Systematic Review / Meta-analysis

ANNALS OF MEDICINE & SURGERY

OPEN

Percutaneous coronary intervention versus coronary artery bypass grafting among patients with left ventricular systolic dysfunction: a systematic review and meta-analysis

Vikash Jaiswal, MD[a,g], Song Peng Ang, MD[c], Abhigan Babu Shrestha, MBBS[j,*], Amey Joshi, MBBS[g], Angela Ishak, MD[g], Jia Ee Chia, MBBS[g,k], Sanchita Suresh Kanakannavr, MBBS[g], Sidra Naz, MD[f], Neel Doshi, MBBS[b], Dhairya Nanavaty, MD[i], Asmita Gera, MBBS[g], Vikash Kumar, MD[i], Farshid Daneshvar, MD[h], David Song, DO[d], Kripa Rajak, MD[e]

Background: Current guidelines have shown the superiority of coronary artery bypass grafting (CABG) over medical therapy. However, there is a paucity of data evaluating the optimal revascularization strategy in patients with ischemic left ventricular systolic dysfunction (LVSD).

Objective: The authors aimed to evaluate the clinical outcomes of postpercutaneous coronary intervention (PCI) and CABG among patients with LVSD.

Methods: The authors performed a systematic literature search using the PubMed, Embase, Scopus, and the Cochrane Libraries for relevant articles from inception until 30 November 2022. Outcomes were reported as pooled odds ratio (OR), and their corresponding 95% CI using STATA (version 17.0, StataCorp).

Results: A total of 10 studies with 13 324 patients were included in the analysis. The mean age of patients in PCI was 65.3 years, and 64.1 years in the CABG group. The most common comorbidities included: HTN (80 vs. 78%) and DM (49.2 vs. 49%). The mean follow-up duration was 3.75 years. Compared with CABG, the PCI group had higher odds of all-cause mortality (OR 1.15, 95% CI 1.01–1.31, $P=0.03$), repeat revascularization (OR 3.57, 95% CI 2.56–4.97, $P<0.001$), MI (OR 1.92, 95% CI 1.01–3.86, $P=0.048$) while the incidence of cardiovascular mortality (OR 1.23, 95% CI 0.98–1.55, $P=0.07$), stroke (OR 0.73 95% CI: 0.51–1.04, $P=0.08$), major adverse cardiovascular and cerebrovascular events (OR 1.36, 95% CI 0.99–1.87, $P=0.06$), and ventricular tachycardia (OR 0.79, 95% CI 0.22–2.86, $P=0.72$) was comparable between both the procedures.

Conclusion: The results of this meta-analysis suggest that CABG is superior to PCI for patients with LVSD. CABG was associated with a lower risk of all-cause mortality, repeat revascularization, and incidence of myocardial infarction compared with PCI in patients with LVSD.

Keywords: acute coronary syndrome, cardiomyopathy, coronary artery bypass grafting, ischemia, percutaneous coronary interventions, revascularization

[a]JCCR Cardiology Research, Varanasi, [b]Pravara Institute of Medical Science, Maharashtra, India, [c]Division of Internal Medicine, Rutgers Health/Community Medical Center, New Jersey, [d]Department of Internal Medicine, Icahn School of Medicine at Mount Sinai Elmhurst Hospital Center, Queens New York, [e]Department of Internal Medicine, UPMC Harrisburg, Pennsylvania, [f]The University of Texas, MD Anderson Cancer Center, Huston, Texas, [g]Department of Research, Larkin Community Hospital, South Miami, [h]Department of Cardiology, AdventHealth, Florida, [i]The Brooklyn Hospital Center, Brooklyn, USA, [j]Department of Medicine, M Abdur Rahim Medical College, Dinajpur, Bangladesh and [k]Department of Medicine, International medical university, Kuala Lumpur, Malaysia

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

**Corresponding author. Address: Department of Research, Larkin Community Hospital, South Miami, Fl 33143, USA. E-mail: vikash29jaxy@gmail.com (V. Jaiswal).*

Annals of Medicine & Surgery (2023) 85:2849–2857

Received 13 January 2023; Accepted 31 March 2023

Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.annalsjournal.com.

Published online 17 April 2023

http://dx.doi.org/10.1097/MS9.0000000000000634

Introduction

The worldwide prevalence and impact of ischemic heart disease on heart failure is evolving as a result of an aging population, increasingly effective treatment of acute coronary syndrome, and consequently, less extensive myocardial fibrosis[1]. Previously, coronary artery bypass graft (CABG), percutaneous coronary intervention (PCI), and medical management were the primary revascularization strategies in patients with ischemic left ventricular systolic dysfunction (LVSD). The STITCH (Surgical Treatment for Ischemic Heart Failure) trial demonstrated a 10-year survival benefit of CABG over medical management alone in these patients[2]. However, there was insufficient evidence to support PCI over CABG. Furthermore, earlier PCI trials in LVSD employed bare metal stents compared to the modern drug-eluting stents[3,4]. Thus, optimal revascularization strategies for patients with LVSD are primarily based on randomized data comparing CABG to medical therapy[5–10].

The 2018 European Society of Cardiology gives a class I recommendation for CABG and IIa for PCI patients with LVSD[11]. The 2021 guidelines from the American College of Cardiology/ American Heart Association/SCAI give a class I recommendation for CABG in patients with LVSD with an ejection fraction (EF) less than 35% and a class IIa recommendation for an EF 35–50%, but with no provision for PCI[12]. Although some recent studies have shown worse survival outcomes with PCI than with CABG, the data has been inconsistent, and further clarity regarding optimal management strategies is required[3,13–27]. This study aimed to perform a meta-analysis to compare the long-term outcomes of PCI and CABG among patients with ischemic LVSD and compare all-cause mortality (ACM) and the incidence of repeat revascularization and myocardial infarction (MI).

HIGHLIGHTS

- There is a paucity of data and trials evaluating the optimal revascularization strategy in patients with ischemic left ventricular systolic dysfunction (LVSD).
- Our study shows coronary artery bypass grafting was associated with a lower risk of all-cause mortality, repeat revascularization, and incidence of myocardial infarction compared with postpercutaneous coronary intervention in patients with LVSD.
- Further studies are warranted among LVSD patients to stratify the optimal revascularization procedure across different aspects of race, sex, pathology, and ejection fraction.

Methods

This study was reported in compliance with the Preferred Reporting Items for Systematic Review and Meta-analysis 2020 (PRISMA) Guidelines[28], Supplemental Digital Content 1, http://links.lww.com/MS9/A67, and performed according to established methods[29,30].

Outcome variables

The primary outcome of interest was ACM. The secondary outcomes of interest were 30-day mortality, major adverse cardiovascular and cerebrovascular (MACCE), stroke, MI, repeat revascularization, cardiovascular mortality, and ventricular tachycardia.

Search strategy

Search strategy

We conducted a systematic search in PubMed, Embase, Scopus, and Cochrane Central for articles from their inception until 30 November 2022, using the following keywords and MeSH terms: 'Percutaneous Coronary Interventions', 'Coronary Artery Bypass Grafting', 'Revascularization', 'ischemic cardiomyopathy', 'Coronary intervention', 'Left ventricular systolic dysfunction'. MeSH terms were used where appropriate. A detailed search strategy has been uploaded in Supplementary Table 1, Supplemental Digital Content 3, http://links.lww.com/MS9/A69. Two authors (V.J. and A.I.) reviewed the abstract and title of the articles for eligibility. The senior author resolved any inclusion-related discrepancy.

Eligibility criteria and study selection

The studies were eligible to be included in our meta-analysis if the study population were age greater than 18, studies with reduced/ low left ventricular EF, studies such as randomized controlled trials, prospective and retrospective studies with a follow-up duration of a minimum of one year, and presence of cardiovascular event data showing the comparison of LVSD-PCI and LVSD-CABG. To decrease the risk of bias inherent in including observational studies, propensity score matching outcomes were included based on given availability. We excluded literature or systematic reviews, letters, studies with a single arm, animal studies, and studies with patients less than 18 years of age were excluded.

Data extraction and statistical analysis

Data from the eligible studies, such as demographic, study design, comorbidity, follow-up, and outcomes between LVSD-PCI and LVSD-CABG group patients, were extracted to an Excel® 2019 spreadsheet by two authors (V.J and S.K).

Baseline continuous variables were summarized in the mean (SD), whereas dichotomous variables were described in frequency or percentage. We performed a conventional meta-analysis for primary and secondary outcomes and adopted the DerSimonian and Laird random-effect model for the study variations[31]. Outcomes were reported as pooled odds ratio (OR), standard mean difference, and their corresponding 95% CI. Statistical significance was met if the 95% CI did not cross the numeric '1' and the two-tailed P-value was less than 0.05. We considered a two-tailed P-value of less than 0.05 to be statistically significant. In addition, we assessed the between-study heterogeneity using the Higgins I-square (I^2) test, with I^2 values less than 75% considered mild-moderate and greater than 75% considered high[32]. For heterogeneity I^2 greater than 75%, a leave-one-out was utilized to explore the cause of heterogeneity. Sensitivity analysis was performed using leave-one-out meta-analysis. All statistical work, inclusive analysis, and graphical illustrations were conducted using STATA (version 17.0, StataCorp).

Table 1

Baseline characteristic of included studies arranged in form of (PCI/CABG)

References	Sample (*n*) PCI/CABG	Study Design	Age, years	Male, %	Diabetes	HTN, %	HLD, %	Previous MI, %	Type of stent	LVEF%	Follow-up, Years
Bangalore *et al.*,[27]	1063\1063	Registry, Multicenter	66.1\65.6	804\799	450/469			63.78/64.25	EES	< 35	2.9
Buszman *et al.*,[26]	55/54	Prospective	60.1/60.9	44/43	15/12	64/59	64/67			< 35	1
Iribarne *et al.*,[21]	718/955	Retrospective	65.4/65.8	531/709	315/415			56.7/57.4	DES = 501	< 35	4.3
Jiang *et al.*[3]	142/201	Prospective	59.8/60.5	112//176	71/87	55.6/58.7	50/44.3	47.2/69.7	DES, BM	< = 40	6.2
Kang *et al.*[20]	469/442	Registry, multicenter	66.9/63.6		235/238	60.8/55.7	30.9/46.9	16.6/20.6	DES	< 35	5
Marui *et al.*[18]	464/444	Retrospective	70.1/67.8	354/347	264/249	89/85		44/45	DES, BMS	< = 50	4.74
Sun *et al.*[15]	2397/2397	Retrospective	66.5/66	1905/1920	1256/1244	84.9/84.2			DES, BMS	< 35	5.2
Toda *et al.*[14]	48/69	Retrospective	67/62	34/50	20/31			23/23		< 35	3.7
Hannan *et al.*[23]	1059/1614	Retrospective	–	–	–	–	–	–	DES	< / = 40	1.5
Yang *et al.*[13]	141/141	Retrospective	66/65	101/111	78/78	86/82	39/40	53/47	DES	< 35	3

Quality assessment

One author (A.I.) independently assessed the quality of the included studies using the Newcastle–Ottawa Scale for cohort studies[33]. The details of the quality assessment are presented in Supplementary Table 2, Supplemental Digital Content 3, http://links.lww.com/MS9/A69.

Results

Our initial comprehensive search identified a total of 2135 articles. After excluding duplicates (1420), 674 studies were further excluded after reviewing the title and abstract, and 41 studies were reviewed in full-text form. However, 31 studies were further excluded based on inclusion criteria. A total of 10 studies qualified for quantitative analysis, where two studies were prospective[3,26], and eight were retrospective[13–15,18,20,21,23,27].

A total of 13 324 patients in 10 studies were included in our analysis: 6245 (47%) in the PCI and 7074 (53%) in the CABG group. The mean follow-up duration was 3.5 years. The mean age was 65.3 years for the PCI group and 64.1 years for the CABG group. Patients were predominantly male (56 vs. 54%) for PCI and CABG, respectively. The most common comorbidity was hypertension (40 vs. 35%) and diabetes mellitus (39 vs. 36%) in PCI and CABG. The study characteristics, demographics, and comorbidities are presented in Table 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram is depicted in Figure 1. The quality assessment of the observational studies was a low risk of bias on NOS for all observational studies. (Supplementary Table 2, Supplemental Digital Content 3, http://links.lww.com/MS9/A69).

Meta-analysis of clinical outcomes

At a mean follow-up of 3.75 years, the PCI group had higher odds of ACM (OR 1.15, 95% CI 1.01–1.31, $P = 0.03$, $I^2 = 19.16\%$), repeat revascularization (OR 3.57, 95% CI 2.56–4.97, $P < 0.001$, $I^2 = 82.12\%$), and MI (OR 1.92, 95% CI 1.01–3.86, $P = 0.048$, $I^2 = 87.3\%$) compared to CABG (Fig. 2A–C). In contrast, the likelihood of cardiovascular mortality (OR 1.23 95% CI 0.98–1.55, $P = 0.07$, $I^2 = 32.09\%$), stroke (OR 0.73 95% CI 0.51–1.04, $P = 0.08$, $I^2 = 47.7\%$) (Fig. 3A, B), MACCE (OR 1.36, 95% CI 0.99–1.87, $P = 0.06$, $I^2 = 0\%$), and ventricular tachycardia (OR 0.79, 95% CI 0.22–2.86, $P = 0.72$, $I^2 = 0\%$) was comparable between both the procedures (Fig. 4A, B).

Sensitivity analysis and publication bias

Sensitivity analysis was carried out for outcomes reported by more than 5 studies with a high overall between-study heterogeneity, which includes MI and repeat revascularization. For MI, sensitivity analysis through the leave-one-out method showed that results were nonsignificant between PCI and CABG, except after the removal of the study by Kang *et al.*[20] and Buszman *et al.*[26] (Supplementary Figure 1, Supplemental Digital Content 3, http://links.lww.com/MS9/A69). Of note, after the removal of the study by Kang *et al.*[20], it was observed that patients with PCI had a significantly higher risk of MI compared to that of CABG (OR 2.57, 95% CI 2.18–3.54, $P < 0.001$) with a substantial reduction in the heterogeneity from 87 to 0% (Supplementary Figure 2, Supplemental Digital Content 3, http://

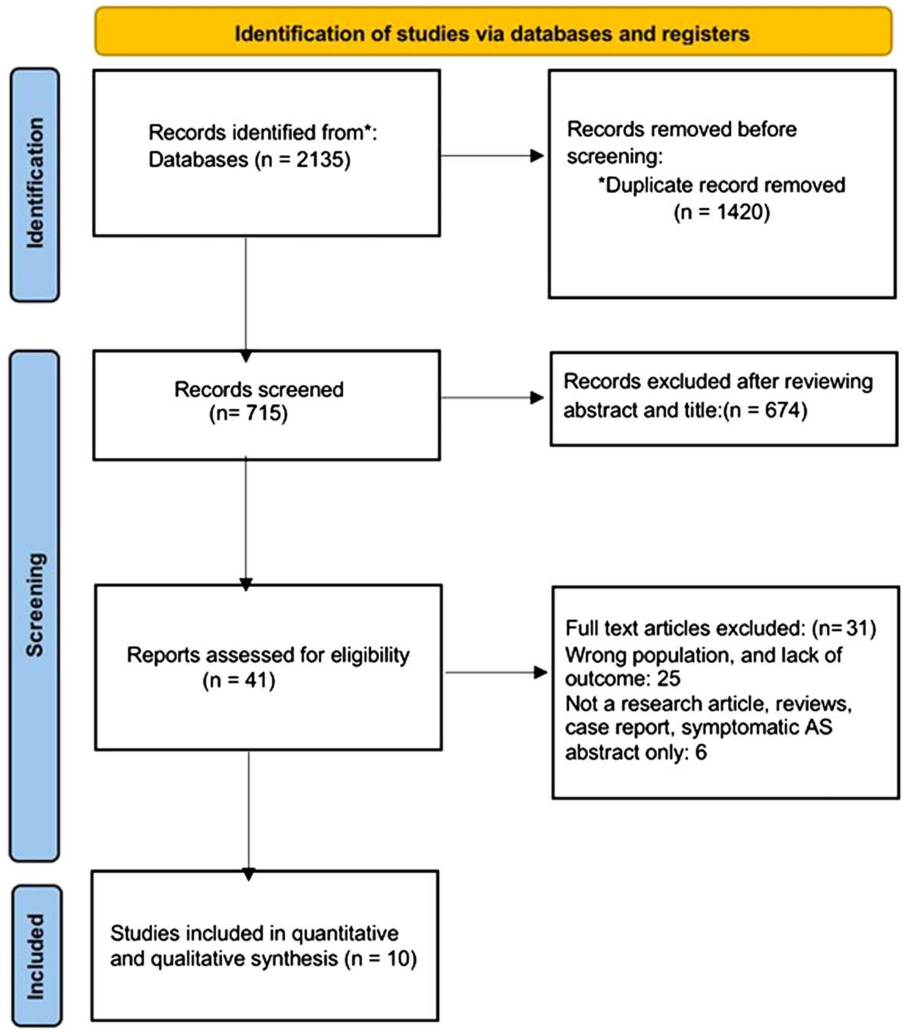

Figure 1. Preferred Reporting items for Systematic review and Meta-analysis flow of the search strategy for systematic review and meta-analysis.

links.lww.com/MS9/A69). The results of repeat revascularization remained unaltered in terms of magnitude and direction, suggesting the robustness of primary analysis (Supplementary Figure 3, Supplemental Digital Content 3, http://links.lww.com/MS9/A69). The likely cause of heterogeneity in the studies mentioned above was selection bias.

An assessment of publication bias was performed for the primary outcome of the ACM. Visualization of funnel plots showed that there was no funnel plot asymmetry, indicating there was no evidence of publication bias for primary outcomes (ACM) (Supplementary Figure 4, Supplemental Digital Content 3, http://links.lww.com/MS9/A69).

Discussion

This is the most updated and comprehensive systematic review and meta-analysis entailing the superiority of CABG over PCI with LVS dysfunction, showing higher odds of ACM, repeat revascularization, and risk of MI in the PCI group than compared to the CABG group. On the other hand, stroke, MACCE, ventricular tachycardia, and cardiovascular mortality were comparable between both procedures.

Although there is a plethora of data on patients with CAD and LVSD, current guidelines favor CABG over PCI. The STICH trial has paramount the beneficial effect of CABG in patients with LVEF less than 35%[2]. Similarly, European Society of Cardiology guidelines provide class I recommendations in patients with LVEF less than 35%, level of evidence B for left anterior descending disease or multivessel disease, and level of evidence C for left main or equivalent disease[11]. Similarly, the American College of Cardiology Foundation/ American Heart Association guidelines points to a reasonable improvement in survival with CABG in patients with LVEF 35–50% and proximal left anterior descending stenosis or multivessel disease (IIa, B) or those with significant CAD and LVEF less than 35% (IIa, B)[12]. However, the FREEDOM (Future Revascularization Evaluation in Patients with Diabetes mellitus; Optimal Management of Multivessel Disease)[34] showed no difference in mortality between PCI and CABG in patients with LVEF less than 40%; similar results were demonstrated in other trials like

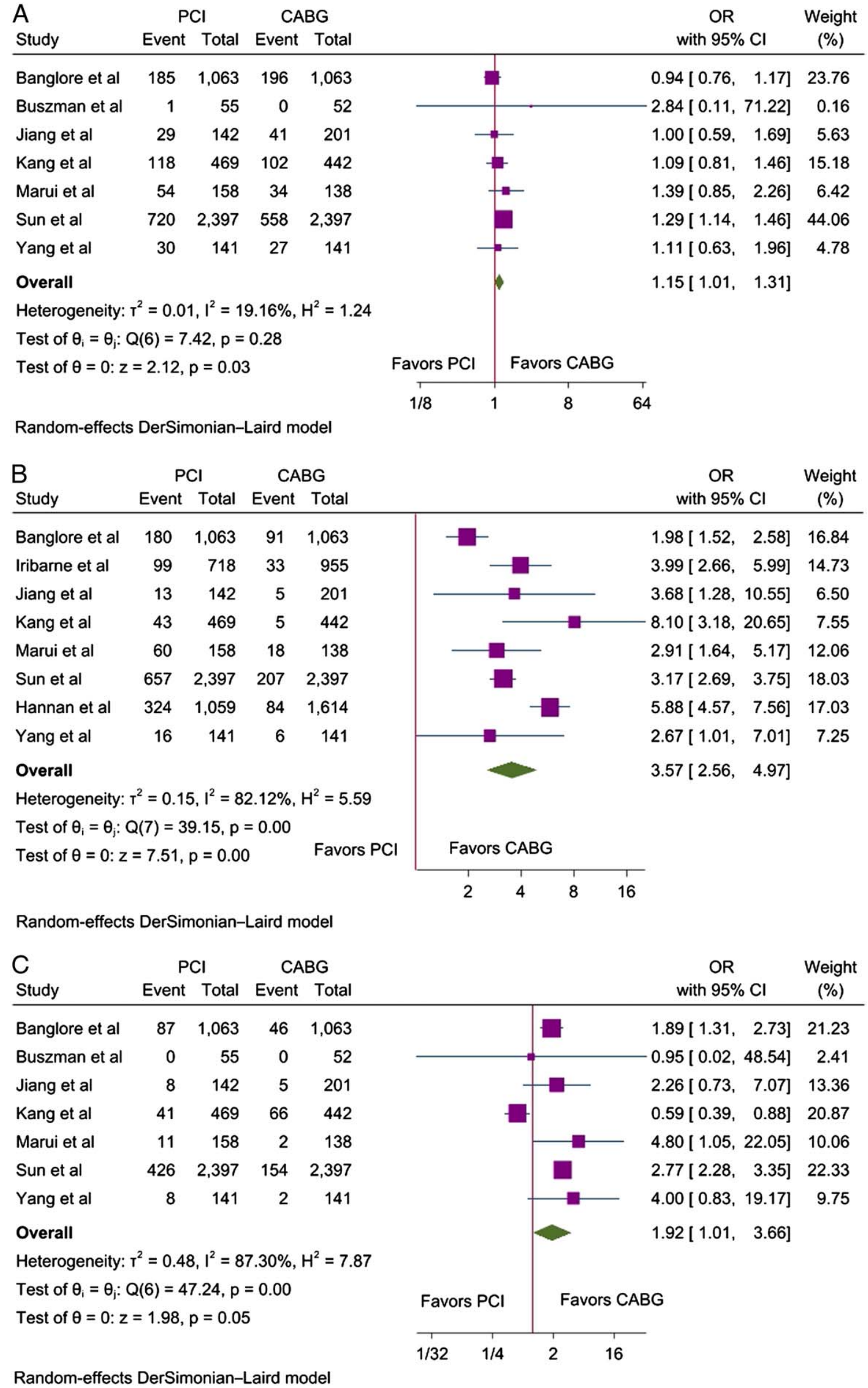

Figure 2. Forest plots of outcomes: (A) All-cause mortality, (B) Repeat revascularization, (C) Myocardial Infarction. CABG, coronary artery bypass grafting; PCI, postpercutaneous coronary intervention.

SYNTAX (Synergy Between PCI with Taxus and Cardiac Surgery) and the AWESOME trails[35,36].

The dual function of CABG can explain the superiority of CABG over PCI in LVSD. It helps in revascularization and, along with it, improves left ventricular function (LVF) postoperatively. Revascularization by CABG and PCI increased LVF by 15 and 5%, respectively, after one year[37]. However, the previous PCI followed by CABG is an independent predictor of mortality[38]. Although PCI can restore LVF, its magnitude is comparatively lower[39]. With ameliorated LVEF, patients are less likely to endure complications due to heart failure and benefit from improved physical fitness levels[16]. CABG bypasses a larger

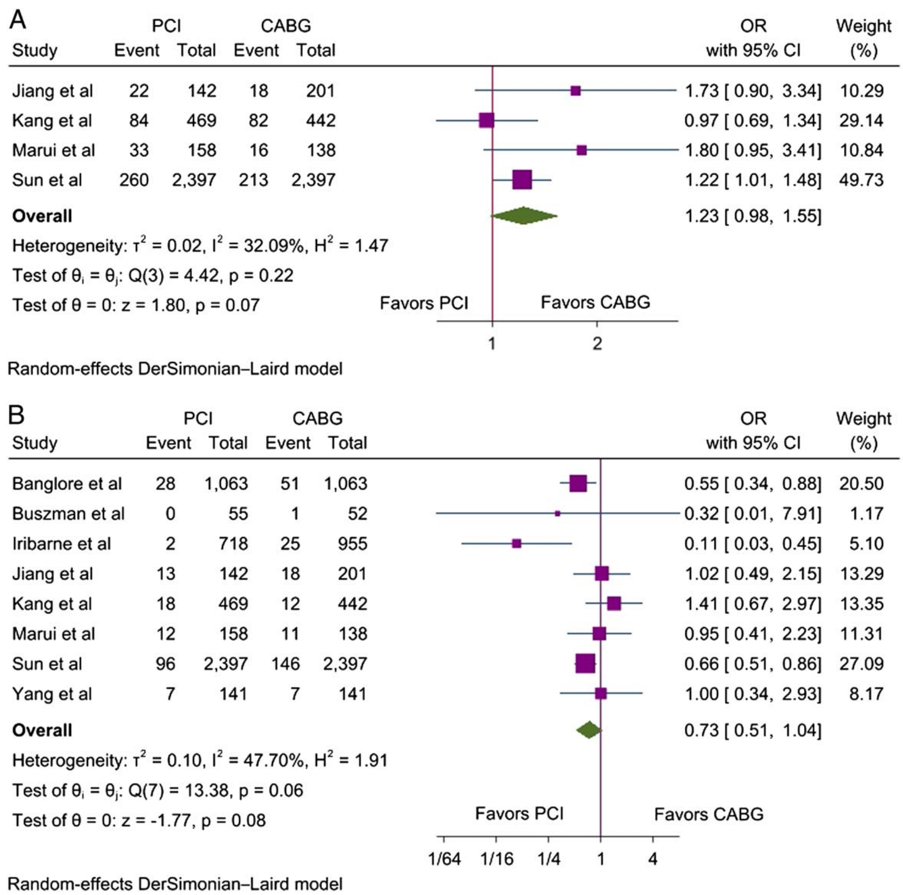

Figure 3. Forest plot of outcomes: (A) Cardiovascular mortality, (B) Stroke. CABG, coronary artery bypass grafting; PCI, postpercutaneous coronary intervention.

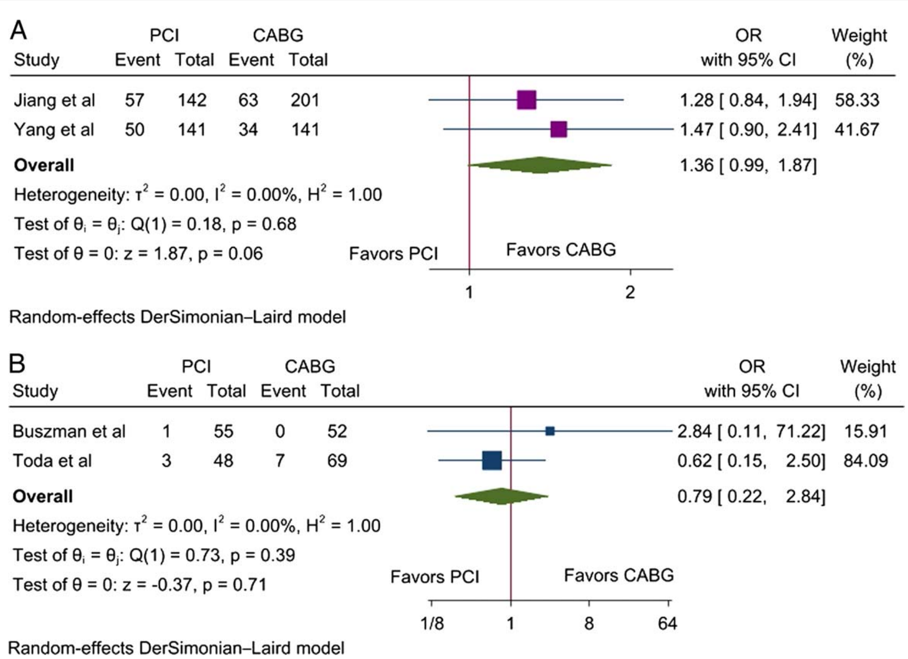

Figure 4. Forest plots of outcomes: (A) MACCE, (B) Ventricular Tachycardia. CABG, coronary artery bypass grafting; PCI, postpercutaneous coronary intervention.

extent of obstructive lesions, thus minimizing the effect of progressive disease in the proximal vessel. Using internal mammary arteries can maintain the long-term patency of the channels, providing better protection. In contrast, PCI checks short segments of severe stenosis that progressive plaque can form new significant lesions and even rupture. Patients with low LVEF will be less tolerant of repeated myocardial insult from restenosis or thrombosis than those without LVD. Hence, patients with viable tissue and LVF would benefit from CABG to restore ventricular dysfunction and prevent further ischemic damage.

The SYNTAX trial showed that compared to CABG, PCI required repeated revascularization[35]. Patients in the PCI arm undergoing repeated revascularization had a greater risk of the composite outcome of death, stroke, and MI than compared to patients not undergoing repeated revascularization. On the other hand, there was no difference noted in the CABG arm. In terms of repeat revascularization, the difference between PCI and CABG arms might be dynamic due to changing practice and availability. With the advancement of technology, the guidance of intravascular ultrasonography and second-generation drug-eluting stents have declined the revascularization rates[40,41]. Similarly, the development of arterial grafts compared to venous grafts for CABG has been associated with reduced repeat revascularization[42]. Our analysis, however, should have considered this factor in account, hence, the relatively older studies may not be accurately justified in context to the current practices.

Similarly, a recent meta-analysis by Galo *et al.*[43] showed a significantly increased risk for MI in the PCI arm compared to the CABG arm for left main coronary artery disease. In CABG, a graft is inserted beyond the lesion, prompting complete revascularization compared to stenting in PCI. Thereby allowing CABG to play the protagonist by preventing future ischemic changes arising from the culprit lesions at proximal segments, consequently declining the probability of MI[44]. Despite new advances in PCI therapeutic modality, it still needs to overcome the benefit of CABG compared to its methodology. Moreover, the significant risk reduction of MI with CABG over time makes it more favorable, especially considering high-risk patients. As MI is associated with periprocedural PCI, it is recommended to measure pre and postcardiac troponin levels. Such an event is a strong independent predictor for 1-year post-PCI ACM[45]. CABG is superior when compared to PCI for patients with LVSD.

Recommendation for future research

Further large multicenter trials are needed among patients with LVSD to stratify the appropriate revascularization strategies and superiority over one another. Baseline EF, and biomarkers roles must be evaluated for predictors of worse outcomes. Along with that, racial and sex-based analysis are needed to understand the role of both in the outcomes of both procedures.

Clinical implications for health managers and policymakers

In consistant with our findings, CABG must be favored over PCI for LVSD patients. However, factors including the cost-benefit ratio, the CABG operating centers and skilled surgeon, and contraindications for CABG must be kept in mind before making a decision.

Limitations

All studies included in our meta-analysis were observational, and the possibility of selection and confounding bias could not be ruled out. In addition, access to the patient's data could have been more feasible, including data regarding adherence to medical therapy, interventional method, incomplete versus complete revascularization, disease complexity, and SYNTAX scores. Lastly, data on mortality and stent thrombosis were unavailable in several studies; hence, a separate analysis could not be performed. More prospective studies and clinical trials should be conducted to verify and cover the limitations of our meta-analysis.

Conclusion

CABG is superior when compared to PCI for patients with LVSD. CABG was associated with a lower risk of ACM, repeat revascularization, and incidence of MI compared with PCI in patients with LVSD.

Ethical approval

NA.

Consent

NA.

Source of funding

None.

Authors contribution

V.J: conceptualization; V.J: methodology; S.P.A, V.J: formal analysis and investigation; A.B.S., V.J., A.I.: writing - review and editing. All authors contributed equally in the writing - original draft preparation.

Conflict of interest disclosure

The authors declare that they have no financial conflict of interest with regard to the content of this report.

Research registration unique identifying number (UIN)

1. Name of the registry: PROSPERO.
2. Unique Identifying number or registration ID: CRD42022360919.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): NA.

Guarantor

David Song DO.
Vikash Jaiswal.
JCCR Cardiology, Varanasi, India.

Data availability statement

All data related to this study has been uploaded in the supplementary files and will be made available upon reasonable request from the corresponding author.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Acknowledgment

None.

References

[1] Vedin O, Lam CSP, Koh AS, *et al*. Significance of ischemic heart disease in patients with heart failure and preserved, midrange, and reduced ejection fraction: a nationwide cohort study. Circ Heart Fail 2017;10:e003875.
[2] Petrie MC, Jhund PS, She L, *et al*. Investigators, S. T. Ten-year outcomes after coronary artery bypass grafting according to age in patients with heart failure and left ventricular systolic dysfunction: an analysis of the extended follow-up of the STICH trial (Surgical Treatment for Ischemic Heart Failure). Circulation 2016;134:1314–24.
[3] Jiang L, Xu L, Song L, *et al*. Comparison of three treatment strategies for patients with triple-vessel coronary disease and left ventricular dysfunction. J Interv Cardiol 2018;31:310–8.
[4] Tsuyuki RT, Shrive FM, Galbraith PD, *et al*. Investigators, A. Revascularization in patients with heart failure. CMAJ 2006;175:361–5.
[5] O'Connor CM, Velazquez EJ, Gardner LH, *et al*. Comparison of coronary artery bypass grafting versus medical therapy on long-term outcome in patients with ischemic cardiomyopathy (a 25-year experience from the Duke Cardiovascular Disease Databank). Am J Cardiol 2002;90:101–7.
[6] Nagendran J, Bozso SJ, Norris CM, *et al*. Coronary artery bypass surgery improves outcomes in patients with diabetes and left ventricular dysfunction. J Am Coll Cardiol 2018;71:819–27.
[7] Veterans Administration Coronary Artery Bypass Surgery Cooperative Study, G. Eleven-year survival in the Veterans Administration randomized trial of coronary bypass surgery for stable angina. N Engl J Med 1984;311:1333–9.
[8] Appoo J, Norris C, Merali S, *et al*. Long-term outcome of isolated coronary artery bypass surgery in patients with severe left ventricular dysfunction. *Circulation* 2004;110(11 suppl 1):II13–7.
[9] Alderman EL, Fisher LD, Litwin P, *et al*. Results of coronary artery surgery in patients with poor left ventricular function (CASS). Circulation 1983;68:pp. 785–795.
[10] Velazquez EJ, Lee KL, Jones RH, *et al*. Investigators, S. Coronary-artery bypass surgery in patients with ischemic cardiomyopathy. N Engl J Med 2016;374:1511–20.
[11] Neumann FJ, Sousa-Uva M, Ahlsson A, *et al*. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J 2019;40: 87–165.
[12] Lawton JS, Tamis-Holland JE, Bangalore S, *et al*. 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: executive summary: a Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation* 2022;145:e4–17.
[13] Yang JH, Choi SH, Song YB, *et al*. Long-term outcomes of drug-eluting stent implantation versus coronary artery bypass grafting for patients with coronary artery disease and chronic left ventricular systolic dysfunction. Am J Cardiol 2013;112:623–9.
[14] Toda K, Mackenzie K, Mehra MR, *et al*. Revascularization in severe ventricular dysfunction (15% < OR = LVEF < OR = 30%): a comparison of bypass grafting and percutaneous intervention. Ann Thorac Surg 2002;74:2082–7.
[15] Sun LY, Gaudino M, Chen RJ, *et al*. Long-term outcomes in patients with severely reduced left ventricular ejection fraction undergoing percutaneous coronary intervention vs coronary artery bypass grafting. JAMA Cardiol 2020;5:631–41.
[16] Shah S, Benedetto U, Caputo M, *et al*. Comparison of the survival between coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with poor left ventricular function (ejection fraction <30%): a propensity-matched analysis. Eur J Cardiothorac Surg 2019;55:238–46.
[17] Sedlis SP, Ramanathan KB, Morrison DA, *et al*. Department of Veterans Affairs Cooperative Study, A. W. E. S. O. M. E. I. Outcome of percutaneous coronary intervention versus coronary bypass grafting for patients with low left ventricular ejection fractions, unstable angina pectoris, and risk factors for adverse outcomes with bypass (the AWESOME Randomized Trial and Registry). Am J Cardiol 2004;94:118–20.
[18] Marui A, Kimura T, Nishiwaki N, *et al*. Comparison of five-year outcomes of coronary artery bypass grafting versus percutaneous coronary intervention in patients with left ventricular ejection fractions ≤ 50% versus > 50% (from the CREDO-Kyoto PCI/CABG Registry Cohort-2). Am J Cardiol 2014;114:988–96.
[19] Kwon DH, Hachamovitch R, Popovic ZB, *et al*. Survival in patients with severe ischemic cardiomyopathy undergoing revascularization versus medical therapy: association with end-systolic volume and viability. *Circulation* 2012;126 (11 suppl 1):S3–8.
[20] Kang SH, Lee CW, Baek S, *et al*. Comparison of outcomes of coronary artery bypass grafting versus drug-eluting stent implantation in patients with severe left ventricular dysfunction. Am J Cardiol 2017;120:69–74.
[21] Iribarne A, DiScipio AW, Leavitt BJ, *et al*. Comparative effectiveness of coronary artery bypass grafting versus percutaneous coronary intervention in a real-world Surgical Treatment for Ischemic Heart Failure trial population. J Thorac Cardiovasc Surg 2018;156:1410–421.e2.
[22] Hawranek M, Zembala MO, Gasior M, *et al*. Comparison of coronary artery bypass grafting and percutaneous coronary intervention in patients with heart failure with reduced ejection fraction and multivessel coronary artery disease. Oncotarget 2018;9:21201–10.
[23] Hannan EL, Wu C, Walford G, *et al*. Drug-eluting stents vs. coronary-artery bypass grafting in multivessel coronary disease. N Engl J Med 2008;358:331–41.
[24] Gioia G, Matthai W, Gillin K, *et al*. Revascularization in severe left ventricular dysfunction: outcome comparison of drug-eluting stent implantation versus coronary artery bypass grafting. Catheter Cardiovasc Interv 2007;70:26–33.
[25] Fortuna D, Nicolini F, Guastaroba P, *et al*. Coronary artery bypass grafting vs percutaneous coronary intervention in a 'real-world' setting: a comparative effectiveness study based on propensity score-matched cohorts. Eur J Cardiothorac Surg 2013;44:e16–24.
[26] Buszman P, Szkrobka I, Gruszka A, *et al*. Comparison of effectiveness of coronary artery bypass grafting versus percutaneous coronary intervention in patients with ischemic cardiomyopathy. Am J Cardiol 2007;99: 36–41.
[27] Bangalore S, Guo Y, Samadashvili Z, *et al*. Revascularization in patients with multivessel coronary artery disease and severe left ventricular systolic dysfunction: everolimus-eluting stents versus coronary artery bypass graft surgery. Circulation 2016;133:2132–40.
[28] Page MJ, McKenzie JE, Bossuyt PM, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ (Clinical research ed) 2021;372:n71.
[29] Jaiswal V, Ishak A, Peng Ang S, *et al*. Hypovitaminosis D and cardiovascular outcomes: a systematic review and meta-analysis. Int J Cardiol Heart Vasc 2022;40:101019.
[30] Jaiswal V, Khan N, Jaiswal A, *et al*. Early surgery vs conservative management among asymptomatic aortic stenosis: a systematic review and meta-analysis. Int J Cardiol Heart Vasc 2022;43:101125.
[31] DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials 1986;7:177–88.
[32] Borenstein M, Hedges LV, Higgins JP, *et al*. A basic introduction to fixed-effect and random-effects models for meta-analysis. Res Synth Methods 2010;1:97–111.
[33] Wells GA, S B, O'Connell D, *et al*. The Newcastle–Ottawa Scale (NOS) for Assessing the Quality of Non-Randomized Studies in Meta-Analysis. Available online: Accessed 30 September 2022. http://www.ohri.ca/programs/clinical_epidemiology/ oxford.htm
[34] Tariq AR, El-Farra AB. The FREEDOM Trial: Revascularization in Diabetics with Multivessel Disease: A Population-Based Evaluation of Outcomes. Available online: Accessed 30 October 2022. https://www.acc.org/latest-in-cardiology/articles/2016/05/12/08/27/the-freedom-trial

[35] Thuijs D, Kappetein AP, Serruys PW, *et al*. Percutaneous coronary intervention versus coronary artery bypass grafting in patients with three-vessel or left main coronary artery disease: 10-year follow-up of the multicentre randomised controlled SYNTAX trial. Lancet 2019;394: 1325–34.
[36] Morrison DA, Sethi G, Sacks J, *et al*. Percutaneous coronary intervention versus repeat bypass surgery for patients with medically refractory myocardial ischemia: AWESOME randomized trial and registry experience with post-CABG patients. J Am Coll Cardiol 2002;40:1951–4.
[37] Yee NP, Siu AM, Davis J, *et al*. Recovery of left ventricular function after percutaneous coronary intervention compared to coronary artery bypass grafting in patients with multi-vessel coronary disease and left ventricular dysfunction. Hawaii J Med Public Health 2016;75:273–7.
[38] Nardi P, Asta L, Trombetti D, *et al*. Early and mid-term results in patients undergoing primary CABG in comparison with patients with PCI prior to CABG. Vessel Plus 2022;6:61.
[39] Nozari Y, Oskouei NJ, Khazaeipour Z. Effect of elective percutaneous coronary intervention on left ventricular function in patients with coronary artery disease. Acta Med Iran 2012;50:26–30.
[40] Philip F, Agarwal S, Bunte MC, *et al*. Stent thrombosis with second-generation drug-eluting stents compared with bare-metal stents. Circulation: Cardiovasc Intervent 2014;7:49–61.
[41] Mahmoud AN, Shah NH, Elgendy IY, *et al*. , Safety and efficacy of second-generation drug-eluting stents compared with bare-metal stents: An updated meta-analysis and regression of 9 randomized clinical trials. Clin Cardiol 2018;41:151–8.
[42] Gaudino M, Benedetto U, Fremes S, *et al*. Association of radial artery graft vs saphenous vein graft with long-term cardiovascular outcomes among patients undergoing coronary artery bypass grafting: a systematic review and meta-analysis. Jama 2020;324:179–87.
[43] Gallo M, Blitzer D, Laforgia PL, *et al*. Percutaneous coronary intervention versus coronary artery bypass graft for left main coronary artery disease: a meta-analysis. J Thorac Cardiovasc Surg 2022;163: 94–105.e15.
[44] Lee PH, Park H, Lee JS, *et al*. Meta-analysis comparing the risk of myocardial infarction following coronary artery bypass grafting versus percutaneous coronary intervention in patients with multivessel or left main coronary artery disease. Am J Cardiol 2019;124:842–50.
[45] Bulluck H, Paradies V, Barbato E, *et al*. Prognostically relevant periprocedural myocardial injury and infarction associated with percutaneous coronary interventions: a Consensus Document of the ESC Working Group on Cellular Biology of the Heart and European Association of Percutaneous Cardiovascular Interventions (EAPCI). Eur Heart J 2021;42:2630–42.