*n* = 3)	1.000
- superficial	0.8% (*n* = 4)	0.8% (*n* = 2)	0.8%(*n* = 2)	1.000
- deep	0.4% (*n* = 2)	0.4% (*n* = 1)	0.4% (*n* = 1)	1.000

Table 4 Secondary outcomes

	Total (*n* = 518)	SIMA (*n* = 259)	BIMA (*n* = 259)	*p*-value
Intensive care unit (ICU) stay (days)	1.6 ± 2.2	1.8 ± 2.9	1.5 ± 1.0	0.119
Re-exploration for bleeding	2.9% (*n* = 15)	4.3% (*n* = 11)	1.6%(*n* = 4)	0.201
Cumulative drainage volume (mL)	1268 ± 1034	1310 mL ± 1229	1225 mL ± 792	0.344
Postoperative delirium	4.8% (*n* = 25)	6.9% (*n* = 18)	2.7% (*n* = 7)	0.044
Postoperative resuscitation	0.8% (*n* = 4)	0.8% (*n* = 2)	0.8% (*n* = 2)	1.000
Cerebrovascular accident	1.2% (*n* = 6)	1.2% (*n* = 3)	1.2% (*n* = 3)	1.000
Postoperative dialysis	0.6% (*n* = 3)	0.8% (*n* = 2)	0.4% (*n* = 1)	0.828
In-hospital mortality	0.0%	0.0%	0.0%	1.000

Primary outcome

In our PSM cohort there were a total of 6 (1.2%) sternal wound infections, evenly distributed over the two groups (SIMA: 1.2% vs. BIMA: 1.2%, $p = 1.000$). These were subdivided into two (0.4%) deep sternal wound infections and four (0.8%) superficial sternal wound infections. These were also evenly distributed between the two cohorts. The primary outcomes are summarized in Table 3.

Secondary outcomes

Upon closely examining other postoperative data, we found no significant differences in intensive care unit stay (SIMA: 1.8d ± 2.9 vs. BIMA: 1.5 ± 1.0, $p = 0.119$), re-exploration for bleeding (SIMA: 4.3% vs. BIMA: 1.6%, $p = 0.201$), cumulative drainage volume (SIMA: 1310 mL ± 1229 vs. BIMA: 1225 mL ± 792, $p = 0.344$), postoperative delirium (SIMA: 6.9% vs. BIMA: 2.7%, $p = 0.044$), postoperative resuscitation (SIMA: 0.8%, vs. BIMA. 0.8%, $p = 1.000$), cerebrovascular accidents (SIMA: 1.2% vs. BIMA: 1.2%, $p = 1.000$), postoperative dialysis (SIMA: 0.8% vs. BIMA:0.4%, $p = 0.828$) and there was no in-hospital mortality. None of the patients requiring re-exploration for bleeding developed a subsequent sternal wound infection. The secondary outcomes are summarized in Table 4.

Table 5 Univariate analysis for postoperative wound infection

Risk factor	*p*-value
Gender (female)	< 0.001
Diabetes	< 0.001
NYHA class ≥ 3	0.003
Obesity (BMI ≥ 30)	0.029
Delirium	< 0.001

Univariate and multivariate regression

After identifying that BIMA grafting did not pose a significant risk factor for postoperative wound infection, both univariate and multivariate regression analysis to identify other contributing factors were conducted. In the univariate analysis, significant preoperative risk factor for postoperative wound infection included gender ($p < 0.001$), diabetes ($p < 0.001$), New York Heart Association (NYHA) class ≥ 3 ($p = 0.003$), BMI ≥ 30 ($p = 0.029$). Additionally, delirium ($p = 0.001$) was the sole postoperative significant risk factor. The results of univariate analysis are summarized in Table 5.

Subsequently, significant univariate risk factors for postoperative wound infection were subjected to multivariate logistic regression analysis. The analysis revealed that female gender emerged as the most important independent risk factor for postoperative wound infection (OR: 3.21, 95%CI: 1.58–6.55, $p = 0.001$). Other significant independent preoperative risk factors included diabetes

Table 6 Multivariate logistic regression

Risk factor	*p*-value	Odds ratio	95% Confidence interval	
			Lower	Upper
Gender (female)	0.001	3.21	1.58	6.55
Diabetes	0.004	3.07	1.42	6.61
Obesity (BMI ≥ 30)	0.053	2.35	0.99	5.61
NYHA class ≥ 3	0.029	2.38	1.09	5.20
Delirium	0.001	1.92	1.29	2.85
BIMA grafting	0.506	0.66	0.19	2.27

(OR: 3.07, 95%CI: 1.42–6.61, $p = 0.004$) and NYHA class ≥ 3 (OR: 2.38, 95%CI: 1.09–5.20, $p = 0.029$). Postoperatively, delirium was the sole significant independent risk factor (OR: 1.92, 95%CI: 1.29–2.85, $p = 0.001$). Interestingly, BIMA grafting was still not confirmed as an independent risk factor for postoperative wound infection (OR: 0.66, 95%CI: 0.19–2.27, $p = 0.506$). The findings of the multivariate analysis are summarized in Table 6.

Discussion

The aim of this retrospective study was to show that skeletonized BIMA grafting does not increase the risk of postoperative wound infections. Despite ongoing discussion, the evidence in this regard is limited and occasionally contradicting. By analysing a diverse CABG population and applying PSM, this study aimed to provide additional insights into the risk of SWI with BIMA grafting. Although the limitations of a retrospective study are evident, the results of this study clearly showed that the use of skeletonized BIMA grafting did not pose a greater risk of postoperative sternal wound infection. In contrary to the largest randomized controlled trial (RCT) on BIMA grafting to date, the ART trial [13]. This trial showed a sternal wound complication rate of 3.5% in BIMA patients, whereas our study had a sternal wound complication rate of just 1.2% in BIMA patients. The wound complication rate of SIMA patients in the ART trial was at 1.9%, whereas the wound complication rate in this study for SIMA patients was at a comparable 1.2%. This seems paradoxical when compared to this and multiple other reports on BIMA and SWI [10, 14]. Even in the American guideline on coronary artery revascularization [3], the use of bilateral internal mammary artery grafting is only recommended when the patient has no other risk factors for (deep) sternal wound infections. Nonetheless, the results clearly accentuate that BIMA grafting is not a risk factor for SWI. This effect mostly seems to be associated with the harvesting technique of the mammary arteries. In the pedicled technique the internal mammary artery is dissected from the chest wall and harvested together with the satellite veins and the fascia. In the skeletonized harvesting technique, the internal thoracic artery is dissected free from the surrounding tissues, including fascia and satellite veins, while preserving the vessel wall, including the adventitia [15]. The latter technique ensures a longer graft and less trauma to the chest wall and the blood supply to the sternum [16]. Whereas the pedicled technique severely impairs sternal blood flow [17] and in this manner increases the risk of sternal wound complications. For instance, in the post-hoc analysis of the ART data, the investigators found that the use of the pedicled technique for both IMA was a risk factor for SWI, but the use of the skeletonized technique was not [18]. Other studies also support these findings of the protective effects of skeletonization when compared to pedicled harvesting [19, 20]. Furthermore, other studies suggest that even in a high-risk population of patients with diabetes, the skeletonized technique does not increase the risk of sternal wound complications [21, 22]. Additionally, a large meta-analysis comparing pedicled and skeletonized IMA grafting found the benefit of the skeletonized technique in regard to SWI too [23]. And while in this study the skeletonized harvesting technique was exclusively utilized, the results seem to support the fact that this technique does not increase the rate of deep SWI.

To mitigate the effect of patient and selection bias, a PSM on the most eminent risk factors for postoperative wound infection was performed. Unfortunately, some preestablished risk factors were still significantly different after propensity score matching, disparities persisted in preoperative risk factors for sternal wound complications like left ventricular function and congestive heart failure with a NYHA class of three or greater [22]. This imbalance may reflect institutional surgical selection patterns and represents a limitation of the present study, as it may introduce residual confounding when comparing outcomes between the groups.

Similar trends were observed in the perioperative data. These showed that BIMA grafting renders a more time-consuming strategy compared to SIMA grafting, resulting in longer procedural times. This can be attenuated to the inherent complexity of graft preparation, and the subsequent suturing of the Y-graft that is additionally time-consuming, as outlined in previous literature [24]. The Y-graft technique is a standard procedure at this department. The RIMA graft is anastomosed in an end-to-side fashion to the LIMA, that remains in situ. The

trend towards slightly prolonged aortic cross-clamp time is most likely explained by the difficulty associated with utilizing arterial grafts compared to venous grafts.

Subsequently, other risk factors potentially influencing the incidence of SWI were considered and researched using univariate analysis. Among these, female gender emerged as the most statistically significant risk factor. This study demonstrates that female gender had a substantial impact on the occurrence of SWI.

However, the effect of gender on SWI is still under debate and the literature on it is inconclusive. A systematic review found female gender to be an independent risk factor for sternal wound infection [25]. Whereas another, more historic, review found male gender to be an independent risk factor [26]. Thus, the precise role of gender in the development of SWI remains controversial. Nevertheless, this study found a strong association between female gender and SWI incidence.

In addition, well known risk factors including obesity and diabetes [27] were also significantly associated with SWI in this study. Hyperglycaemia in diabetic patients interferes with the physiologic response to bacterial wound infections, like impeding normal leukocyte function, and decreases physiological wound healing. Moreover, obesity increases the risk of wound infections due to reduced capillary density in fatty tissue, making it more susceptible to infection [28].

Another variable found to be significant in the univariate analysis was a NYHA functional class of III or higher, which can be seen as an indicator of the preoperative state of patients. Patients in congestive heart failure are known to have impaired wound healing, a correlation supported by Chen et al. [29].

Additionally, one postoperative risk factor for SWI was identified in the univariate analysis was postoperative delirium. This condition may increase the risk of SWI, due to decreased patient compliance and their inability to follow instructions to protect sternal stability. The fact that postoperative delirium is a risk factor for sternal wound complications has been documented before [30].

Subsequently a multivariate analysis of these univariate risk factors was completed. In this logistic regression female gender, diabetes, and delirium were distinguished to be independent risk factors for postoperative wound infection. Obesity was associated with an increased risk of sternal wound infection in the univariate analysis but did not reach statistical significance in the multivariable model. Whereas gender and diabetes can't be changed before an operation, it seems sensible to encourage patients to lose weight prior to an operation to prevent postoperative wound infections. Furthermore it is important to make sure that postoperative delirium be treated immediately and preferably be prevented by non-pharmacological treatment options beforehand [31]. Interestingly enough, the multivariate analysis confirmed that bilateral internal mammary artery grafting is not a risk factor for postoperative wound infections in this patient cohort.

Due to the very low number of sternal wound infection events observed in this cohort, the study is statistically underpowered to detect small but potentially clinically meaningful differences between groups. Furthermore, the limited number of events increases the risk of model overfitting in multivariable regression analyses. Therefore, the results of these analyses should be interpreted cautiously and primarily considered hypothesis-generating.

It should be noted that the present cohort represents a comparatively low-risk population with regard to several established predictors of sternal wound complications. This likely reflects routine clinical decision-making in the selection of patients for BIMA grafting and should be taken into account when interpreting the results.

Conclusions

In conclusion, this retrospective observational study demonstrates that skeletonized BIMA grafting does not increase the risk of postoperative wound infections. These findings contribute to the growing body of evidence suggesting that the skeletonized harvesting of IMA does not increase the risk of wound infections, challenging earlier research on BIMA grafting, that did not differentiate between skeletonized and pedicled harvesting. However, the limitations inherent in retrospective observational studies underscore the need for further prospective research to validate these findings. Specifically, future research should focus on collecting randomized prospective data to assess the long-term mortality benefits of BIMA grafting. Fortunately, ongoing large randomized controlled trials are already including patients in this respect and their findings are anticipated to shape the future role of BIMA grafting.

Abbreviations

3VD	Three-vessel Disease
ACS	Acute Coronary Syndrome
ART	Arterial Revascularization Trial
BIMA	Bilateral Internal Mammary Artery
BMI	Body Mass Index
CABG	Coronary Artery Bypass Grafting
CAD	Coronary artery disease
CAG	Coronary Angiogram
EF	Ejection Fraction
ICU	Intensive Care Unit
LAD	Left Anterior Descending
LIMA	Left Internal Mammary Artery
LM	Left Main
MIDCAB	Minimally Invasive Direct Coronary Artery Bypass
NYHA	New York Heart Association
PCI	Percutaneous Coronary Intervention
PSM	Propensity Score Matching
RCT	Randomized Controlled Trial
RIMA	Right Internal Mammary Artery

SIMA Single Internal Mammary Grafting
SVG Saphenous Vein Graft
SWI Sternal Wound Infection

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43057-026-00206-3.

Supplementary Material 1

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Author contributions
WHtG and CB conceived the study, wrote the manuscript and performed the statistical methods. JJ analysed and verified the statistical methods. GR aided in interpreting the results and the writing of the manuscript. MK conceived the study and supervised the project. RA supervised the study and statistical methods. BD conceived the study, supervised the study and interpretated the results. All authors discussed the results and contributed to the final manuscript.

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Data availability
The data that support the findings of this study are available on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the regional ethics committee (EC number: S-911/2021 from 20-12-2021) and was consistent with the declaration of Helsinki. Due to the retrospective nature of this study, patient consent was waived.

Consent for publication
Due to the retrospective nature of this study, patient consent was waived.

Competing interests
The authors have no relevant financial or non-financial interests to disclose.

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