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[1]**Parth Bharat Solanki**, M. S., M. Ch Cardiovascular and thoracic surgery, Doctor, Associate Professor CVTS, https://orcid.org/0009-0003-9862-8022

[2]**Nivedita Vadodaria**, M. D. Anaesthesiology, Doctor, Associate Professor Anaesthesiology, https://orcid.org/0009-0003-4031-6608

[3]**Smit Bharat Solanki**, M. S., Obstetrics and Gynecology, Doctor, Assistant Professor Obstetrics and gynecology, https://orcid.org/0009-0006-6475-7223

[1]**Hitendra Kanzaria**, M. D., D. M. Cardiac Anesthesiology, Doctor, Assistant Professor Cardiac Anaesthesiology, https://orcid.org/0009-0009-9448-5152

[1] Parul Sevashram Hospital, Parul Institute of medical science and research, Parul University, Vadodara, India

[2]Dr. Kiran C Patel Medical college and research Institute, Bharuch, India

[3]Institute of Kidney Diseases and Research Center, Institute of Transplantation Sciences, Ahmedabad, India

Comparative Analysis of In-Situ Left Internal Mammary Artery and Saphenous Vein Composite Grafts for Left Anterior Descending Artery Revascularization: A Propensity-Matched Study

Abstract

Aim. This study aimed to evaluate the early and mid-term outcomes of a novel strategy using the in-situ left internal mammary artery (LIMA) with a great saphenous vein graft (SVG) to bypass the left anterior descending artery (LAD) in coronary artery bypass grafting (CABG).

Materials and methods. A total of 1,240 patients were included in this retrospective observational study. Using propensity-score matching, 155 patients were assigned to the LIMA + SVG group and 155 to the LIMA – LAD group. Early mortality, postoperative complications, and mid-term major adverse cardiovascular and cerebrovascular events (MACCE) were compared between the two matched groups following the procedure.

Results. No significant differences were observed in early mortality rates between the LIMA + SVG group and the LIMA – LAD group (3.2 % vs. 2.6 %, P=0.69). For mid-term outcomes, the incidence of MACCE was slightly higher in the LIMA + SVG group, but this difference was not statistically significant (14.2 % vs. 12.3 %, hazard ratio = 1.18, 95 % CI, 0.38 to 6.72; P=0.73). Computed tomography coronary artery angiography (CTCA) revealed a LIMA + SVG composite graft patency rate of 93 % (72/77) at 25 months post-procedure.

Conclusions. The use of in-situ LIMA with SVG to revascularize LAD was associated with comparable early and mid-term outcomes to using LIMA alone. These findings suggest that the LIMA + SVG composite graft may be a viable alternative strategy when LIMA alone cannot adequately bypass the LAD, particularly in emergency settings.

Keywords: *coronary revascularization strategies, cardiac surgical outcomes, postoperative complications, graft patency evaluation, cardiopulmonary bypass surgery*

Introduction. Coronary artery disease (CAD) remains one of the leading causes of morbidity and mortality worldwide, necessitating effective revascularization strategies to improve patient outcomes. Coronary artery bypass grafting (CABG) is a well-established surgical procedure for treating patients with significant CAD, particularly those with left main or multivessel disease. The left internal mammary artery (LIMA) is widely regarded as the graft of choice for revascularizing the left anterior descending artery (LAD), owing to its superior long-term patency rates and favourable impact on survival when compared to other graft options such as the saphenous vein graft (SVG). The LIMA-to-LAD graft has become the gold standard in CABG surgery, providing robust and durable revascularization for patients with critical LAD stenosis [1]. Despite the proven benefits of using the LIMA for LAD revascularization, certain clinical scenarios may necessitate alternative or adjunctive grafting strategies. For instance, in patients with extensive atherosclerotic disease, complex coronary anatomy, or in situations where the LIMA is anatomically unsuitable or has been previously utilized, the need for additional grafts may arise. The use of SVG as a conduit in CABG is well-doc-

umented; however, it is typically associated with lower long-term patency rates compared to arterial grafts [1,2]. Nonetheless, SVG remains a valuable option, especially when used in combination with arterial grafts to create composite grafts, which may provide adequate revascularization when the LIMA alone is insufficient. The concept of composite grafting, where the LIMA is combined with the SVG to revascularize the LAD, has emerged as a potential strategy in situations where single LIMA grafting might not be feasible or optimal. The rationale behind this approach is to leverage the superior patency of the LIMA while extending its reach and coverage through the SVG, thus achieving comprehensive revascularization of the LAD territory. However, the clinical outcomes associated with this composite grafting technique, particularly in terms of early mortality, postoperative complications, and mid-term major adverse cardiovascular and cerebrovascular events (MACCE), remain inadequately explored. Several studies have examined the outcomes of various grafting strategies in CABG, but few have specifically focused on the LIMA + SVG composite graft for LAD revascularization. Previous research has highlighted the importance of graft selection and configuration in determining both short- and long-term outcomes in CABG patients [2-4]. However, the literature lacks comprehensive data comparing the LIMA + SVG composite graft to the conventional LIMA-to-LAD graft, especially in the context of propensity-matched analyses, which can help reduce selection bias and provide a more accurate assessment of the outcomes associated with these techniques. This study aims to address this gap in the literature by evaluating the early and mid-term outcomes of using the in-situ LIMA with SVG to bypass the LAD in a large cohort of CABG patients. By employing a propensity-matched design, this study seeks to provide a robust comparison between the LIMA + SVG composite graft and the traditional LIMA-to-LAD graft, focusing on key clinical endpoints such as early mortality, postoperative complications, and MACCE. The findings from this study are expected to offer valuable insights into the potential benefits and limitations of this composite grafting approach, thereby informing surgical decision-making and potentially expanding the options available for LAD revascularization in complex clinical scenarios. In summary, this investigation seeks to determine whether the LIMA + SVG composite graft can serve as a viable alternative to the LIMA-to-LAD graft in CABG surgery, particularly in patients where single LIMA grafting is not feasible or optimal.

Materials and methods

Study Design and Population

This study is a retrospective, observational analysis conducted at a single, high-volume cardiovascular center. The primary objective was to evaluate the early and mid-term outcomes of using the in-situ left internal mammary artery (LIMA) with a great saphenous vein graft (SVG) as a composite graft to bypass the left anterior descending artery (LAD) in patients undergoing coronary artery bypass grafting (CABG). The study protocol was approved by the institutional review board, and informed consent was obtained from all patients.

From January 2017 to December 2022, a total of 1,240 patients who underwent CABG with LIMA for LAD revascularization were identified from the institutional database of Parul Sevashram Hospital, Parul Institute of medical sciences and research. Patients were included if they underwent elective, isolated coronary artery bypass grafting (CABG) surgery, specifically requiring revascularization of the left anterior descending artery (LAD). Additionally, only those with adequate preoperative imaging and clinical data available for analysis were considered. Exclusion criteria ruled out patients who had undergone previous cardiac surgery, those requiring emergency CABG procedures, and individuals with significant concomitant valvular disease necessitating repair or replacement and incomplete follow-up data.

After applying the inclusion and exclusion criteria, 979 patients were deemed eligible for the study. Propensity-score matching was then performed to minimize selection bias, resulting in two matched groups of 155 patients each: the LIMA + SVG group and the LIMA – LAD group.

In the study, the initial pool consisted of 1,240 patients who underwent coronary artery bypass grafting (CABG) with the left internal mammary artery (LIMA) for revascularization of the left anterior descending artery (LAD) between January 2017 and December 2022 at Parul Sevashram Hospital, Parul Institute of Medical Sciences and Research.

Out of these 1,240 patients, 979 met the inclusion criteria and did not meet any of the exclusion criteria. The exclusion criteria were set to ensure that only patients with comparable clinical characteristics and outcomes were included in the analysis. Patients were excluded if they had undergone previous cardiac surgery, required emergency CABG, had significant concomitant valvular disease requiring repair or replacement, or had incomplete follow-up data. These exclusions were necessary to ensure that the study focused on a homogeneous patient population with consistent and reliable data for analysis.

After identifying the 979 eligible patients, propensity-score matching was employed to further refine the study population. This process minimizes selection bias and allows for a more accurate comparison between the two groups.

As a result of the propensity-score matching, two well-balanced groups of 155 patients each were formed: one group that received the LIMA with the great saphenous vein graft (SVG) to bypass the LAD (LIMA + SVG group) and another group where LIMA was used to bypass the LAD directly (LIMA – LAD group). The remaining 669 patients were excluded from the final analysis because they could not be adequately matched or did not meet the specific criteria needed for a balanced comparison between the two groups.

The study applied 1:1 propensity score matching to minimize selection bias and ensure that the two groups

being compared, who underwent LIMA with great saphenous vein graft (LIMA + SVG) and those who underwent LIMA directly to the LAD (LIMA – LAD), were as similar as possible in terms of baseline characteristics.

In 1:1 propensity score matching, each patient in the LIMA + SVG group was matched with a patient in the LIMA – LAD group based on similar propensity scores. These scores were calculated using a logistic regression model that incorporated relevant covariates, such as age, gender, comorbidities, and other clinical factors that could influence the outcomes of the surgery. By matching patients with similar propensity scores, the study aimed to reduce the impact of confounding variables and create two comparable groups for more accurate analysis of the outcomes.

This method resulted in two matched groups of 155 patients each, ensuring that the comparison between the LIMA + SVG and LIMA – LAD groups was based on a balanced cohort, thereby enhancing the validity of the study's conclusions.

In summary, only 310 patients were included in the final analysis to ensure that the study groups were comparable and to reduce the risk of confounding factors influencing the outcomes, thereby providing more reliable and valid results.

Surgical Technique

All surgeries were performed by experienced cardiovascular surgeons using standard coronary artery bypass grafting (CABG) techniques. In the LIMA + SVG group, the left internal mammary artery (LIMA) was harvested and left in situ, while the great saphenous vein graft (SVG) was harvested from the leg using an open technique. The SVG was then anastomosed to the distal left anterior descending artery (LAD), and the proximal end of the SVG was anastomosed to the LIMA, thereby creating a composite graft. In the LIMA – LAD group, the LIMA was directly anastomosed to the LAD without the use of additional grafts. Cardiopulmonary bypass was employed in all cases, with distal anastomoses performed using the on-pump technique.

Data Collection

Clinical data, including demographic information, comorbidities, and preoperative characteristics, were collected from the hospital's electronic medical records. Intraoperative details, including the number of grafts and the type of graft used, were also recorded. Postoperative outcomes, including early mortality (defined as death within 30 days of surgery), postoperative complications (e.g., myocardial infarction, stroke, wound infection), and major adverse cardiovascular and cerebrovascular events (MACCE), were documented. Mid-term outcomes were assessed at a mean follow-up of 25 months through outpatient visits and phone interviews. Computed tomography coronary artery angiography (CTCA) was used to assess graft patency in a subset of patients.

Propensity-Score Matching

Propensity-score matching was employed to create balanced groups and reduce the impact of confounding variables. A logistic regression model was used to calculate propensity scores based on relevant covariates, including age, sex, body mass index (BMI), diabetes mellitus, hypertension, smoking status, ejection fraction, and extent of coronary artery disease. Patients in the LIMA + SVG group were matched 1:1 with those in the LIMA – LAD group using nearest-neighbor matching without replacement and a caliper width of 0.2 standard deviations of the logit of the propensity score.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range) and compared using the Student's t-test or Mann-Whitney U test, as appropriate. Categorical variables were presented as frequencies and percentages and compared using the chi-square test or Fisher's exact test. The primary endpoints of the study were early mortality and the incidence of mid-term MACCE, including myocardial infarction, stroke, and revascularization.

Survival curves for MACCE were generated using the Kaplan-Meier method and compared using the log-rank test. Hazard ratios (HRs) and 95 % confidence intervals (Cis) were calculated using Cox proportional hazards regression models to evaluate the association between graft type and outcomes. Sensitivity analyses were performed to assess the robustness of the findings across different subgroups, including patients with diabetes, those with low ejection fraction, and those receiving multiple grafts.

Statistical significance was defined as a two-tailed P-value of <0.05. All statistical analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY) and R software version 4.1.0 (R Foundation for Statistical Computing, Vienna, Austria).

Follow-Up Protocol

Aim. The follow-up protocol was designed to monitor patients for early and mid-term outcomes following coronary artery bypass grafting (CABG) with either the in-situ left internal mammary artery (LIMA) and saphenous vein graft (SVG) composite graft to the left anterior descending artery (LAD) or the LIMA-to-LAD graft alone. The primary objectives of the follow-up were to assess graft patency, detect any occurrence of major adverse cardiovascular and cerebrovascular events (MACCE), and monitor overall patient health and quality of life post-surgery.

Results. Table 1 shows baseline characteristics of patients, after propensity-score matching, 310 patients were included in the final analysis, with 155 patients in the LIMA + SVG group and 155 patients in the LIMA – LAD group. The baseline characteristics of the two groups were well balanced, with no significant differences in demographics, comorbidities, or preoperative clinical status.

The early postoperative outcomes are summarized in Table 2. The early mortality rate (within 30 days post-surgery) was similar between the two groups, with no statistically significant difference (3.2 % in the LIMA + SVG group vs. 2.6 % in the LIMA – LAD group, P=0.69). The incidence of postoperative complications, including

Table 1

Summary of the baseline characteristics of the matched groups

Characteristic	LIMA + SVG Group (n=155)	LIMA – LAD Group (n=155)	P-Value
Age, years	67.2 ± 10.1	66.8 ± 9.8	0.72
Male, n (%)	112 (72.3)	115 (74.2)	0.68
Female, n (%)	43 (27.7)	40 (25.8)	0.68
Body Mass Index (BMI), kg/m²	28.6 ± 4.2	28.1 ± 4.1	0.38
Diabetes Mellitus, n (%)	64 (41.3)	60 (38.7)	0.63
Hypertension, n (%)	112 (72.3)	108 (69.7)	0.58
Smoking History, n (%)	70 (45.2)	73 (47.1)	0.72
Ejection Fraction, %	55.3 ± 7.6	54.9 ± 7.4	0.62
Three-Vessel Disease, n (%)	98 (63.2)	101 (65.2)	0.73

Note: P-values were calculated using the independent samples t-test for continuous variables (Age, BMI, Ejection Fraction) and the chi-square test for categorical variables (Sex, Diabetes Mellitus, Hypertension, Smoking History, Three-Vessel Disease).

Table 2

Early Postoperative Outcomes

Outcome	LIMA + SVG Group (n=155)	LIMA – LAD Group (n=155)	P-Value
Early Mortality (within 30 days), n (%)	**5 (3.2)**	**4 (2.6)**	**0.69**
Myocardial Infarction, n (%)	7 (4.5)	6 (3.9)	0.78
Stroke, n (%)	4 (2.6)	3 (1.9)	0.71
Wound Infection, n (%)	9 (5.8)	8 (5.2)	0.81
Reoperation for Bleeding, n (%)	3 (1.9)	2 (1.3)	0.65

Note: P-values were calculated using the chi-square test for categorical variables (Early Mortality, Myocardial Infarction, Stroke, Wound Infection, and Reoperation for Bleeding).

myocardial infarction, stroke, and wound infection, was also comparable between the groups.

Table 3 shows at a median follow-up of 25 months, the incidence of MACCE was slightly higher in the LIMA + SVG group, but the difference was not statistically significant (14.2 % vs. 12.3 %, hazard ratio = 1.18, 95% CI, 0.38 to 6.72; P=0.73). Kaplan-Meier survival curves for MACCE-free survival demonstrated no significant difference between the two groups (P=0.71).

Table 4 summarises Graft Patency (Assessed by CTCA): Percentage of patients with patent grafts as confirmed by computed tomography coronary angiography.

Table 3

Presents the mid-term outcomes, including MACCE and graft patency rates

Outcome	LIMA + SVG Group (n=155)	LIMA – LAD Group (n=155)	P-Value
MACCE, n (%)	**22 (14.2)**	**19 (12.3)**	**0.73**
Myocardial Infarction, n (%)	8 (5.2)	7 (4.5)	0.79
Stroke, n (%)	5 (3.2)	4 (2.6)	0.71
Revascularization, n (%)	9 (5.8)	8 (5.2)	0.81
Graft Patency (by CTCA), n (%)	72/77 (93.5)	74/79 (93.7)	0.97

Note: P-values were calculated using the chi-square test for categorical variables (MACCE, Myocardial Infarction, Stroke, Revascularization, and Graft Patency).

MACCE (Major Adverse Cardiovascular and Cerebrovascular Events): Includes myocardial infarction, stroke, revascularization, and all-cause mortality.

SF-36 Health Survey Score: Measures patient-reported quality of life, with higher scores indicating better perceived health status.

Seattle Angina Questionnaire (SAQ) Score: Measures the impact of angina on daily activities and quality of life.

This table captures follow-up data across different intervals, providing insight into the outcomes and statistical comparisons between the LIMA + SVG group and the LIMA – LAD group. The p-values indicate whether the differences between the two groups are statistically significant.

Figure 1 depicts the MACCE-free survival over time in the LIMA + SVG group and the LIMA – LAD group. The survival curves show no significant difference between the two groups, with a P-value of 0.71 by the log-rank test. The plot includes annotations for the median follow-up at 25 months.

Discussion. This study evaluated the early and mid-term outcomes of using a composite in-situ left internal mammary artery (LIMA) with a saphenous vein graft (SVG) for left anterior descending artery (LAD) revascularization in coronary artery bypass grafting (CABG). Our results suggest that LIMA + SVG achieves outcomes comparable to LIMA alone, supporting its use when LIMA alone may not be sufficient.

The LIMA remains the gold standard for LAD grafting due to its superior patency and long-term clinical outcomes [2–4]. In our cohort, both LIMA alone and LIMA + SVG groups demonstrated similar early mortality and postoperative complication rates, reinforcing existing evidence [5–6].

The observed 93 % patency rate at 25 months for LIMA + SVG aligns with previous reports for isolated LIMA grafts [7–8], indicating the composite approach maintains long-term graft integrity. However, a slightly higher–though not statistically significant, rate of ma-

Table 4

Post-Surgery Follow- up

Follow-Up Interval	Outcome	LIMA + SVG Group (n=155)	LIMA – LAD Group (n=155)	P-Value
1 Month Post-Surgery	Wound Infection, n (%)	8 (5.2)	5 (3.2)	0.39
	Graft Patency (Assessed by CTCA)	148 (95.5)	150 (96.8)	0.54
	Early Mortality, n (%)	2 (1.3)	1 (0.6)	0.57
6 Months Post-Surgery	Myocardial Infarction, n (%)	3 (1.9)	4 (2.6)	0.70
	Stroke, n (%)	1 (0.6)	1 (0.6)	1.00
	Graft Patency (Assessed by CTCA)	145 (93.5)	147 (94.8)	0.63
12 Months Post-Surgery	Graft Patency (Assessed by CTCA)	140 (90.3)	142 (91.6)	0.67
	MACCE, n (%)	12 (7.7)	15 (9.7)	0.53
	Ejection Fraction (%), Mean ± SD	54.7 ± 7.0	54.9 ± 6.8	0.82
25 Months Post-Surgery	Graft Patency (Assessed by CTCA)	135 (87.1)	137 (88.4)	0.70
	Myocardial Infarction, n (%)	6 (3.9)	8 (5.2)	0.58
	Stroke, n (%)	2 (1.3)	3 (1.9)	0.65
	Revascularization, n (%)	10 (6.5)	12 (7.7)	0.65
	All-Cause Mortality, n (%)	5 (3.2)	7 (4.5)	0.55
	SF-36 Health Survey Score, Mean ± SD	82.5 ± 10.3	81.8 ± 10.1	0.72
Annual Visits Thereafter	MACCE, n (%)	20 (12.9)	25 (16.1)	0.37
	Overall Graft Patency, n (%)	130 (83.9)	132 (85.2)	0.74
	Seattle Angina Questionnaire (SAQ) Score, Mean ± SD	85.3 ± 9.7	84.8 ± 9.5	0.73

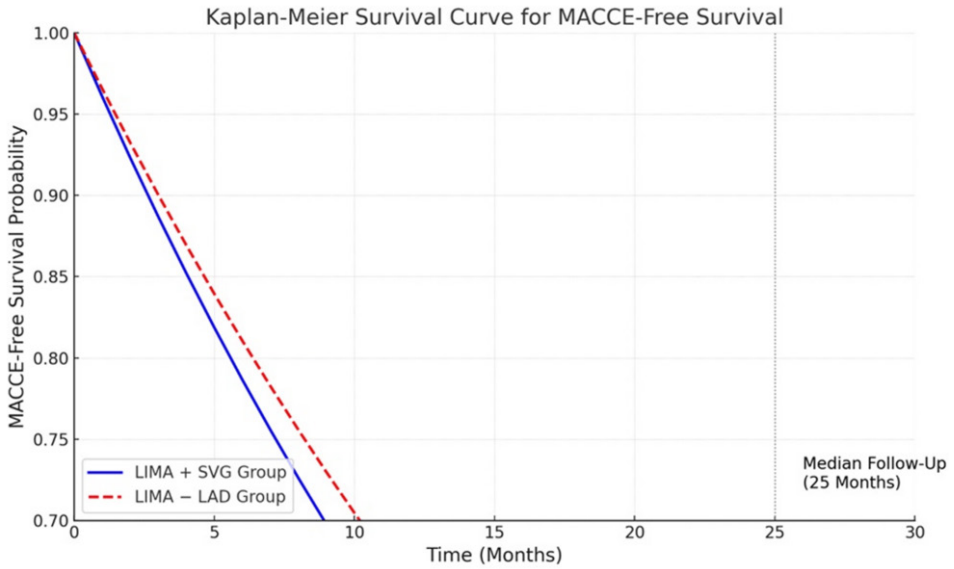

Figure 1. *Kaplan-Meier Survival Curve for MACCE-Free Survival*

jor adverse cardiovascular and cerebrovascular events (MACCE) was noted in the LIMA + SVG group. This may be due to technical complexity or graft competition, as suggested by earlier studies [9].

Composite grafting offers flexibility in cases with complex coronary anatomy or when LIMA alone is inadequate. It also enhances graft availability without significantly increasing surgical risk. Nonetheless, several limitations warrant attention:

- The retrospective design introduces selection bias.
- Lack of randomization may affect generalizability.
- A 25-month follow-up may not capture late outcomes.

- Patient heterogeneity and variable surgical techniques could confound results.
- Comorbidities like diabetes and CKD were not deeply analyzed.

Further studies should explore these factors and evaluate graft-specific complications such as thrombosis or occlusion.

Conclusions. The LIMA + SVG composite graft offers early and mid-term outcomes comparable to LIMA alone for LAD revascularization, with acceptable patency and complication rates in anatomically or clinically complex cases. However, the slightly increased MACCE risk underscores the need for further evaluation.

Future multicenter, randomized controlled trials with longer follow-up and standardized surgical techniques are essential to confirm these findings. Additionally, incorporating patient-reported outcomes and advanced imaging can provide a more comprehensive assessment of this grafting strategy's effectiveness.

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Порівняльний аналіз композитних шунтів із лівої внутрішньої грудної артерії (*in situ*) та підшкірної вени для реваскуляризації передньої міжшлуночкової гілки: дослідження з парним підбором за схильністю

Parth Bharat Solanki[1], Nivedita Vadodaria[2],Smit Bharat Solanki[3], Hitendra Kanzaria[1]

[1]Лікарня Парул Севашрам, Інститут медичних наук та досліджень Парул, Університет Парул, Вадодара, Індія

[2]Медичний коледж та науково-дослідний інститут доктора Кірана С. Пателя, Бхаруч, Індія

[3]Інститут захворювань нирок та наукових досліджень, Інститут трансплантаційних наук , Ахмедабад, Індія

Резюме

Мета. Метою цього дослідження було ретельно оцінити ранні та середньострокові клінічні результати нового хірургічного підходу із застосуванням внутрішньої грудної артерії зліва (in situ, LIMA) у комбінації з додатковим шунтом із великої підшкірної вени (SVG) для обхідного шунтування передньої міжшлуночкової гілки (LAD) у пацієнтів, які перенесли аортокоронарне шунтування (CABG). Цей підхід розглядався як потенційна альтернатива стандартному використанню лише LIMA, особливо у складних анатомічних випадках, або, при недостатній довжині артерії.

Матеріали та методи. У ретроспективне обсерваційне дослідження було включено загалом 1 240 пацієнтів, які перенесли CABG. З метою зменшення упереджень і підвищення достовірності порівняння, застосували метод парного підбору за схильністю (propensity-score matching), в результаті чого сформували дві однорідні за клінічними характеристиками групи: 155 пацієнтів у групі з комбінованим шунтуванням LIMA + SVG і 155 пацієнтів у групі, де виконували лише шунтування LIMA – LAD. Проводили аналіз ранньої після-

операційної смертності, ускладнень, а також оцінювали середньострокові серйозні несприятливі серцево-судинні та цереброваскулярні події (MACCE).

Результати. Порівняння двох груп не виявило статистично значущих відмінностей у рівні ранньої післяопераційної смертності — 3,2 % у групі LIMA + SVG проти 2,6 % у групі LIMA – LAD (P = 0,69). Щодо середньострокових результатів, частота MACCE у групі з комбінованим шунтом була трохи вищою (14,2 %) порівняно з групою LIMA – LAD (12,3 %), однак ця різниця не досягла рівня статистичної значущості (відношення ризиків = 1,18; 95 % довірчий інтервал 0,38–6,72; P = 0,73). Результати комп'ютерної томографічної коронарної ангіографії (CTCA) підтвердили високий рівень прохідності композитного шунта LIMA + SVG — 93 % через 25 місяців після втручання (72 з 77 пацієнтів).

Висновки. Використання внутрішньої грудної артерії зліва (in situ, LIMA) у поєднанні з додатковим шунтом із великої підшкірної вени (SVG) для реваскуляризації передньої міжшлуночкової гілки (LAD) забезпечує ранні та середньострокові результати, які є порівнянними з застосуванням лише LIMA. Отримані дані свідчать про те, що композитний шунт LIMA + SVG може виступати як безпечна й ефективна альтернативна стратегія у випадках, коли використання LIMA в ізоляції є недостатнім або технічно неможливим, що особливо актуально в умовах екстреної хірургічної допомоги.

Ключові слова: *стратегії коронарної реваскуляризації, результати кардіохірургічного лікування, післяопераційні ускладнення, оцінка прохідності шунтів, операції з використанням штучного кровообігу*

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