Percutaneous coronary intervention versus repeat surgical revascularization in patients with prior coronary artery bypass grafting: A systematic review and meta-analysis

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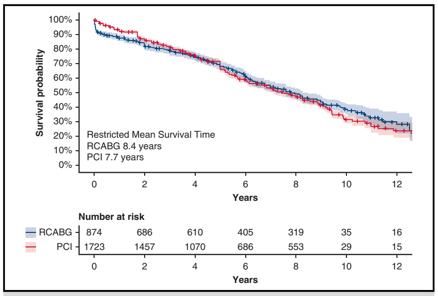
ABSTRACT

Objectives: Repeat coronary artery bypass grafting (RCABG) and percutaneous coronary intervention (PCI) are both used for the treatment of symptomatic patients with coronary artery disease and prior CABG, but the optimal treatment strategy remains unknown. We sought to perform a systematic review and meta-analysis to compare operative and follow-up outcomes following RCABG versus PCI in patients with prior CABG.

Methods: Medline and Embase were searched for studies comparing RCABG versus PCI. The primary outcome was follow-up mortality, and secondary outcomes were follow-up repeat revascularization, operative mortality, periprocedural stroke, and myocardial infarction. Time-to-event outcomes were summarized as incidence rate ratios, whereas operative outcomes were summarized as odds ratios. A random effect meta-analysis was performed. Individual patient survival data was extracted from available survival curves and reconstructed using restricted mean survival time.

Results: Among 2982 articles, 7 studies (9945 patients) were included. In the aggregated data meta-analysis, there was no difference in follow-up survival between RCABG and PCI (incidence rate ratio, 1.02; 95% CI, 0.83-1.25); however, restricted mean survival time analysis of individual data showed a survival benefit for RCABG over PCI (0.7 years; 95% CI, 0.23-1.19 years; $P = .004$). PCI was found to have a higher incidence rate of follow-up need for repeat revascularization (incidence rate ratio, 1.61; 95% CI, 1.16-2.23), but lower odds for operative mortality and stroke. No difference in the odds for myocardial infarction was found.

Conclusions: In patients with prior CABG, PCI is associated with better operative outcomes, but RCABG is associated with better survival and freedom from repeat revascularization at follow-up. (JTCVS Open 2022;12:177-91)



Restricted mean survival time comparing repeat CABG and PCI.

CENTRAL MESSAGE

PCI has better operative outcomes but repeat surgical revascularization can outperform PCI with regard to long-term mortality and repeat revascularization.

PERSPECTIVE

The decision between repeat CABG and PCI should take into consideration patient comorbidities; strategic preoperative and intraoperative planning; and a patient's life expectancy, preferences, and goals.

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Dr Cancelli is supported by a grant from the Enrico ed Enrica Sovena Foundation, Rome, Italy.

Received for publication May 23, 2022; revisions received Oct 16, 2022; accepted for publication Oct 24, 2022; available ahead of print Nov 18, 2022.

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2666-2736

https://doi.org/10.1016/j.xjon.2022.10.006

Patients with prior coronary artery bypass grafting (CABG) surgery and with recurrent angina represent challenging clinical cases with regard to the best revascularization strategy to be used. These patients are known to be older and have more comorbidities than at the time of the primary surgery and therefore both percutaneous coronary intervention (PCI) and CABG can expose them to a higher periprocedural risk and higher operative mortality.[1-5] Moreover, patients eligible for CABG may not have available conduits for the grafting procedure.

Current North American and European guidelines support PCI over CABG in most patients.[6,7] However, CABG

Abbreviations and Acronyms

- CABG = coronary artery bypass grafting
- IRR = incidence rate ratio
- MI = myocardial infarction
- PCI = percutaneous coronary intervention
- RCABG = repeat coronary artery bypass grafting

is recommended in patients with extensively diseased grafts or native coronary vessels, especially when there is no patent arterial graft supplying the myocardium.[7]

We performed a systematic review and meta-analysis with the aim to summarize the evidence regarding the comparison of the operative and follow-up outcomes following PCI versus repeat CABG (RCABG) because no such assessment has hitherto been performed. In addition to the traditional meta-analytic frameworks, we also applied analytic strategies that allowed us to account for violation of proportional hazard assumption for follow-up mortality.

METHODS

This systematic review and meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[8] Institutional review board and ethical approval of this analysis were not required because no human or animal subjects were involved.

Search Strategy

The search strategy is described in Table E1. We searched Ovid Medline (In-Process & Other Non-Indexed Citations), Ovid Medline (1946 to present), and Ovid Embase (1946 to present). Search terms included all subject headings and associated key words for the concepts of coronary artery bypass surgery, percutaneous coronary intervention, and reoperation. The search is updated to May 17, 2022.

Selection Criteria

Titles and abstracts were reviewed against predefined inclusion/exclusion criteria. Inclusion criteria were: comparative study of PCI versus RCABG in patients with prior CABG and studies reporting follow-up survival in the 2 groups with or without reporting also operative outcomes. Exclusion criteria were commentary, editorial, letters, book chapters, and reviews; studies not comparing outcomes following PCI versus RCABG; and studies in the setting of acute coronary syndromes. No exclusion based on article language or publishing year was made.

After results were de-duplicated, a total of 2533 abstracts were screened by 2 reviewers (A.D. and G.C.). Discrepancies were resolved by a third reviewer (D.C.). After abstract review, full text of abstracts was independently assessed for eligibility by 2 reviewers. The reference lists of the selected articles were also screened for potential additional studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram is shown in Figure E1.

Data Extraction

Two reviewers (A.D. and G.C.) independently extracted quantitative data from the selected studies. Conflicts in extracted data were resolved by a third reviewer (D.C.). The following variables were extracted: study characteristics (ie, sample size, publication year, country, study period, and study design), baseline patient characteristics and comorbidities (ie, age, sex, diabetes, left ventricular ejection fraction, left main disease, number of diseased vessels, and use of the internal thoracic artery in the prior CABG). The risk of bias was assessed using the Newcastle-Ottawa Scale assessment tool for observational studies. The highest possible score is 9 stars: studies with <6 stars were considered of low quality, whereas studies with $\geq$6 stars were considered of high quality.

Outcomes

The primary outcome was follow-up all-cause mortality. The secondary end points were follow-up repeat revascularization and operative outcomes (ie, operative mortality, perioperative stroke, and perioperative myocardial infarction [MI]).

Statistical Analysis

For follow-up outcomes, we took into account the different length of follow-up in each study and therefore these end points were analyzed pooling the natural logarithm of the incidence rate ratio (IRR), which represents the number of events observed per total number of patient-years. Pooled meta-analytic estimates were obtained using inverse variance method with a random effect model. Because the way of reporting these outcomes could differ between studies, IRRs were computed by different means, as previously reported:[9,10]

When the study provided the number of events and the median follow-up in both the PCI and CABG group, IRR was calculated as:

$$IRR = \frac{PCI_{\,events}}{PCI_{\,total\ patient-years}} \bigg/ \frac{CABG_{\,events}}{CABG_{\,total\ patient-years}}$$

When survival/nonevent rates were reported in each group, IRR was calculated as:

$$IRR = \frac{1}{PCI_{\,nonevent\ rate}} \bigg/ \frac{1}{CABG_{\,nonevent\ rate}}$$

When hazard ratio (HR) was reported, the natural logarithm of the HR was used.

The standard error associated with the natural logarithm of IRR was calculated as follows:

When the study provided the number of events and the median follow-up in the 2 groups:

$$SE_{\ln(IRR)} = \sqrt{\frac{1}{PCI_{\,events}} + \frac{1}{CABG_{\,events}}}$$

When the log-rank P value for Kaplan-Meier curves was provided:

$$SE_{\ln(IRR)} = \frac{\ln(IRR)}{NORMSINV\left(p-\frac{value}{2}\right)}$$

NORMSINV is an Excel (Microsoft Corp) function that provides a Z value for a cumulative probability:

When the 95% CI of the HR was provided:

$$SE_{\ln(IRR)} = \frac{\ln(Upper\ 95\%\ CI\ limit) - \ln(Lower\ 95\%\ CI\ limit)}{3.92}$$

Moreover, when the article included a figure of the Kaplan-Meier curves for the follow-up mortality, the individual patient data were retrieved from it and used to create aggregated survival curves. This was performed using an iterative algorithm that assumes constant censoring and find numerical solutions to the inverted Kaplan–Meier equation.[11] Hazard rate from these curves was assessed using the R package "muhaz" and Cox proportional hazard assumption was tested by means of the scaled Schoenfeld residuals. To overcome proportional assumption violation (very common in PCI vs CABG studies), restricted mean survival time was used to compare survival between PCI and RCABG, using the R package "survRM2." Restricted mean survival time represents the area under the survival curves for each treatment group and provides a summary of the whole survival curve instead of the survival rates at a certain time point.

Operative outcomes (ie, mortality, MI, and stroke) were extracted as the number of events in each group and were pooled using an inverse variance method and reported as odds ratio (OR) and 95% CI. Continuity correction was applied for cell with 0 events.

Statistical heterogeneity and consistency were assessed with I^2, which described the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance). Low, moderate, and high heterogeneity were defined as I^2 <25%, 25% to 50%, and >50%, respectively.[12] A random effect model was applied. The presence of small-study effect was assessed visually by inspection of the funnel plot and quantitatively by means of Egger test.

As sensitivity analysis for the primary outcome, a leave-1-out approach was used: the meta-analytic estimates were recalculated after exclusion of 1 study per time. Also, a univariate meta-regression was performed by regressing the meta-analytic estimates against the publication year.

In all analyses, RCABG was the reference group. Statistical analyses were performed in R version 4.0.3 (R Foundation for Statistical Computing) using the packages: "meta," "dmetar," "ipdfromKM," and "survminer."

RESULTS

Among the 2982 screened studies, 7 were included[13-19] in this meta-analysis for a total of 9945 patients distributed as follows: 4256 (43%) undergoing RCABG and 5689 (57%) undergoing percutaneous procedures (ie, angioplasty/PCI). The sample size of the studies ranged from 32 to 1561 and 67 to 2613 in the RCABG and PCI groups, respectively. Only 1 study[14] was multicenter; all the remaining were single center and were from the United States except 1 from the Netherlands.[16] The year of publication of the studies ranged from 1996 to 2019, most studies were published in first decade of 2000s. Studies characteristics are presented in Table 1. The risk of bias is presented in Table E2. All included studies had a Newcastle-Ottawa Scale score of 6 or more.

Baseline patient characteristics are presented in Table 2. The mean age ranged from 61 to 70 years in both the CABG and PCI groups and female sex was homogenously underrepresented in all studies (highest proportion: 26% in RCABG and 27% in PCI). Except for 1 study that included only patients with diabetes,[17] the proportion of diabetes ranged from 21% to 44% in CABG studies and from 19% to 38% in PCI studies. In all studies but 1,[16] more than half of patients had a 3-vessel coronary artery disease. The weighted mean follow-up was 5.1 years.

Primary Outcome

There was no difference in the incidence rate of follow-up mortality between patients undergoing RCABG and patients undergoing PCI (IRR, 1.02; 95% CI, 0.83-1.25; I^2 = 83%) (Figure 1). This finding was supported by the leave-1-out analyses, which showed consistent nonsignificant difference in follow-up mortality between the 2 groups (Figure E2). At meta-regression, the IRR for the primary outcome was significantly associated with the year of publication with more recent studies reporting higher IRR (Figure E3). The funnel plot and Egger test showed no evidence of publication bias or small-study effect (Figure E4).

TABLE 1. Characteristics of the studies included in the meta-analysis

First author, year of publication	Design	Adjustment	Study period	Center	Follow-up (y)
Locker, 2019[13]	Observational, retrospective (propensity score matched)	Propensity score matching	2000-2013	Mayo Clinic, United States	Median (IQR) = 10.4 (5.7-14.4)
Morrison, 2002 RCT[14]	RCT	–	1995-2000	16 Veterans Affairs Medical Centers, United States	Maximum = 3
Morrison, 2002 PD[14]	Observational, prospective	Unadjusted	1995-2000	16 Veterans Affairs Medical Centers, United States	Maximum = 3
Morrison, 2002 PC[14]	Observational, prospective	Unadjusted	1995-2000	16 Veterans Affairs Medical Centers, United States	Maximum = 3
Brener, 2005[15]	Observational, retrospective	Multivariable regression	1995-2000	Cleveland Clinic, United States	Mean ± SD = 6.5 ± 2.1
Harskamp, 2013[16]	Observational, retrospective	Multivariable regression	2003-2008	Academic Medical Center, the Netherlands	Median = 3.9
Cole, 2002[17]	Observational, retrospective	Multivariable regression	1985-1999	Emory University Hospitals, United States	Median = 6
Stephan, 1996[18]	Observational, retrospective	Multivariable regression	1987-1988	Mid America Heart Institute, United States	Mean ± SD = 4.0 ± 1.8
Weintraub, 1997[19]	Observational, retrospective	Multivariable regression	1980-1994	Emory University Hospitals, United States	Mean ± SD = 4.2 ± 3.1

IQR, Interquartile range; *RCT*, randomized controlled trial; *PD*, physician driven; *PC*, patient choice; *SD*, standard deviation.

TABLE 2. Patient baseline characteristics of the studies included in the meta-analysis

First author, year of publication	Treatment group	n	Age (y)	Female (%)	DM (%)	LVEF	LMD (%)	Diseased vessels	ITA prior CABG (%)
Locker, 2019[13]	RCABG	140	70 ± 9	18	34	<40%: 17%	29	1: 3% 2: 20% 3: 77%	65
	PCI	140	69 ± 9	20	31	<40%: 19.3%	23	1: 3% 2: 21% 3: 76%	65
Morrison, 2002[14]	RCABG	75	>70: 40%	NR	44	<35%: 15%	NR	3: 70%	NR
RCT	PCI	67	>70: 39%	NR	28	<35%: 16%	NR	3: 65%	NR
Morrison, 2002[14]	RCABG	155	>70: 36%	NR	28	<35%: 11%	NR	3: 71%	NR
PD	PCI	357	>70: 38%	NR	35	<35%: 17%	NR	3: 58%	NR
Morrison, 2002[14]	RCABG	32	>70: 47%	NR	20	<35%: 28%	NR	3: 62%	NR
PC	PCI	74	>70: 45%	NR	38	<35%: 8%	NR	3: 62%	NR
Brener, 2005[15]	RCABG	1487	65 ± 9	16	34	44 ± 9	29	2: 12% 3: 88%	32% (patent)
	PCI	704	66 ± 10	21	34	48 ± 14	29	2: 17% 3: 83%	68% (patent)
Harskamp, 2012[16]	RCABG	44	68 ± 6	15	30	<30%: 5%	NR	3: 22%	NR
	PCI	243	70 ± 10	14	25	<30%: 11%	NR	3: 0.4%	NR
Cole, 2002[17]	RCABG	598	64 ± 9	26	100%	47 ± 14	17	1: 6 2: 14 3: 63	NR
	PCI	1123	64 ± 9	27	100%	49 ± 13	0	1: 7 2: 22 3: 72	NR
Stephan, 1996[18]	RCABG	164	64 ± 9	15	21	48 ± 15	NR	3: 74%	NR
	PCI	468	62 ± 9	17	19	46 ± 24	NR	3: 77%	NR
Weintraub, 1997[19]	RCABG	1561	61 ± 9	16	22	51 ± 14	NR	3/LMD: 75%	NR
	PCI	2613	61 ± 10	20	22	3 ± 13	NR	3/LMD: 56%	NR

DM, Diabetes mellitus; *LVEF*, left ventricular ejection fraction; *LMD*, left main stem disease; *ITA*, internal thoracic artery; *CABG*, coronary artery bypass grafting; *RCABG*, repeat coronary artery bypass grafting; *PCI*, percutaneous coronary intervention; *RCT*, randomized controlled trial; *NR*, not reported; *PD*, physician driven; *PC*, patient choice.

When individual patient data were used to reconstruct Kaplan–Meier curves from 3 studies,[13,17,18] an interaction between time and the treatment groups was found and the scaled Schoenfeld residuals indicated violation of the proportional hazard assumption ($P < .0001$) (Figure E5). Survival was therefore compared using restricted mean survival time, which was higher in RCABG (8.41 years; 95% CI, 8.01-8.80 years) compared with PCI (7.70 years; 95% CI, 7.41-7.97 years). The difference in the areas under the survival curves was significantly in favor of RCABG, with PCI being associated with a reduction in the mean survival time of an average of 0.7 years (95% CI, 0.23-1.19; $P = .004$) during a mean follow-up of 5.7 years (interquartile range, 3.1-9.8 years) (Figure 2 and Table E3).

Secondary Outcomes

Follow-up repeat revascularization was reported in 4 studies. PCI was associated with a higher rate of repeat revascularization during the follow-up (IRR, 1.61; 95% CI, 1.16-2.23; $I^2 = 77\%$) (Figure 3).

Compared with RCABG, PCI was associated with lower odds of experiencing operative mortality (7 studies; OR, 0.24; 95% CI, 0.11-0.53; $I^2 = 84\%$) (Figure E6) and postoperative stroke (4 studies; OR, 0.04; 95% CI, 0.01-0.15; $I^2 = 31\%$) (Figure E7). No difference was found for periprocedural MI (5 studies; OR, 0.55; 95% CI, 0.13-2.36; $I^2 = 96\%$) (Figure E8). Perioperative outcomes in each study are summarized in Table E4.

DISCUSSION

In this meta-analysis of 7 studies (9945 patients), we found that in patients with prior CABG, PCI and RCABG were associated with similar follow-up mortality (Figure 4). However, when individual patient survival data were used and analyzed with restricted mean survival time, RCABG showed a survival benefit over PCI

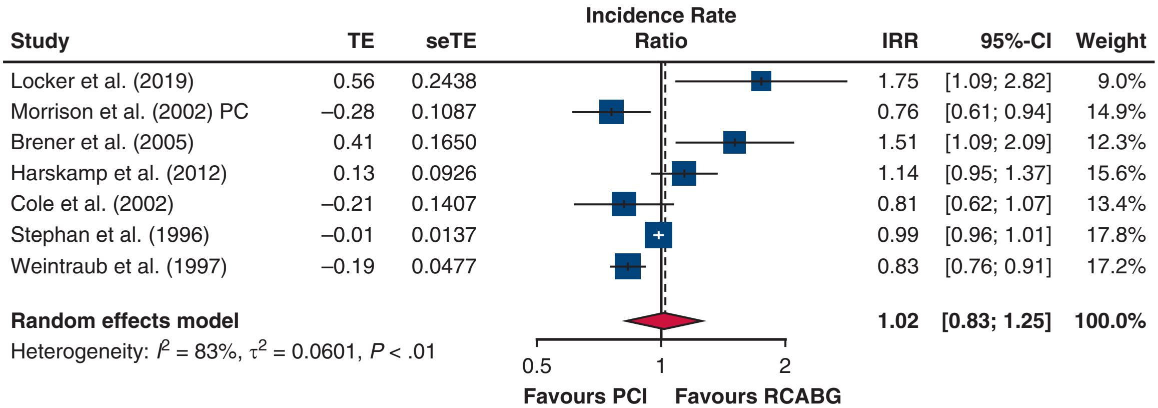

FIGURE 1. Forest plot of studies comparing the effect of repeat coronary artery bypass grafting (*RCABG*) and percutaneous coronary intervention (*PCI*) on the primary outcome of follow-up mortality. *TE,* Treatment effect; *seTE,* standard error of the treatment effect; *IRR,* incidence rate ratio; *CI*, confidence interval.

(Figure 2). PCI was also associated with higher follow-up need for repeat revascularization. However, the operative outcomes were more favorable for PCI, which was associated with lower risk of operative death and postoperative stroke.

Whereas the comparison of primary CABG versus PCI has been extensively investigated and meta-analyzed, this study represents the first effort to summarize the evidence comparing percutaneous versus surgical revascularization in patients with prior CABG. RCABG or PCI are usually indicated in patients with previous CABG and angina refractory to medical therapy and limiting daily activities. Symptoms can result from the progression of the underlying atherosclerotic disease of the native coronary arteries and/or from atherosclerosis of the grafts.

The number of RCABGs in relation to PCIs has been recently reported to be increasing. In an analysis using the National Inpatient Sample database, the rate of RCABG increased from 5.3% in 2004 to 10.3% in 2015.[20] However, the average number of RCABG remains low and outnumbered by PCI.[21-23] This is likely the result of a higher referral of patients to PCI, a hypothesis supported by the

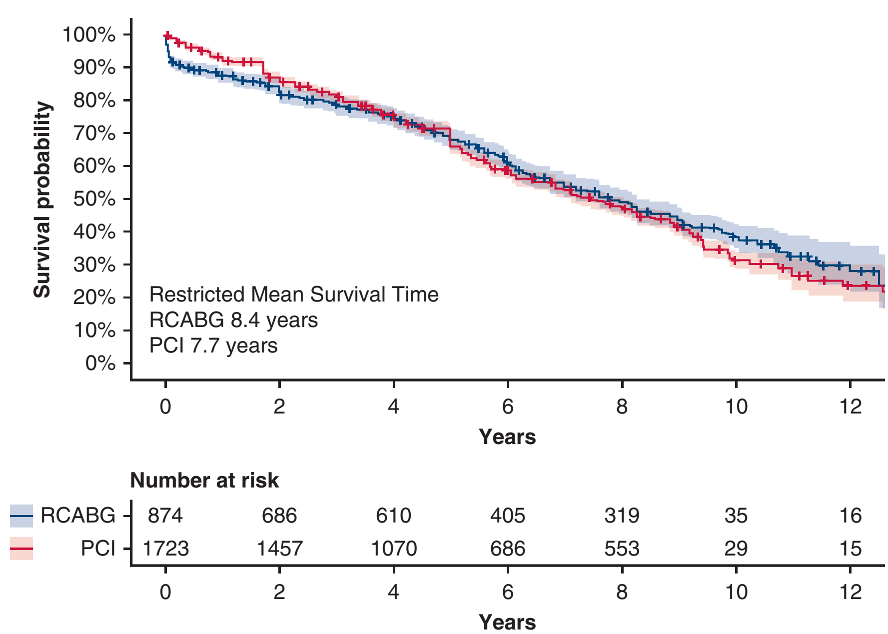

FIGURE 2. Survival curves from reconstructed individual patient data comparing repeat coronary artery bypass grafting (*RCABG*) and percutaneous coronary intervention (*PCI*) with related restricted mean survival times.

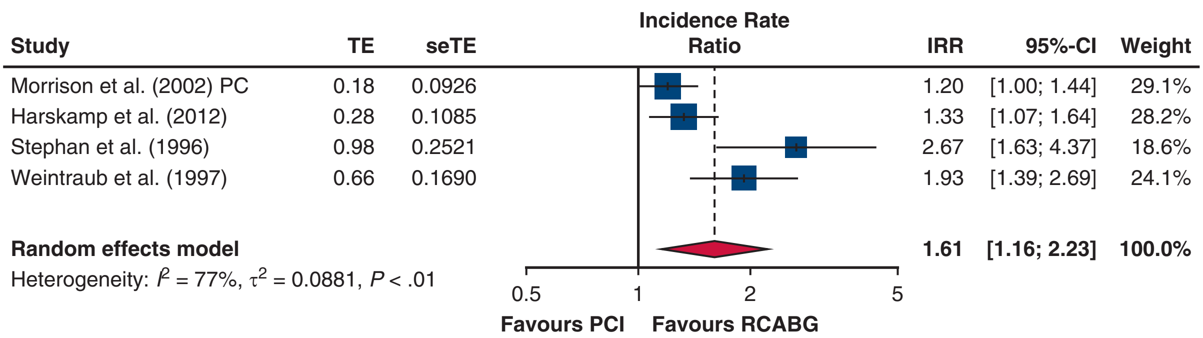

FIGURE 3. Forest plot of studies comparing the effect of repeat coronary artery bypass grafting (*RCABG*) and percutaneous coronary intervention (*PCI*) on the secondary outcome of follow-up repeat revascularization. *TE,* Treatment effect; *seTE,* standard error of the treatment effect; *IRR,* incidence rate ratio; *CI,* confidence interval.

results of the nonrandomized subgroups of the Angina with Extremely Serious Operative Mortality Evaluation trial in which 70% of patients with previous CABG were assigned to PCI by physicians, and 60% of patients preferred PCI over CABG.[14]

Patients requiring repeat revascularization after primary CABG represent a high-risk surgical cohort because they are usually older and present with a more adverse burden of comorbidities. Moreover, RCABG carries procedural hazards related to re-sternotomy, which can be particularly risky for the presence of retrosternal bypass conduits, injury to which may result in periprocedural MI in a significant proportion of patients.[24] There is also an increased risk of injuries to the heart and great arteries during mediastinal and heart dissection, complicated by fibrotic adherences from the previous CABG. This extra care needed during re-sternotomy and chest dissection prolongs the operative times of RCABG. All these factors account for the higher operative mortality following RCABG compared with primary CABG.[25]

In an analysis from the Society of Thoracic Surgeons Database, the mortality associated with RCABG steadily decreased from 6.0% in 2000 to 4.6% in 2009, with a relative risk reduction of 23.7%, despite patients undergoing RCABG having progressively greater medical comorbidities (eg, heart failure, diabetes, hypertension, and renal failure) and more complex coronary disease.[21] A previous report showed that in high-volume centers operative mortality associated with RCABG is similar to mortality after primary CABG.[15]

PCI after prior CABG is associated with an higher risk of restenosis and stent thrombosis, which influences the effectiveness of the treatment.[2,26] This could explain why in this meta-analysis we found a better follow-up freedom from repeat revascularization in RCABG and a survival benefit from RCABG.

It is important to note that the proportional hazard assumption did not hold true in this analysis and that using reconstructed individual patient data a survival benefit for CABG was found. This is not surprising giving the very different hazard phase for the 2 interventions (ie, early risk for CABG and late risk for PCI) and suggests that traditional meta-analytic frameworks based on study-level granularity may not always result in accurate estimates for time-to-event outcomes when comparing PCI and CABG.

Current North American and European guidelines support PCI over CABG in patients with amenable anatomy because PCI carries lower periprocedural risk.[6,7] CABG is instead recommended for patients with diffuse native coronary diseases and extensively diseased or occluded grafts. In particular, RCABG should be performed in patients who do not have a patent internal thoracic artery to the left anterior descending artery and when the internal thoracic artery was not used previously and is available for harvesting at the time of RCABG.[6,7,27]

Clinical decision making for RCABG versus PCI should take into consideration not only patient comorbidities, but also a strategic preoperative and operative planning and each patient's life expectancy and preferences and goals. Patients should undergo preoperative imaging study to better delineate the poststernotomy changes in the mediastinum and detect the presence of previous grafts potentially at risk of injury during sternotomy or mediastinal dissection. Patients should also be thoroughly investigated with regard to available conduits because the use of RCABG is also limited by the lack of grafts. Finally, patients should be thoroughly informed of the different time horizon of the benefit of the 2 procedures (better early outcomes with PCI and long-term survival benefit with RCABG), so that they can make a decision that fits better their personal goals and expectations. To better take into account all the variables in this fine decision, discussion with the patient together with the heart team would represents the most suitable approach.

Limitations

The results of this meta-analysis must be interpreted within the context of its limitations. It is possible that

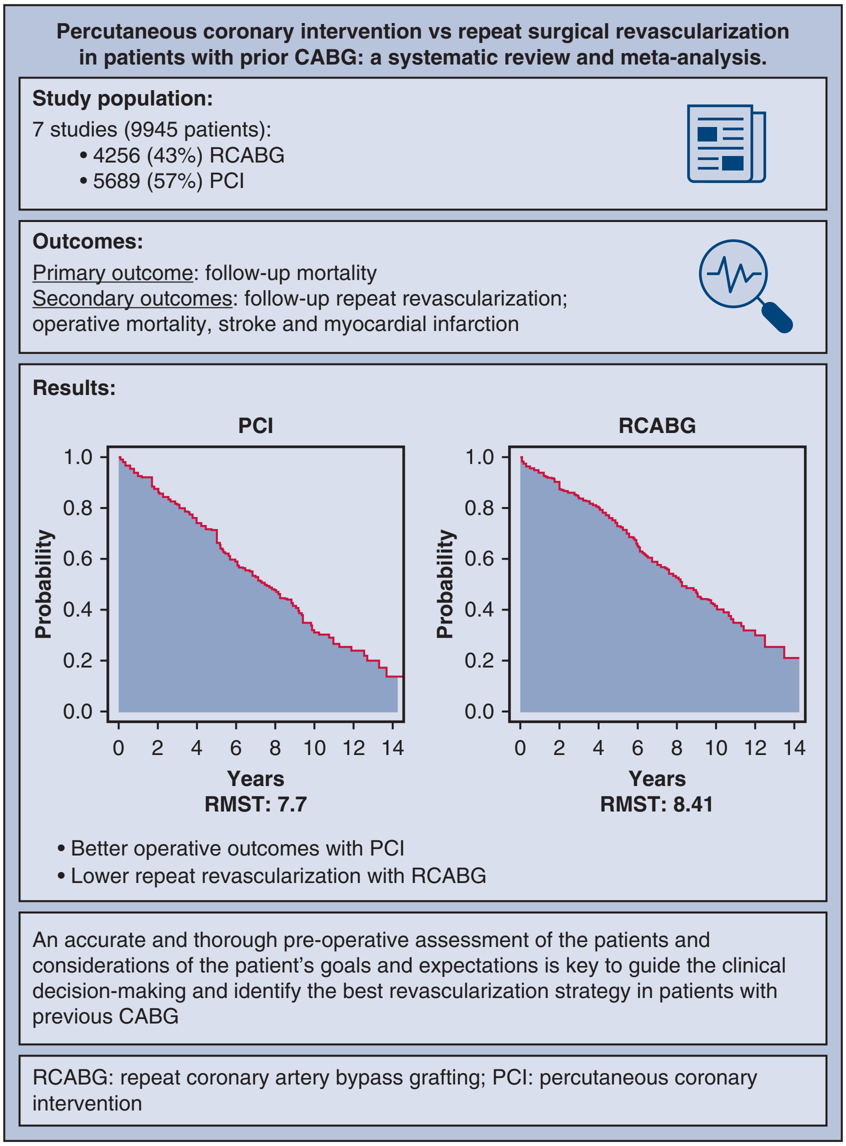

FIGURE 4. In a meta-analysis of 7 studies, for a total of 9945 patients, we found that percutaneous coronary intervention (*PCI*) is associated with better operative outcomes but repeat coronary artery bypass grafting (*RCABG*) can provide better follow-up mortality, according to the restricted mean survival time (RMST) analysis, and freedom from repeat revascularization. *CABG*, Coronary artery bypass grafting.

treatment allocation bias (sicker patients may have been turned down for surgery) and residual confounders may be responsible for our results. As with all analyses of aggregated analyses, it is also possible that surgical techniques, perioperative care, and secondary prevention strategies among the included studies differed and influenced the results. There was no information on the nature of periprocedural MI and some of the studies were old and may not be reflective of current practice in myocardial revascularization. The outcome of repeat revascularization should also be interpreted in the context of procedure-related details, such as completeness of revascularization; however, only in 2 studies presented these data.[15,18] There was also not enough granularity to investigate whether or not the revascularization involved a previously treated vessel (eg, in-stent stenosis) or a was due to progression of the disease in naïve coronaries. No information was available regarding follow-up antiplatelet therapy. Lastly, some comparisons may be underpowered to detect meaningful clinical differences because of the limited number of studies included.

CONCLUSIONS

Despite the better operative outcomes, PCI can be outperformed in terms of follow-up all-cause mortality and need for repeat revascularization by RCABG. An accurate and thorough preoperative assessment of the patients and considerations of the patient's goals and expectations is key to guide clinical decision making and identify the best revascularization strategy in patients with previous CABG. Further studies including more contemporary cohorts of patients and care protocols are needed to answer this question thoroughly.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: coronary artery disease, coronary artery bypass grafting, percutaneous coronary intervention, repeat coronary artery bypass grafting

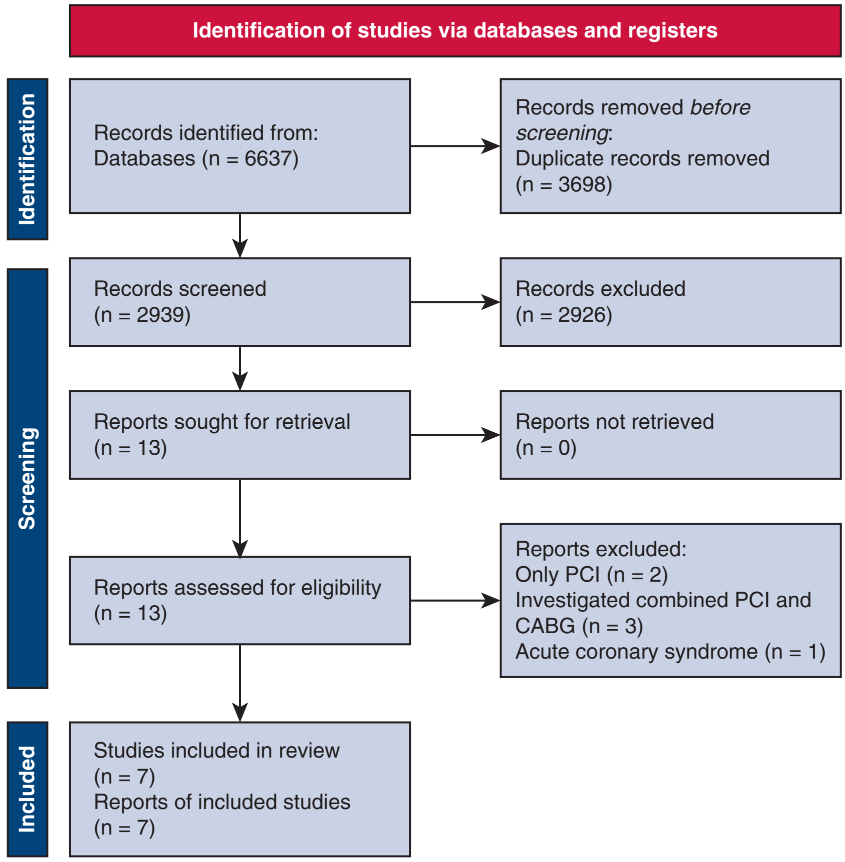

FIGURE E1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis flow diagram. *PCI*, Percutaneous coronary intervention; *CABG*, coronary artery bypass grafting.

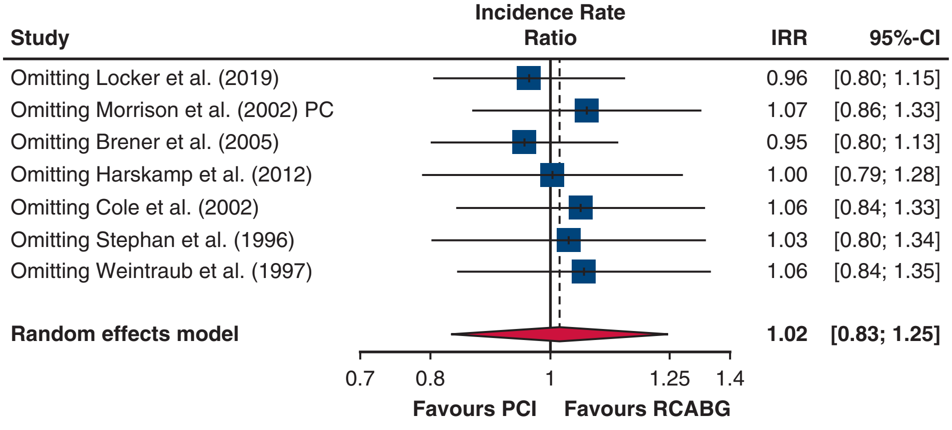

FIGURE E2. Leave-1-out analysis for the primary outcome of long-term mortality. *IRR,* Incidence rate ratio; *CI*, confidence interval; *PCI*, percutaneous coronary intervention; *RCABG*, repeat coronary artery bypass grafting.

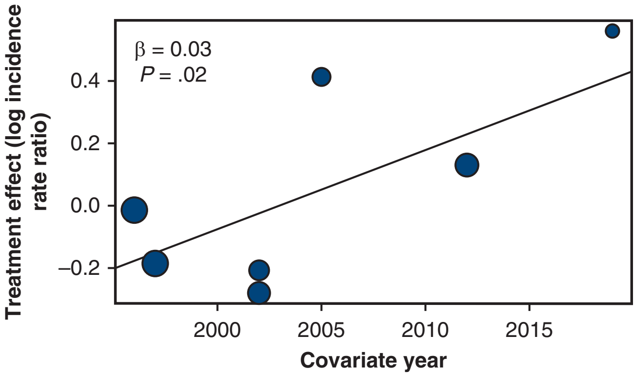

FIGURE E3. Meta-regression for the primary outcome of long-term mortality on year of publication.

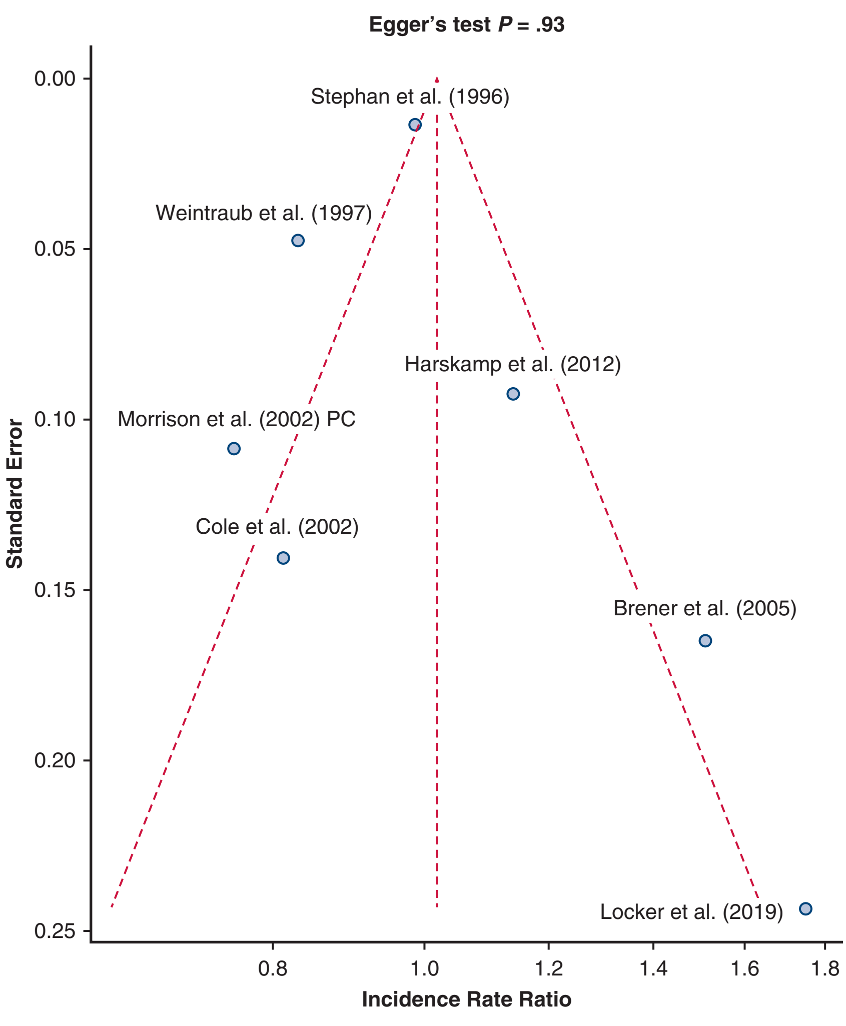

FIGURE E4. Funnel plot with trim-and-fill method and Egger test results. *PC,* Patient choice.

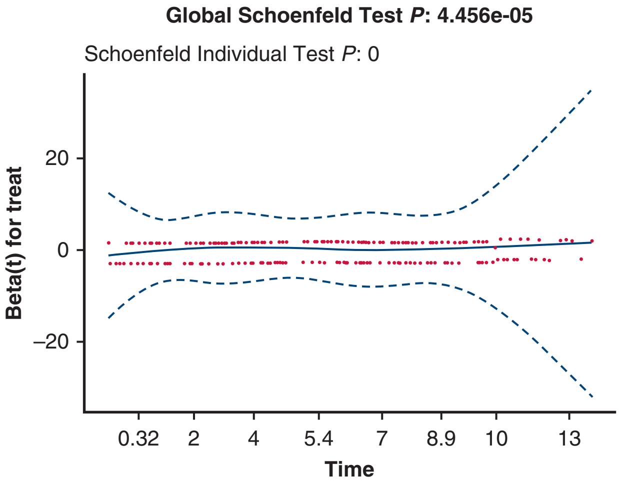

FIGURE E5. Scaled Schoenfeld residuals to test Cox proportional hazard assumption.

	Experimental		Control				
Study	**Events**	**Total**	**Events**	**Total**	**OR**	**95%-CI**	**Weight**
Locker et al. (2019)	15	140	10	140	1.56	[0.68; 3.60]	14.1%
Morrison et al. (2002) RCT	0	67	6	75	0.08	[0.00; 1.43]	5.3%
Morrison et al. (2002) PD	2	357	13	155	0.06	[0.01; 0.28]	10.5%
Morrison et al. (2002) PC	0	74	5	32	0.03	[0.00; 0.63]	5.2%
Brener et al. (2005)	12	704	43	1487	0.58	[0.31; 1.11]	15.0%
Harskamp et al. (2012)	17	243	1	44	3.23	[0.42; 24.95]	8.0%
Cole et al. (2002)	18	1123	67	598	0.13	[0.08; 0.22]	15.5%
Stephan et al. (1996)	2	468	12	164	0.05	[0.01; 0.25]	10.5%
Weintraub et al. (1997)	31	2613	106	1561	0.16	[0.11; 0.25]	16.0%
Random effects model		**5789**		**4256**	**0.24**	**[0.11; 0.53]**	**100.0%**

Heterogeneity: $I^2 = 84\%$, $\tau^2 = 1.0085$, $P < .01$

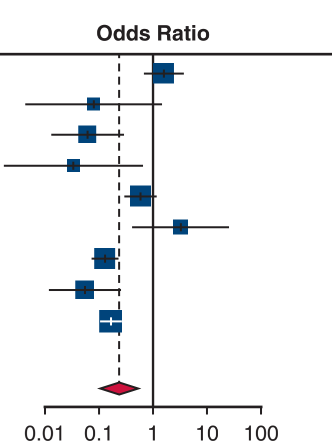

FIGURE E6. Forest plot of studies comparing the effect of redo coronary artery bypass grafting (*RCABG*) and percutaneous coronary intervention (*PCI*) on 30-day mortality. *CI*, confidence interval.

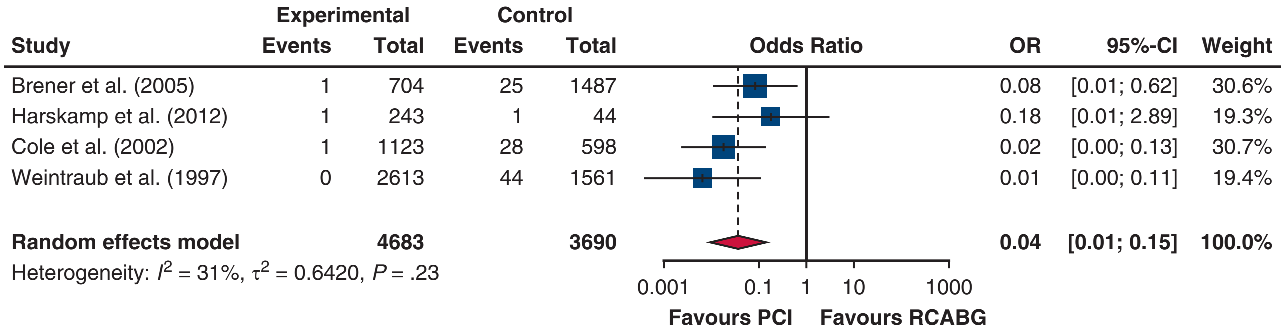

FIGURE E7. Forest plot of studies comparing the effect of redo coronary artery bypass grafting (*RCABG*) and percutaneous coronary intervention (*PCI*) on perioperative stroke. *CI*, confidence interval.

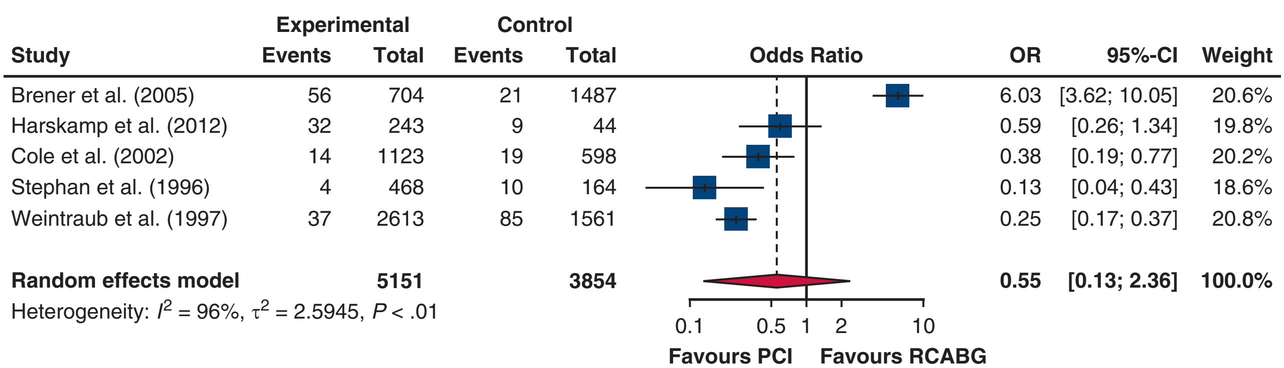

FIGURE E8. Forest plot of studies comparing the effect of redo coronary artery bypass grafting (*RCABG*) and percutaneous coronary intervention (*PCI*) on perioperative myocardial infarction. *CI*, confidence interval.

TABLE E1. Full search strategy

Line #	Ovid Medline <1946 to present> search term	Number of results
1	Coronary Artery Bypass/or Coronary Artery Bypass.mp. [mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	67,629
2	(coronary adj2 (bypass* or graft* or surger*)).tw.	53,547
3	(CABG or aortocoronary anastomosis or total arterial revasculari*ation* or multiple arterial revasculari*ation*).tw.	18,977
4	(CABG or aortocoronary anastomosis or total arterial revasculari*ation* or multiple arterial revasculari*ation*).tw.	18,977
5	(myocardial revasculari*ation* or myocardium revasculari*ation* or mammary artery implant* or mammary arterial implant* or mammary artery reimplant* or mammary arterial reimplant* or vineberg operation*).tw.	5112
6	or/1-5	77,091
7	Percutaneous Coronary Intervention/	22,668
8	(percutaneous coronary intervention* or percutaneous coronary revascularization* or PCI or percutaneous coronary angioplasty or stent or stents or stenting).tw.	137,020
9	Angioplasty, Balloon, Coronary/	35,793
10	(coronary balloon angioplasties or coronary balloon angioplasty or transluminal coronary balloon dilation or coronary artery balloon dilation or percutaneous transluminal coronary angioplasty or coronary angioplasty or coronary angioplasties or PTCA).tw.	15,351
11	or/7-10	162,717
12	(animals not humans).sh.	4,865,863
13	((comment or editorial or meta-analysis or practice-guideline or review or letter) not "randomized controlled trial").pt.	4,880,804
14	(reoperation or re-operation or repeat or repeat surgery or redo).mp. [mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	276,357
15	6 and 11	15,696
16	15 and 14	2146
17	16 not (12 or 13)	1802

CABG, Coronary artery bypass grafting; *PCI*, percutaneous coronary intervention; *PTCA*, percutaneous transluminal coronary angioplasty.

TABLE E2. Newcastle-Ottawa scale for included studies

First author, year of publication	Selection	Comparability	Outcome/Exposure	Total
Locker, 2019	4	2	3	9
Morrison, 2002 (RCT)	4	2	1	7
Morrison, 2002 (PD)	3	1	2	6
Morrison, 2002 (PC)	3	1	2	6
Brener, 2005	4	2	3	9
Harskamp, 2012	4	2	3	9
Cole, 2002	4	1	3	8
Stephan, 1996	3	1	3	7
Weintraub, 1997	4	1	3	8

RCT, Randomized clinical trial; *PD*, physician-driven; *PC*, patient choice.

TABLE E3. Restricted mean survival times (95% CI) from reconstructed Kaplan-Meier curves

Treatment group	1 y	5 y	10 y
RCABG	0.96 (0.95-0.97)	4.34 (4.24-4.43)	7.14 (6.91-7.37)
PCI	0.97 (0.96-0.97)	4.22 (4.15-4.29)	6.71 (6.55-6.88)
Difference	0.002 (–0.2 to 0.015) $P = .82$	–0.12 (–0.23 to 0.002) $P = .05$	–0.42 (–0.71 to 0.14) $P = .003$

RCABG, Redo coronary artery bypass grafting; *PCI*, percutaneous coronary intervention.

TABLE E4. Perioperative outcomes (mortality, stroke, and myocardial infarction) reported in each study included in the meta-analysis by year

Year	Outcome	
	RCABG	PCI
Mortality		
1996	12 (7.3)	2 (0.4)
1997	106 (6.8)	31 (1.2)
2002	91 (10.6)	20 (1.2)
2005	43 (2.9)	12 (1.7)
2012	1 (2.3)	17 (7.0)
2019	10 (4.7)	15 (1.1)
Perioperative stroke		
1996	NA	NA
1997	44 (2.8)	0 (0)
2002	28 (4.7)	1 (0.1)
2005	25 (1.7)	1 (0.1)
2012	1 (2.3)	1 (0.4)
2019	NA	NA
Perioperative myocardial infarction		
1996	10 (6.1)	4 (0.9)
1997	85 (5.4)	37 (1.4)
2002	19 (3.2)	14 (1.2)
2005	21 (1.4)	56 (7.9)
2012	9 (20.4)	32 (13.2)
2019	NA	NA

Values are presented as n (%). *RCABG*, Redo coronary artery bypass grafting; *PCI*, percutaneous coronary intervention; *NA*, not applicable.