Right internal thoracic artery versus radial artery as the second best arterial conduit: Insights from a meta-analysis of propensity-matched data on long-term survival

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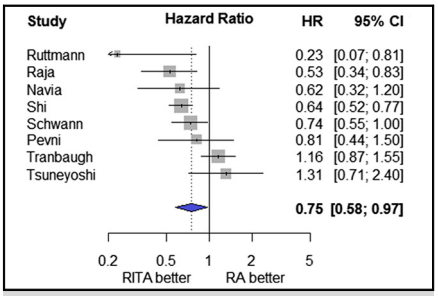
ABSTRACT

Objective(s): We conducted a meta-analysis of propensity score-matching (PSM) studies comparing long-term survival of patients receiving right internal thoracic artery (RITA) versus radial artery (RA) as a second arterial conduit for coronary artery bypass grafting.

Methods: A literature search was conducted using MEDLINE, EMBASE, and Web of Science to identify relevant articles. Primary endpoint was long-term mortality. Secondary endpoints were operative mortality, incidence of sternal wound infection, and repeat revascularization. Binary events were pooled using the DerSimonian and Laird method. For time-to-event outcomes, estimates of log hazard ratio (HR) and standard errors obtained were combined using the generic inverse-variance method.

Results: A total of 8 PSM studies were finally selected including 15,374 patients (RITA, 6739; RA, 8635) with 2992 matched pairs for final comparison. Mean follow-up time ranged from 45 to 168 months. When compared with RA, RITA was associated with a lower risk reduction of late death (HR, 0.75; 95% confidence interval [CI], 0.58-0.97; $P = .028$) and repeat revascularization (HR, 0.37; 95% CI, 0.16-0.85; $P = .03$). On the other hand, RITA did not increase operative mortality (odds ratio [OR], 1.53; 95% CI, 0.97-2.39; $P = .07$). RITA was associated with an increased risk of sternal wound complication when pedicled harvesting was used (OR, 3.18; 95% CI, 1.34-7.57), but not with skeletonized harvesting (OR, 1.07; 95% CI, 0.67-1.71).

Conclusions: The present PSM data meta-analysis suggests that the use of RITA compared with RA was associated with superior long-term survival and freedom from repeat revascularization, with similar operative mortality and incidence of sternal wound complication when the skeletonized harvesting technique was used. (J Thorac Cardiovasc Surg 2016;152:1083-91)



By pooling data from 8 propensity score-matching studies, the right internal thoracic artery (RITA) was found to be associated with a 25% risk reduction of late death compared with the radial artery (RA).

Central Message

Compared with the radial artery, the right internal thoracic artery is associated with superior long-term survival and freedom from reintervention when used as second arterial conduit.

Perspective

The choice of the right internal thoracic artery or radial artery as a second conduit in coronary artery bypass graft surgery remains controversial. The present propensity-matched data meta-analysis showed that the right internal thoracic artery was associated with superior long-term survival and freedom from repeat revascularization, with similar operative mortality and incidence of sternal wound complication when the skeletonized harvesting technique was used.

See Editorial Commentary page 1092.

Despite increasing recognition that multiple arterial conduits improve long-term outcomes following coronary artery bypass grafting (CABG),[1] the quest for the second best arterial conduit to supplement the left internal thoracic artery continues.[2] In particular, whether the use of the right internal

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
CI = confidence interval
HR = hazard ratio
OR = odds ratio
PSM = propensity score matching
RA = radial artery
RAPCO = Radial Artery Patency and Clinical Outcomes
RCT = randomized controlled trial
RITA = right internal thoracic artery

thoracic artery (RITA) confers a survival advantage when compared with the radial artery (RA) still needs to be determined.[3] The lack of clear evidence, the potentially increased sternal wound complication rate, and the perceived technical complexity using bilateral internal thoracic arteries often result in the RA as the preferred second conduit of choice.[1] To date, only a single randomized controlled trial (RCT), the Radial Artery Patency and Clinical Outcomes (RAPCO) study,[3] has been published in the literature, largely underpowered to detect any difference in long-term survival between the RITA and RA groups. Propensity score-matching (PSM)–based analysis of observational data is emerging as an attractive alternative in view of the paucity of evidence from RCTs, and can be relied on as evidence when RCTs are not possible.[4] Several large PSM studies comparing RITA with RA have been recently published with inconclusive findings.[5-12] Here, we propose to overcome the potential limitations related to underpowered individual reports by conducting a meta-analysis of PSM studies comparing RITA with RA as a second arterial conduit on long-term survival in patients undergoing CABG.

METHODS

Search Strategy and Selection of Studies

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[13] (see Table E1 for the PRISMA checklist). A literature search was conducted using MEDLINE, EMBASE, and Web of Science to identify relevant articles on January 2016. Observational studies included in the present meta-analysis met the following criteria: (1) patients underwent first time isolated CABG; (2) comparison of long-term survival of patients receiving RITA versus RA as second arterial conduit was made; and (3) PSM was used to account for non-random allocation to treatment (RITA vs RA). Non-English language, review articles, and editorials were excluded. Search terms used the controlled vocabularies of MEDLINE and EMBASE alone or in combination with text words including "radial artery," "right internal thoracic artery," "bilateral internal thoracic artery," "propensity score," and "propensity score matching." Two reviewers (U.B. and M.G.) independently reviewed the results on titles and abstracts to determine whether the study met the inclusion criteria. In the case of disagreement, an agreement was negotiated. In the case of several publications with overlapping study populations, the largest sample size study with longest follow-up available was selected. The quality of included studies was assessed with the Newcastle-Ottawa Scale for observational studies.[14] The total score was 9 stars, and the quality was graded as low level (<6 stars) or high level (≥6 stars).

Data Extraction

Microsoft Office Excel 2010 (Microsoft, Redmond, Wash) was used for data extraction. Data extraction of all included studies was performed independently by 2 researchers (U.B. and A.D.F). In the case of disagreement about extracted data, an agreement was negotiated. Study design, study period, country, and center where the study was conducted, unmatched and matched sample size, designated target for experimental graft, PSM methods, completeness of follow-up, and follow-up duration were documented. The following patient characteristics in the unmatched and matched groups were also registered: age, female gender, diabetes mellitus, reduced left ventricular ejection fraction (as defined by authors), chronic obstructive pulmonary disease, renal impairment (as defined by authors), and predicted operative risk according to the EuroSCORE or Society of Thoracic Surgeons score.[15]

Long-term mortality was the primary endpoint of our meta-analysis. Secondary endpoints were operative mortality, incidence of sternal wound complication, and repeat revascularization. Time-to-event outcomes (long-term mortality and repeat revascularization) were extracted as hazard ratios (HRs) and their variance from the matched sample. When only the graphic survival curves and the number of persons at risk at each of several time points in the PSM comparison groups were provided, the method of Williamson et al[16] was used to obtain the HR estimates and variance. Binary endpoints (operative mortality and sternal wound complication) were extracted as event and sample size in the matched groups.

Statistical Analysis

The meta-analysis was pre-specified to use a random effects model because of the anticipated variety in study designs and populations and thus a more conservative value was obtained. Binary event data from the RITA versus RA cohorts were computed as odds ratios (ORs) and associated 95% confidence intervals (CIs) and pooled using the method of DerSimonian and Laird.[17] For time-to-event outcomes, estimates of log HRs and standard errors obtained were combined using the generic inverse-variance method. The I^2 statistic was used to estimate the percentage of total variation across studies due to heterogeneity rather than chance. Suggested thresholds for heterogeneity were used, with I^2 values of 25%-49%, 50%-74%, and ≥75% indicative of low, moderate, and high heterogeneity, respectively.[18] Publication bias was evaluated using visual inspection of funnel plot asymmetry and the Begg and Mazumdar rank correlation test.[19] For the primary outcome, secondary analyses were conducted including leave-one-out sensitivity analyses and a radial (or Galbraith) plot to assess the influence of outliers. The radial plot is designed to assess the extent of heterogeneity between studies. The y axis shows the (log-transformed) effect size divided by its standard error (z score) and the inverse of the standard error on the x axis. Each study is represented by a single dot, and a regression line runs centrally through the plot. Parallel to the regression line, at a 2-standard deviation distance, 2 lines create an interval in which most dots would be expected to decrease if the studies were estimating a single fixed parameter. A line projected from (0,0) through a particular point within the plot onto this arc indicates the value of the observed outcome for that point. In addition, estimates obtained from PSM were pooled with those from available RCTs. Finally, to support the external validity of the main analysis, estimates obtained from all unmatched populations (including observational non-PSM studies) were pooled. Subgroup analysis was conducted according to the target selected for the experimental conduit (left coronary artery system only vs both left and right coronary artery systems) and to the internal thoracic artery harvesting technique. A subgroup analysis on the incidence of sternal wound complication according to the internal thoracic artery harvesting technique (skeletonized vs pedicled) was also conducted. Statistical analysis was

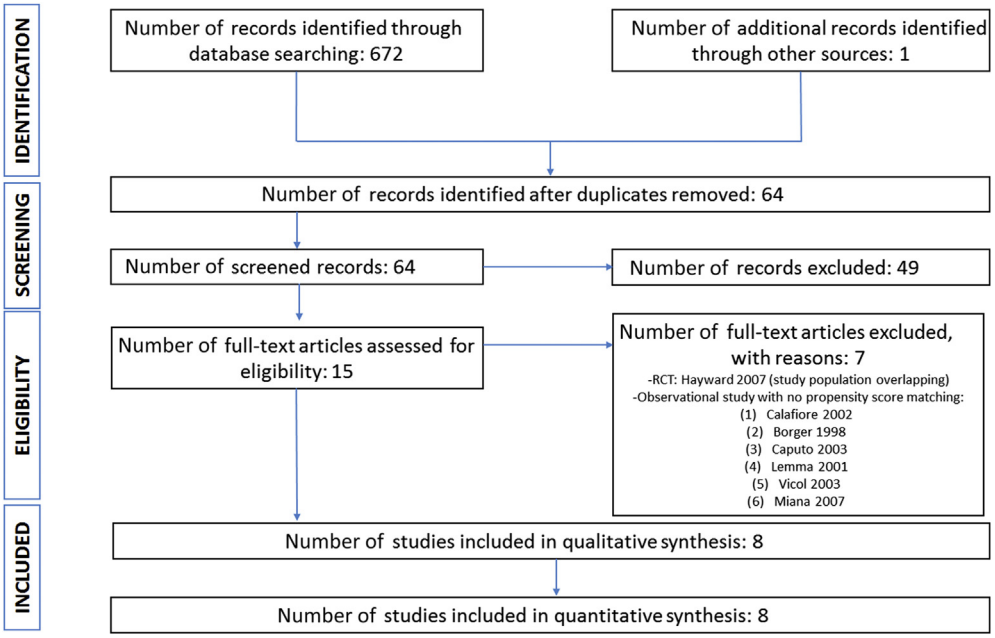

FIGURE 1. Flow chart for study selection. *RCT*, Randomized controlled trial.

conducted using the meta package for R (meta: General Package for Meta-Analysis. R package version 4.3-2. https://CRAN.R-project.org/package=meta).

RESULTS

Selected Studies

From 673 abstracts, we selected 15 full-text articles fitting our selection criteria. After evaluating the full-text articles, we excluded 6 observational studies[20-25] that did not perform PSM adjustment, and 1 RCT, the RAPCO trial[3] (Table E2). A total of 8 PSM studies[5-12] were finally selected for the systematic review and meta-analysis. Of note, the study population in the RAPCO trial[3] was also part of a large Australian multicenter registry[10] included in the main analysis. An outline of the systematic review process is depicted in Figure 1. An overview of the PSM studies is summarized in Tables 1 and 2 (variables included for PSM are summarized in Table E3). Overall, selected studies reported on 15,374 patients (RITA, 6739; RA, 8635) with 2992 matched pairs for final comparisons. Risk factor distribution before and after matching for each study is reported in Table 3. PSM and unmatched populations presented a similar preoperative risk factors distribution. The Newcastle-Ottawa Scale confirmed a high quality level for all PSM studies included in the main analysis (Table E4).

Primary Analysis on Long-Term Mortality

All studies reported on comparisons of long-term mortality. The mean follow-up time ranged from 45 to 168 months. The RITA group was associated with a statistically significant 25% risk reduction of late death when compared with the RA group (HR, 0.75; 95% CI, 0.58-0.97; $P = .028$; Figure 2). We found a moderate heterogeneity among the studies ($I^2 = 66.5\%$; 95% CI, 29.1%-84.2%). No publication bias was found ($P = .62$; Figure E1).

Operative Mortality

All studies selected reported on comparisons of operative mortality, although different definitions were adopted (Table E5). Operative mortality rate ranged from 0.7% to 4.03% and from 0% to 3.4% in the RITA and RA groups, respectively, and pooled estimates showed no significant difference between the 2 groups (OR, 1.53; 95% CI, 0.97-2.39; $P = .07$; Figure 3, *A*). There was no significant heterogeneity among the studies ($I^2 = 0\%$; 95% CI, 0%-56.5%). No publication bias was found ($P = .80$; Figure E2, *A*).

Sternal Wound Complications

All but one[5] study reported on sternal wound complications in the matched population, although different definitions were adopted. These ranged from 1.7% to 3.2% and from 0% to 3.6% in the RITA and RA groups, respectively. The pooled estimates showed a trend toward a higher incidence of sternal wound complications in patients receiving RITA (OR, 1.50; 95% CI, 0.86-2.60; $P = .15$; Figure 3, *B*). Low-to-moderate heterogeneity among studies was found ($I^2 = 43.4\%$; 95% CI, 0%-76.2%). Subgroup analysis according to the internal thoracic artery harvesting technique showed that RITA was associated with a significant 3-fold increased risk of sternal wound complication when pedicled

TABLE 1. Overview of propensity score-matching studies included in the primary analysis

Study	Year of publication	Country	Centers	Study period	Target	Outcomes of interest reported	ITA-H
Navia et al[5]	2014	Argentina	Cardiovascular Institute of Buenos Aires	2003-2011	LCA/RCA	Hospital mortality, deep sternal wound infection (not in the matched population) Late survival, readmission/ reintervention	Skeleton
Pevni et al[6]	2016	Israel	Tel Aviv Medical Center	1996-2010	LCA only	Operative mortality, deep sternal infection, late survival	Skeleton
Raja et al[7]	2014	United Kingdom	Harefield Hospital	2001-2013	LCA/RCA	Operative mortality, sternal wound infection, late mortality, repeat revascularization	Pedicled/Skeleton
Ruttmann et al[8]	2011	Austria	Innsbruck Medical University	2001-2010	LCA only	Operative mortality, Sternal dehiscence, late survival, repeat revascularization	Pedicled/Skeleton
Schwann et al[9]	2014	United States	University of Toledo, Mercy Saint Vincent (Toledo, Ohio), Yale New Haven Hospital	1987-2011	LCA only	30-d mortality, deep sternal infection, late survival	Pedicled
Shi et al[10]	2015	Australia	Austin Hospital, Epworth Hospital Richmond, Epworth Eastern Hospital, Knox Hospital, Royal Melbourne Hospital, St Vincent's Hospital Melbourne, Warringal Hospital	1995-2010	LCA only	30-d mortality, deep sternal wound infection, late survival	Pedicled/Skeleton
Tranbaugh et al[11]	2013	United States	Beth Israel Medical Center, St. Luke's Roosevelt Hospital Center	1995-2009	LCA only	Surgical mortality, sternal wound infection, late survival, symptom-driven cardiac catheterization	Pedicled
Tsuneyoshi et al[12]	2015	Japan	Kurashiki Central Hospital	2000-2013	LCA only	Hospital death, deep sternal wound infection, late survival	Skeleton

ITA-H, Internal thoracic artery harvesting; *LCA*, left coronary artery; *RCA*, right coronary artery.

harvesting only was used[9,11] (OR, 3.18; 95% CI, 1.34-7.57), whereas the 2 groups were comparable in studies where a skeletonized approach was used[6-8,10,12] (OR, 1.07; 95% CI, 0.67-1.71) (test for subgroup differences $P = .12$). No publication bias was found ($P = .17$; Figure E2, *B*).

Repeat Revascularization

Three studies only reported on the incidence of repeat revascularization in the matched population.[5,7,8] The pooled estimate showed that RITA was associated with a significantly lower risk of repeat revascularization (HR, 0.37; 95% CI, 0.16-0.85; $P = .03$; Figure 3, *C*). However, heterogeneity was significantly higher between the 3 studies ($I^2 = 74.7\%$; 95% CI, 15.9%-92.4%). No significant publication bias was found ($P = .11$; Figure E2, *C*).

Secondary Analyses on Long-Term Survival

The forest plots of the leave-one-out sensitivity analysis (Figure 4, *left*) and the radial plot (Figure 4, *right*) showed that there were no significant outliers in the meta-analysis. The survival advantage by choosing RITA was also confirmed by pooling PSM studies with the RAPCO trial (HR, 0.77; 95% CI, 0.60-0.99; $I^2 = 64.7\%$; $P = .04$)

TABLE 2. Overview of propensity score-matching methods in studies included in the primary analysis

Study	UNM RITA, n	UNM RA, n	PSM RITA, n	PSM RA, n	PSM methodology	Methods for comparison accounting for matched groups	Follow-up (mo)	Completeness of follow-up (%)	Proportional hazard assumption	PSM-HR for mortality provided
Navia et al[5]	1447	253	149	149	5-digit 1:1 matching without replacement	Not specified (log rank)	Mean, 45; IQR, 24-66	94.1	Not reported	No
Pevni et al[6]	1329	389	268	268	1:1 matching with a 5% difference as a matching threshold value	Yes (Cox stratified on matched pairs)	Mean, 168; 95% CI, 161-179	97	Not reported	Yes
Raja et al[7]	747	779	510	510	Greedy 1:1 matching with caliper of width of 0.20 SD of the logit of the PSM	Yes (Klein and Moeschberger)	Mean, 96; IQR, 36-124	100	Not reported	Yes
Ruttmann et al[8]	277	724	277	277	2-digit 1:1 matching without replacement	Yes (Cox stratified on matched pairs)	Mean, 58; range, 3-112	Not reported	Not reported	Yes
Schwann et al[9]	641	3095	551	551	Nearest-neighbor matching caliper of width ± 1% difference in PSM	Not specified (Cox regression)	Range, 3-189	100	Not reported	Yes
Shi et al[10]	912	1909	591	591	Greedy 1:1 matching with a fixed caliper width of 0.05	Yes (Klein and Moeschberger)	NA	100	Not reported	No
Tranbaugh et al[11]	1154	1334	528	528	Nearest-neighbor, caliper-constrained matching technique	Not specified (Cox regression)	RITA, 102 ± 55; RA, 108 ± 52	Not reported	Reported	Yes
Tsuneyoshi et al[12]	232	152	118	118	1:1 matching; method not reported	Not specified (log rank)	RITA, 73; RA, 94	91	Not reported	No

UNM, Unmatched; *RITA*, right internal thoracic artery; *RA*, radial artery; *PSM*, propensity score matching; *HR*, hazard ratio; *IQR*, interquartile range; *CI*, confidence interval; *SD*, standard deviation; *PSM*, propensity score matching; *NA*, not applicable.

(Figure E3). All but 1 PSM study[7] and all but 2 non-PSM observational cohorts[24,25] reported on late mortality in the overall population. Pooled estimates from unmatched populations supported a survival benefit of RITA over RA (HR, 0.74; 95% CI, 0.56-0.98; $P = .03$; $I^2 = 77.5\%$; Figure E4). Subgroup analysis showed that, compared with RA, the use of RITA was associated with better long-term survival when used to graft either the left coronary artery system only (HR, 0.81; 95% CI, 0.60-1.10) or both the left and right coronary systems (HR, 0.56; 95% CI, 0.38-0.81; test for subgroup differences $P = .12$; Figure E5), and no significant differences were found between studies where skeletonized harvesting[5-8,10,12] (HR, 0.67; 95% CI, 0.50-0.89) versus pedicled harvesting only[9,11] was used (test for subgroup differences $P = .22$).

DISCUSSION

The main finding of the present PSM data meta-analysis is that, compared with RA, the use of RITA was associated with superior long-term survival and lower incidence of repeat revascularization in patients undergoing CABG with an additional arterial conduit. The use of RITA was associated with superior survival regardless of the target coronary location.

Moreover, the use of RITA did not significantly increase operative mortality and, when harvested as a skeletonized conduit, RITA did not increase the risk of sternal wound complication compared with RA. However, when harvested as a pedicle, RITA was found to be associated with 3-fold increased risk of sternal wound complication.

Despite a slow initial adoption, multiple arterial grafting is now widely advocated by the cardiovascular community.[1] The use of both RITA and RA has been shown to be associated with better long-term survival compared with the traditional strategy using a single internal thoracic artery and additional saphenous vein grafts.[9] Contention still remains on whether RITA is superior to RA in terms of long-term survival and patency rate.[10] The only randomized direct comparison in the literature is the RAPCO,[3] which randomized 196 patients to RITA and 193 to RA. At mid-term follow-up, no significant differences in terms of angiographic patency and clinical outcome were found. However, the trial was largely underpowered to detect significant differences in survival between the 2 groups. On the other hand, results of larger observational studies have been discordant and inconclusive.[9,10]

Along with large registry data, meta-analysis of PSM data is emerging as an attractive alternative in view of the paucity of evidence from RCT,[4] and it overcomes potential limitations related to underpowered individual studies. By pooling data from PSM studies, we found that the use of RITA was associated with a 25% risk reduction of late

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TABLE 3. Risk factor distribution in the unmatched and matched populations in studies included in the primary analysis

	Unmatched							Propensity score matched						
	Age (y), mean ± SD	Female (%)	DM (%)	LVD (%)	COPD (%)	RD (%)	Operative risk	Age (y), mean ± SD	Female (%)	DM (%)	LVD (%)	COPD (%)	RD (%)	Operative risk
Navia et al[5]														
RITA	63 ± 9	8	26	20	NR	4	2.7 ± 2.3*	68 ± 8	17	30	30	NR	6	3.9 ± 2.4*
RA	69 ± 10	12	33	35		6	4.8 ± 3.3*	67 ± 10	19	32	30		4	3.9 ± 2.6*
Pevni et al[6]														
RITA	18††	22	38	8	5	8	5.8 ± 3.2*	18††	31	54	4	12	8	6.05 ± 3.3*
RA	36††	36	61	6	15	12	7.5 ± 4.1*	22††	31	52	4	8	8	5.90 ± 3.17*
Raja et al[7]														
RITA	60	11	16	13	8	2	NR	62	12	21	15	7	1	NR
RA	62	16	31	18	7	1		62	15	25	17	7	1	
Ruttmann et al[8]														
RITA	57 ± 10	10	21	20	33	3	2.3 ± 2.6*	57 ± 10	10	21	20	33	3	2.3 ± 2.6*
RA	60 ± 10	14	24	24	20	1	2.8 ± 2.3*	58 ± 9	10	22	20	33	2	2.4 ± 2.5*
Schwann et al[9]														
RITA	60 ± 10	12	15	54 ± 11‡	6	NR	NR	60 ± 10	14	17	53 ± 11‡	7	NR	NR
RA	62 ± 10	25	37	49 ± 10‡	18			58 ± 10	13	18	52 ± 10‡	8		
Shi et al[10]														
RITA	60 ± 10	8	13	23	3	NR	NR	63 ± 9	11	19	23	3	NR	NR
RA	68 ± 10	25	30	27	5			63 ± 10	11	18	24	4		
Tranbaugh et al[11]														
RITA	66 ± 11	29	35	46 ± 15‡	8	3	NR	61 ± 11	23	36	48 ± 14	10	2	NR
RA	58 ± 8	17	38	48 ± 13‡	19	2		60 ± 8	22	37	47 ± 14‡	10	2	
Tsuneyoshi et al[12]														
RITA	68 ± 8	19	55	3	2	NR	1.56†	68 ± 10	19	53	2	2	NR	1.64†
RA	69 ± 11	23	46	2	3		1.57†	68 ± 10	25	45	1	2		1.61†

SD, Standard deviation; *DM*, diabetes mellitus; *LVD*, left ventricular dysfunction (different definition adopted); *COPD*, chronic obstructive pulmonary disease; *RD*, renal failure (different definition adopted); *RITA*, right internal thoracic artery; *NR*, not reported; *RA*, radial artery. *EuroSCORE. †Society of Thoracic Surgeons score. ††Percentage of patients aged ≥75. ‡Mean left ventricular ejection fraction.

mortality. When compared with RA, the use of RITA was associated with better survival regardless of the target coronary location, thus supporting previous reports.[26,27] The main reason for the long-term benefit of RITA might be attributed partially to its higher capacity for nitric oxide release than RA, which could be responsible for the inferior long-term graft patency.[28] The superiority of RITA over RA in terms of long-term survival is also supported by a recent network meta-analysis of RTC[2] which found RITA to be associated with a 27% absolute risk reduction for late (>4 years) functional graft occlusion compared with RA. Of note, we found a significant heterogeneity for late mortality among studies. The different risk profiles of study populations might partially explain such variability. The study by Ruttmann et al[8] reported the highest effect size in a relatively younger population (mean age 57 years), with a relatively low prevalence of women (10%) and diabetes mellitus (20%). At the other extreme is the study by

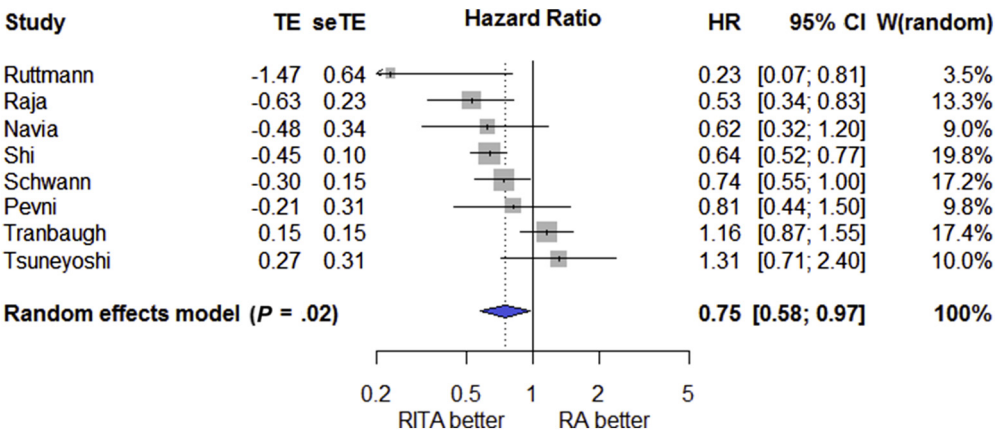

FIGURE 2. Forest plot comparing the effect of right internal thoracic artery (*RITA*) versus the radial artery (*RA*) on late mortality across individual studies and by means of pooled estimates. *TE*, Treatment effect; *seTE*, standard error; *HR*, hazard ratio; *CI*, confidence interval.

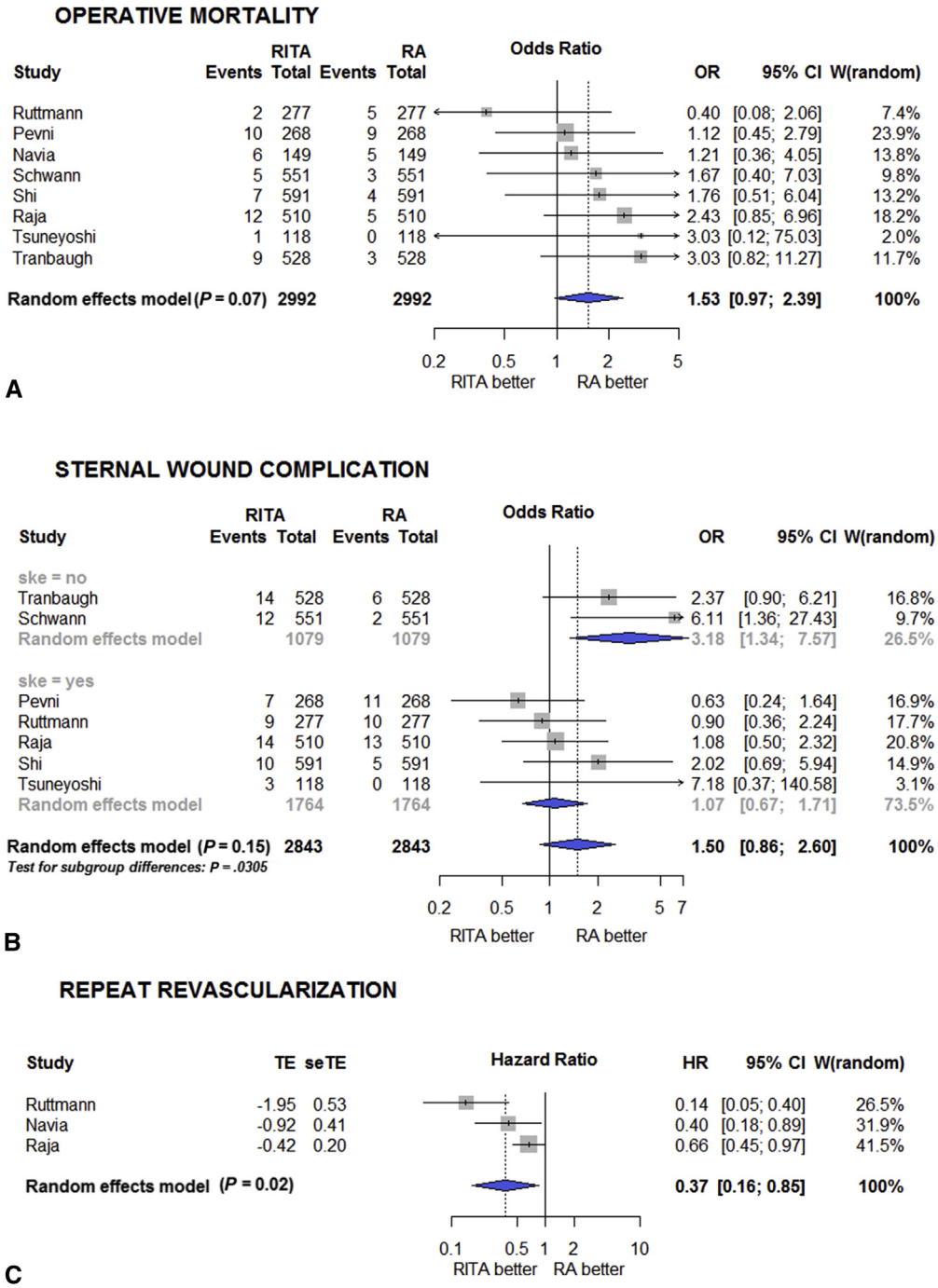

FIGURE 3. Forest plot comparing the effect of right internal thoracic artery (*RITA*) versus the radial artery (*RA*) on operative mortality (A), incidence of sternal wound complication (B), and repeat revascularization (C) across individual studies and by means of pooled estimates. *OR*, Odds ratio; *CI*, confidence interval; *TE*, treatment effect; *seTE*, standard error.

Tsuneyoshi et al,[12] which reported the lowest effect size in a relatively older population (mean age 68 years), with a higher prevalence of women (∼20%) and diabetes mellitus (∼50%). Also, Tranbaugh et al[11] failed to show any benefit from RITA. Of note, in their study the prevalence of women and diabetes was relatively high (∼23% and ∼36%, respectively). It has been proposed that low-risk patients with prolonged life expectation are more likely to present a survival benefit from the use of RITA. In fact, its beneficial effect on survival may be delayed by as much as 7 to 10 years but persists beyond that time; however, it may be less beneficial in older patients with coexistent morbidities

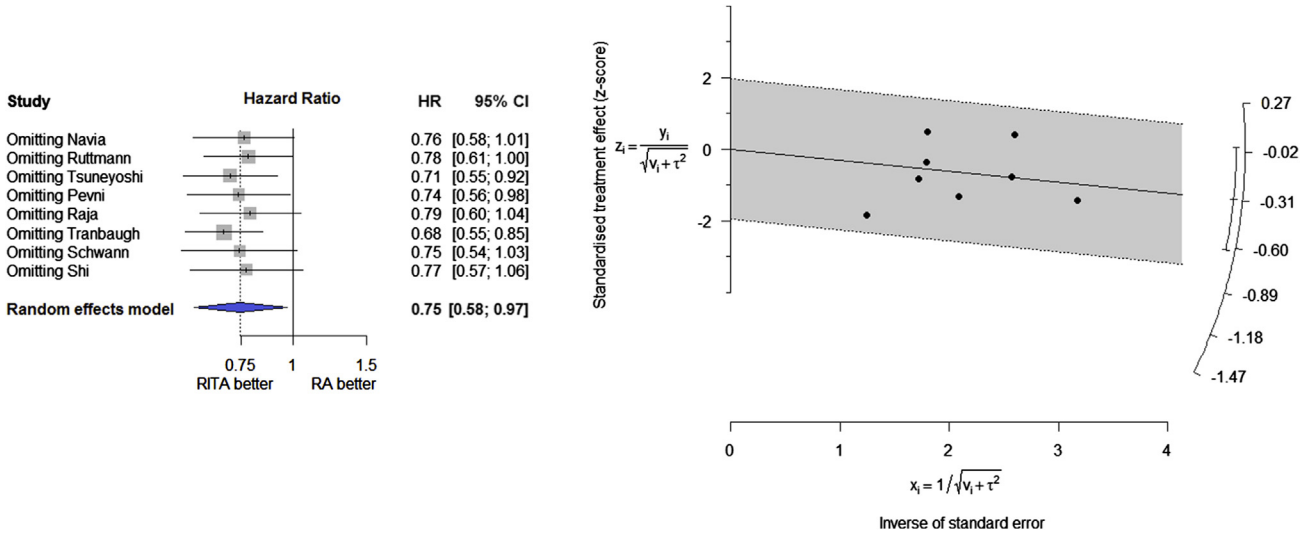

FIGURE 4. Forest plot of the leave-one-out sensitivity analysis (*left*) and the radial plot (*right*) comparing the effect of right internal thoracic artery (*RITA*) versus radial artery (*RA*) on late mortality. *HR*, Hazard ratio; *CI*, confidence interval.

and limited life expectancy.[29-31] Another possible explanation for the heterogeneity among studies is the use of different surgical techniques. In the study by Ruttmann et al,[8] RITA was preferentially used as in situ graft through the transverse sinus, whereas in the study by Tranbaugh et al,[11] it was used as a Y graft in most cases. The latest configuration is more technically demanding and leads to higher rates of competitive flow, which can potentially increase graft failure,[32] although no definitive data are available to confirm this finding.[33]

We found that when harvested as a skeletonized conduit, the use of RITA was associated with a similar rate of postoperative sternal complications observed in those receiving RA. However, when harvested as a pedicle, RITA was associated with a 3-fold increased risk of sternal wound infection. Skeletonized harvesting has been consistently demonstrated to minimize the risk of sternal wound complications in patients receiving bilateral internal thoracic arteries,[34-36] in particular in those with diabetes mellitus.[35,36]

The present analysis has intrinsic limitations. Propensity matching can adjust only for measurable and included variables, and we cannot exclude a selection bias based on nonmeasurable ''eye-ball'' variables (with RITA reserved for healthier patients). Moreover, the use of propensity matching increases the internal validity of studies and limits the ability to generalize findings. Only 39% of the overall study population in the present meta-analysis was included in the propensity-matched groups. In particular, data on diabetic patients were not reported separately. Therefore, we could not draw conclusions on the superiority of RITA in such a high-risk subgroup. Finally, different authors used different PSM models so that the homogeneity of the included populations cannot be regarded as optimal. In particular, 3 of 8 studies included in the main analysis[5,9,12] did not specify whether the methods used for comparison accounted for matched pairs,[37] and only 1 study[11] tested the non-violation of proportional hazard assumption.

In conclusion, the present PSM data meta-analysis suggests that, compared with RA, the use of RITA can be associated with superior long-term survival and a lower incidence of repeat revascularization. However, this benefit might be less relevant in high-risk subgroups such as older, female, and diabetic patients. In particular, specific data on diabetic populations are not available. In this group, RA should be considered as a valid option, taking into account the increased risk of sternal wound complications in the case of harvesting bilateral internal thoracic arteries. Skeletonized harvesting should be strongly recommended when RITA is preferred over RA, because this technique minimizes the risk of sternal wound complication.

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Key Words: propensity score matching, right internal thoracic artery, radial artery

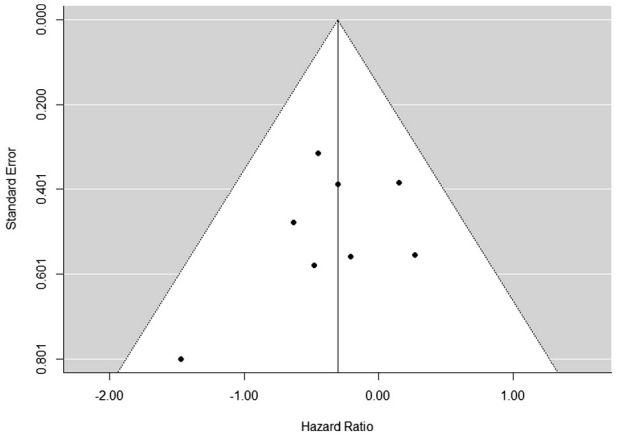

FIGURE E1. Funnel plot comparing the effect of right internal thoracic artery (RITA) versus radial artery (RA) on late mortality.

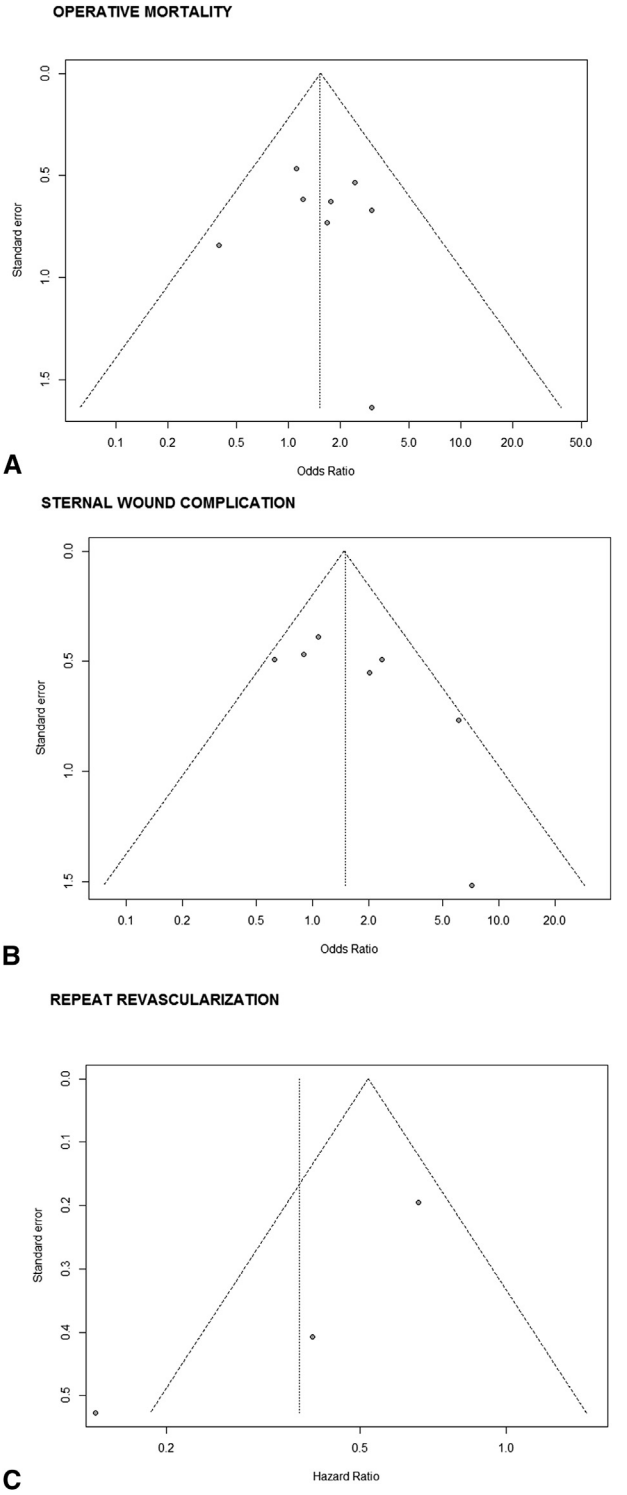

FIGURE E2. Funnel plot comparing the effect of right internal thoracic artery (RITA) versus radial artery (RA) on operative mortality (A), incidence of sternal wound complication (B), and repeat revascularization (C).

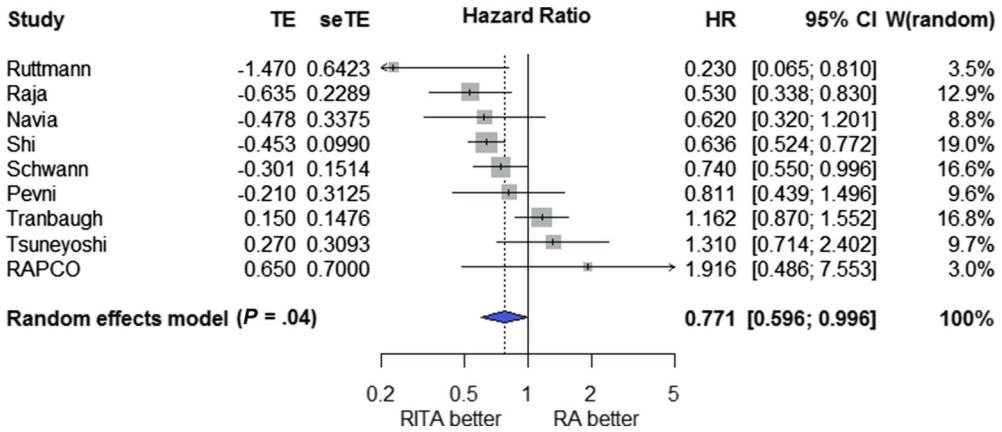

FIGURE E3. Forest plot comparing the effect of right internal thoracic artery (*RITA*) versus radial artery (*RA*) on operative mortality in propensity matching studies and the RAPCO trial across individual studies and by means of pooled estimates. *TE*, Treatment effect; *seTE*, standard error; *HR*, hazard ratio; *CI*, confidence interval.

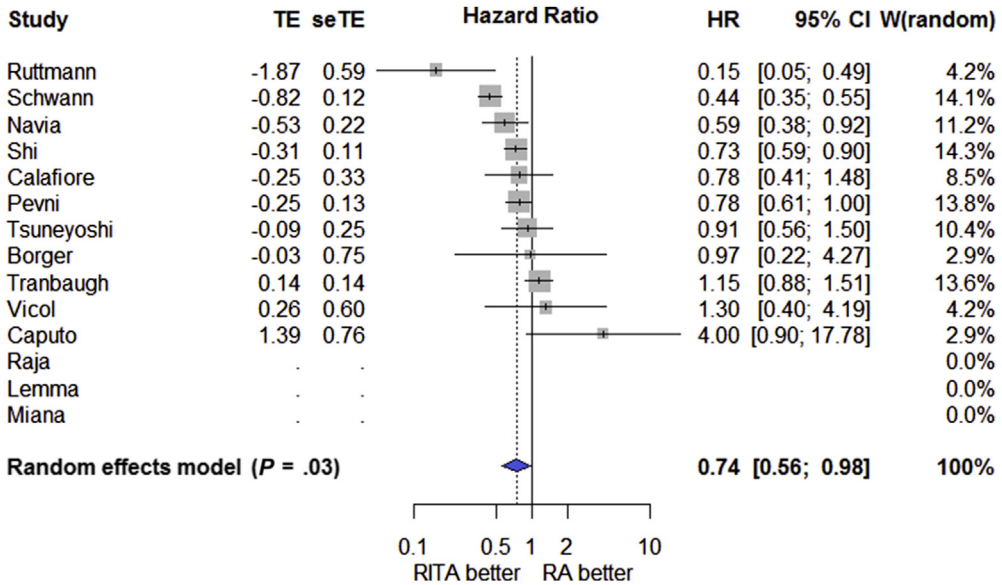

FIGURE E4. Forest plot comparing the effect of right internal thoracic artery (*RITA*) versus radial artery (*RA*) on operative mortality in all unmatched populations. *TE*, Treatment effect; *seTE*, standard error; *HR*, hazard ratio; *CI*, confidence interval.

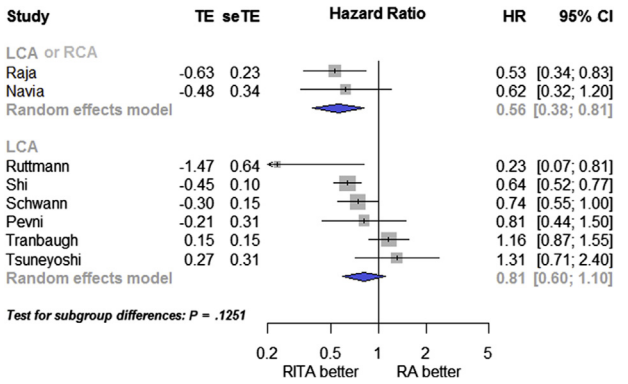

FIGURE E5. Forest plot comparing the effect of right internal thoracic artery (*RITA*) versus radial artery (*RA*) on operative mortality according to the target. *LCA*, Left coronary artery; *RCA*, right coronary artery; *TE*, treatment effect; *seTE*, standard error; *HR*, hazard ratio; *CI*, confidence interval.

TABLE E1. PRISMA 2009 checklist

Section/topic	Number	Checklist item	Reported on page number
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number	3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known	8
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS)	8
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (eg, Web address), and, if available, provide registration information including registration number	None
Eligibility criteria	6	Specify study characteristics (eg, PICOS, length of follow-up) and report characteristics (eg, years considered, language, publication status) used as criteria for eligibility, giving rationale	9
Information sources	7	Describe all information sources (eg, databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched	9
Search	8	Present full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated	9
Study selection	9	State the process for selecting studies (ie, screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis)	9
Data collection process	10	Describe method of data extraction from reports (eg, piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators	9, 10
Data items	11	List and define all variables for which data were sought (eg, PICOS, funding sources) and any assumptions and simplifications made	9
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis	9
Summary measures	13	State the principal summary measures (eg, risk ratio, difference in means)	10, 11
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (eg, I^2) for each meta-analysis	10, 11
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (eg, publication bias, selective reporting within studies)	10, 11
Additional analyses	16	Describe methods of additional analyses (eg, sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified	10, 11
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram	12

(Continued)

TABLE E1. Continued

Section/topic	Number	Checklist item	Reported on page number
Study characteristics	18	For each study, present characteristics for which data were extracted (eg, study size, PICOS, follow-up period) and provide the citations	12
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12)	12
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (1) simple summary data for each intervention group and (2) effect estimates and confidence intervals, ideally with a forest plot	12-14
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency	12-14
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see item 15)	12-14
Additional analysis	23	Give results of additional analyses, if done (eg, sensitivity or subgroup analyses, meta-regression [see item 16])	14
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (eg, healthcare providers, users, and policy makers)	15
Limitations	25	Discuss limitations at study and outcome level (eg, risk of bias), and at review-level (eg, incomplete retrieval of identified research, reporting bias)	15, 16
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research	16-18
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (eg, supply of data); role of funders for the systematic review	1

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 2009;6:e1000097.

TABLE E2. Overview of non-propensity score-matched studies excluded from the primary analysis

Study	Year of publication	Study design	Center	Study period	RITA	RA	Target	Mean follow-up (mo)	Conclusions
Hayward et al[3]	2007	RCT	Australia (Austin Hospital)	1996-2002	140	145	LCA/RCA	60	These 2 arterial conduits may yield equivalent clinical outcomes at 5 or more years
Borger et al[20]	1998	Observational (no adjustment)	Canada	1989-1996	132	171	LCA/RCA	NA	Sternal complication: RITA, 5.3% vs RA, 0.6%; $P = .01$ Comparable 3 y survival (both 98%; $P = .88$)
Calafiore et al[21]	2002	Observational (no adjustment)	Italy	1992-1996	149	139	LCA only	77 ± 16	Comparable incidence of sternal complication: RA, 4.3% vs RITA, 2.7% ($P = .6$); 8 y survival 86.7% in RA group vs 89.6% in RITA group ($P = .4$)
Caputo et al[22]	2003	Observational (adjusted Cox model)	United Kingdom	1996-2001	336	325	LCA/RCA	RITA, 21; RA, 18	18 mo survival RITA, 98.4% vs RA, 99.7%, HR, 0.25; 95% CI, 0.06-1.10; $P = .07$
Lemma et al[23]	2001	Observational (no adjustment)	Italy	1999-2000	94	156	LCA/RCA	8 ± 4	Superficial sternal wound infection greater in RITA group (6.3% vs 1.3%; $P =$ ns); the probability of survival was similar ($P =$ ns)
Miana et al[24]	2007	Observational (no adjustment)	Brazil	2003-2006	20	38	LCA/RCA	NA	Mediastinitis was not seen in this series of patients. No follow-up available
Vicol et al[25]	2003	Observational (no adjustment)	Germany	1997-2001	129	84	Not reported	35 ± 28	Mediastinitis RITA, 0.8% vs RA, 1.2% $P =$ ns; late mortality RITA, 6.9% vs RA, 5.3%

RITA, Right internal thoracic artery; *RA*, radial artery; *RCT*, randomized controlled trial; *LCA*, left coronary artery; *RCA*, right coronary artery; *NA*, not applicable; *HR*, hazard ratio; *CI*, confidence interval; *ns*, not significant.

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TABLE E3. Pre-treatment variables included for propensity score matching

Study	Variables
Navia et al[5]	Age
	Male
	Diabetes mellitus
	Left ventricular function
	EuroSCORE
	Preoperative renal dysfunction
	Aortic calcification
	Prior coronary surgery
	Preoperative hematocrit
	Non-elective surgery
	Number of vessel disease
	Left main disease
Ruttman et al[8]	Male
	Age
	Body mass index
	Smoker (active or previous)
	Diabetes mellitus
	Chronic obstructive pulmonary disease
	Preoperative renal dysfunction
	Peripheral arterial disease
	Cerebrovascular disease
	Previous percutaneous coronary intervention
	Left ventricular function
	Isolated left main stenosis
	Logistic EuroSCORE
Tsuneyoshi et al[12]	Age
	Male
	Body mass index
	Diabetes mellitus
	Hypertension
	Hyperlipidemia
	Chronic obstructive pulmonary disease
	Estimated glomerular filtration rate
	Previous myocardial infarction
	Peripheral arterial disease
	Left ventricular function
	Mitral regurgitation more than mild
	SYNTAX score
	STS score
Pevni et al[6]	Age
	Female
	Non-insulin-dependent diabetes mellitus
	Insulin-dependent diabetes mellitus
	Diabetes mellitus + end organ damage
	Peripheral vascular disease
	Chronic obstructive pulmonary disease
	Congestive heart failure
	Chronic renal failure
	Recent myocardial infarction
	Old myocardial infarction
	Acute myocardial infarction
	Left ventricular function
	Preoperative intra-aortic balloon pump
	Emergency
	Repeat operation
	Unstable angina
	Prior percutaneous coronary intervention
	Left main
	Number of vessel disease
	EuroSCORE
	Time of operation
Raja et al[7]	Propensity score distance
	Age
	Female
	New York Heart Association class
	Congestive heart failure
	Prior myocardial infarction
	Previous percutaneous coronary intervention
	Hypercholesterolemia
	Hypertension
	Current smoking
	Chronic obstructive pulmonary disease
	Cerebrovascular accident
	Peripheral vascular disease
	History of atrial fibrillation
	Left main stem disease
	Left ventricular function
	Non-elective surgery
	Renal impairment
	Diabetes mellitus
	Body mass index
	Preoperative intra-aortic balloon pump
	Trainee as operator
	Number of grafts
	Incomplete revascularization
	Cardiopulmonary bypass
Tranbaugh et al[11]	Mean age
	Male
	Female
	Body mass index
	Ethnicity
	Left ventricular function
	Prior myocardial infarction
	Stroke
	Cerebrovascular disease
	Aortoiliac peripheral vascular disease
	Femoral popliteal peripheral vascular disease
	Hemodialysis
	Creatinine value >2.5 mg/dL
	Calcified aorta
	Current chronic heart failure
	Chronic obstructive pulmonary disease
	Diabetes
	Hypertension
	Previous percutaneous coronary intervention
	Number of vessel disease
Schwann et al[9]	Age
	Left ventricular ejection fraction
	Completeness of revascularization index

(Continued)

TABLE E3. Continued

Study	Variables
	Male
	Body mass index
	Diabetes
	Hypercholesterolemia
	Chronic obstructive pulmonary disease
	Smoker
	Previous myocardial infarction
	Peripheral vascular disease
	Previous surgery
	Left main disease
	Number of diseased vessels
	Number of grafts
	Deep sternal infection
	Bleeding postoperation
Shi et al[10]	Age
	Male
	Time of operation
	Body mass index
	Hypertension
	Diabetes
	Cerebrovascular disease
	Peripheral vascular disease
	Previous acute myocardial infarction
	Acute myocardial infarction within 7 d
	Previous percutaneous coronary intervention
	Non-elective case
	Active smoking
	Chronic obstructive pulmonary disease
	New York Heart Association class
	Left ventricular function
	Left main disease
	Number of vessel disease
	Hospital where operation was performed
	Number of anastomoses

STS, Society of Thoracic Surgeons.

ACQ

TABLE E4. Newcastle-Ottawa Scale for propensity score-matched studies included in the primary analysis

	Selection					Outcome		
Study, total score	**Representativeness of the exposed cohort**	**Selection of the non-exposed cohort**	**Ascertainment of exposure**	**Demonstration that outcome of interest was not present at start of study**	**Comparability of cohorts on the basis of the design or analysis**	**Assessment of outcome**	**Was follow-up long enough for outcomes to occur**	**Adequacy of follow-up of cohorts**
Navia et al,[5] 9*	* = **truly representative** [page 1: "This is a retrospective analysis of prospectively gathered data over an 8-year period of all patients undergoing off-pum coronary artery bypass (OPCAB) at the Institute Cardiovascular of Buenos Aires and who received total arterial revascularization (TAR) with LITA grafting and a RITA or RA bypass as a second arterial conduit. From January 2003 to May 2011, a total of 1700 consecutive patients (of 1894) were scheduled for urgent or elective procedure undergoing TAR OPCAB and fulfilled the inclusion criteria of our observational study. A total of 1447 patients (85.11%) received BITA grafting, and 253 patients (14.89%) received LITA-RA grafting."]	* = **drawn from the same community as the exposed cohort** [page 1: "This is a retrospective analysis of prospectively gathered data over an 8-year period of all patients undergoing off-pum coronary artery bypass (OPCAB) at the Institute Cardiovascular of Buenos Aires and who received total arterial revascularization (TAR) with LITA grafting and a RITA or RA bypass as a second arterial conduit. From January 2003 to May 2011, a total of 1700 consecutive patients (of 1894) were scheduled for urgent or elective procedure undergoing TAR OPCAB and fulfilled the inclusion criteria of our observational study. A total of 1447 patients (85.11%) received BITA grafting, and 253 patients (14.89%) received LITA-RA grafting."]	* = **secure record** [page 2: "Preoperative, operative, and postoperative data were obtained by retrospective review of clinical and pathology reports from the database and crosschecked with all medical charts."]	* = **yes**	** = **study controls for several variables (PSM study)** [page 2: "Propensity score matching was used to reduce the impact of treatment selection in comparing RA and RITA as the second conduit for TAR."]	* = **record linkage** [page 2: "Preoperative, operative, and postoperative data were obtained by retrospective review of clinical and pathology reports from the database and crosschecked with all medical charts… Late events were achieved by direct communication with the patient, their family, and attending physician, and medical records were revised."]	* = **yes** [page 4: "Median follow-up of all patients was 1364.5 d (IQR, 724-1984 d). Median follow-up of the BITA group was 1283 d (IQR, 697-1861 d). Median follow-up of the LITA-RA group was 2080 d (IQR, 1313-2587 d) ($P < .001$). There was no difference in the proportion of patients with completed follow-up: BITA 94% vs LITA-RA 95.3% ($P = .39$)."]	* = **subjects lost to follow-up unlikely to introduce bias** [page 4: "Median follow-up of all patients was 1364.5 d (IQR, 724-1984 d). Median follow-up of the BITA group was 1283 d (IQR, 697-1861 d). Median follow-up of the LITA-RA group was 2080 d (IQR, 1313-2587 d) ($P < .001$). There was no difference in the proportion of patients with completed follow-up: BITA 94% vs LITA-RA 95.3% ($P = .39$)."]
Pevni et al[6] 9*	* = **truly representative.** [page 2: "This retrospective review of medical records and telephone questionnaires obtaining follow-up was approved by the Institutional Review Board of the Tel Aviv Medical Center. Between 1996 and 2010, a total of 3165 consecutive patients with multivessel coronary artery disease underwent left-sided arterial revascularization at the center. They constituted 74.9% of	* = **drawn from the same community as the exposed cohort.** [page 2: "This retrospective review of medical records and telephone questionnaires obtaining follow-up was approved by the Institutional Review Board of the Tel Aviv Medical Center. Between 1996 and 2010, a total of 3165 consecutive patients with multivessel coronary artery disease underwent left-sided arterial revascularization at the center. They	* = **secure record.** [page 2: "This retrospective review of medical records and telephone questionnaires obtaining follow-up was approved by the Institutional Review Board of the Tel Aviv Medical Center."]	* = **yes.**	** = **study controls for several variables (PSM study).** [page 3: "Propensity score was used to account for differences between groups in preoperative characteristics."]	* = **record linkage.** [page 2: "This retrospective review of medical records and telephone questionnaires obtaining follow-up was approved by the Institutional Review Board of the Tel Aviv Medical Center."]	* = **yes.** [page 4: "Follow-up was 97% complete. The median follow-up was 14.19 (95% CI 13.43-14.95) years."]	* = **subjects lost to follow-up unlikely to introduce bias.** [page 4: "Follow-up was 97% complete. The median follow-up was 14.19 (95% CI 13.43-14.95) years."]

(Continued)

TABLE E4. Continued

Study, total score	Selection: Representativeness of the exposed cohort	Selection: Selection of the non-exposed cohort	Selection: Ascertainment of exposure	Selection: Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Outcome: Assessment of outcome	Outcome: Was follow-up long enough for outcomes to occur	Outcome: Adequacy of follow-up of cohorts
	primary coronary artery bypass grafting procedures for multivessel disease that were performed in our institution during this time period. The composite T-graft technique was employed in 1718 of them. In 1329 patients, one IMA (in most cases, the right) was attached end-to-side to the other IMA. In the remaining 389 patients, the RA was connected end-to-side to the left IMA. The BIMA grafting method was the dominant revascularization procedure performed in our institution throughout the study period for patients who had multivessel disease (4247 patients). In all, 3165 (74.9%) underwent left-sided arterial revascularization (2776 BIMA and 389 single IMA + RA procedures); the remaining 1082 underwent single IMA + saphenous vein grafting.'']	constituted 74.9% of primary coronary artery bypass grafting procedures for multivessel disease that were performed in our institution during this time period. The composite T-graft technique was employed in 1718 of them. In 1329 patients, one IMA (in most cases, the right) was attached end-to-side to the other IMA. In the remaining 389 patients, the RA was connected end-to-side to the left IMA. The BIMA grafting method was the dominant revascularization procedure performed in our institution throughout the study period for patients who had multivessel disease (4247 patients). In all, 3165 (74.9%) underwent left-sided arterial revascularization (2776 BIMA and 389 single IMA + RA procedures); the remaining 1082 underwent single IMA + saphenous vein grafting.'']						
Raja et al[7] 9*	* = **truly representative.** [page 2: ''We retrospectively analysed prospectively collected data from the institutional surgical database (PATS; Dendrite Clinical Systems, Ltd, Oxford, United Kingdom) from April 2001 to May 2013. The PATS database captures detailed information on a wide range of preoperative, intraoperative, and hospital	* = **drawn from the same community as the exposed cohort.** [page 2: ''We retrospectively analysed prospectively collected data from the institutional surgical database (PATS; Dendrite Clinical Systems, Ltd, Oxford, United Kingdom) from April 2001 to May 2013. The PATS database captures detailed information on a wide range of preoperative, intraoperative, and	* = **secure record.** [page 2: ''We retrospectively analysed prospectively collected data from the institutional surgical database (PATS; Dendrite Clinical Systems, Ltd, Oxford, United Kingdom) from April 2001 to May 2013. The PATS database captures detailed information on a wide range of preoperative, intraoperative, and hospital postoperative	* = **yes.**	** = **study controls for several variables (PSM study).** [page 3: ''To control for measured potential confounders in the data set, a propensity score (PS) was generated for each patient from a multivariable logistic regression model based on 24 pre-treatment covariates as independent variables with treatment type (RA vs RIMA) as a binary dependent variables.'']	* = **record linkage.** [page2: ''We retrospectively analysed prospectively collected data from the institutional surgical database (PATS; Dendrite Clinical Systems, Ltd, Oxford, United Kingdom) from April 2001 to May 2013. The PATS database captures detailed information on a wide range of preoperative, intraoperative, and hospital postoperative	* = **yes.** [page 3: ''In the matched sample the mean follow-up time was 8.0 y [interquartile range: 3.0e10.3, max 12.2.'']	* = **subjects lost to follow-up unlikely to introduce bias.** [page 3: ''Fraction missing ranged from 0% (age) to 2.1% (HxCHF).'']

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TABLE E4. Continued

Study, total score	Selection: Representativeness of the exposed cohort	Selection: Selection of the non-exposed cohort	Selection: Ascertainment of exposure	Selection: Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Outcome: Assessment of outcome	Outcome: Was follow-up long enough for outcomes to occur	Outcome: Adequacy of follow-up of cohorts
	postoperative variables (including complications and mortality) for all patients undergoing CABG in our institution. …Patients included in the final analysis met the following criteria: a) first time isolated CABG; b) 2 grafts received; c) surgical strategies included single LIMA for the left anterior descending (LAD) artery and the radial artery for non LAD targets with or without additional saphenous vein grafts (RA group) or the use of the bilateral internal mammary arteries with or without additional saphenous vein grafts (RIMA group).'']	hospital postoperative variables (including complications and mortality) for all patients undergoing CABG in our institution. …Patients included in the final analysis met the following criteria: a) first time isolated CABG; b) 2 grafts received; c) surgical strategies included single LIMA for the left anterior descending (LAD) artery and the radial artery for non LAD targets with or without additional saphenous vein grafts (RA group) or the use of the bilateral internal mammary arteries with or without additional saphenous vein grafts (RIMA group).'']	variables (including complications and mortality) for all patients undergoing CABG in our institution. The data is collected and reported in accordance with the Society for Cardiothoracic Surgery in Great Britain & Ireland database criteria. The database is maintained by a team of full-time clinical information analysts, who are responsible for continuous prospective data collection as part of a continuous audit process. Data collection is validated regularly.'']			variables (including complications and mortality) for all patients undergoing CABG in our institution. The data is collected and reported in accordance with the Society for Cardiothoracic Surgery in Great Britain & Ireland database criteria. The database is maintained by a team of full-time clinical information analysts, who are responsible for continuous prospective data collection as part of a continuous audit process. Data collection is validated regularly.'' – page 3: ''Information about death from any cause is regularly obtained from the General Register Office approximately 1 wk after the event and data on repeat revascularization from national surgical and interventional database.'']		
Ruttmann et al[8] 9*	* = **truly representative.** [page 2: ''This study analyzes all patients who underwent CABG between August 2001 and August 2010 at the Innsbruck Medical University and who received MAR with a LITA graft and either a RITA or RA bypass as a second arterial conduit. Inclusion criteria for this study were first, non-emergent isolated coronary CABG for multivessel coronary artery disease performed by a median sternotomy	* = **drawn from the same community as the exposed cohort.** [page 2: ''This study analyzes all patients who underwent CABG between August 2001 and August 2010 at the Innsbruck Medical University and who received MAR with a LITA graft and either a RITA or RA bypass as a second arterial conduit. Inclusion criteria for this study were first, non-emergent isolated coronary CABG for multivessel coronary artery disease performed by a	* = **secure record.** [page 2: ''Patient data were prospectively collected in full accordance with the standards of the Quality Control Working Group of the Austrian Society of Cardiothoracic Surgery. The data acquisition included a telephone interview by a trained study nurse a month after patient discharge to obtain 30-d mortality and morbidity. Long-term follow-up was performed by telephone interviews with patients and referring	* = **yes.**	** = **study controls for several variables (PSM study).** [page 3: ''Propensity score matching was used to reduce the impact of treatment selection in comparing RA and RITA as the second conduit for MAR.'']	* = **record linkage.** [page 2: ''Patient data were prospectively collected in full accordance with the standards of the Quality Control Working Group of the Austrian Society of Cardiothoracic Surgery. The data acquisition included a telephone interview by a trained study nurse a month after patient discharge to obtain 30-d mortality and morbidity. Long-term follow-up was performed by telephone interviews with patients and referring	* = **yes.** [page 2: ''Median follow-up of all patients was 57.7 mo (range 3–112 mo).'']	**no statement** (however, since ''late death was obtained from routine anniversary follow-up supplemented with the Social Security Death Index (Statistics Austria database),'' it is unlikely that a significant number of subjects was lost at follow-up)

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TABLE E4. Continued

	Selection					Outcome		
Study, total score	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts
	access. Patients suffering a prior myocardial infarction within 1 wk before the CABG procedure were excluded. Additionally, patients receiving a bilateral internal thoracic artery (BITA) together with a concomitant RA (n 89 patients) and patients receiving a totally endoscopic CABG procedure assisted by the Da Vinci telemanipulation device for multivessel disease (either 2-vessel disease or as a hybrid procedure with concomitant percutaneous coronary intervention [PCI]) were excluded from the study (n 45 patients).'']	median sternotomy access. Patients suffering a prior myocardial infarction within 1 wk before the CABG procedure were excluded. Additionally, patients receiving a bilateral internal thoracic artery (BITA) together with a concomitant RA (n 89 patients) and patients receiving a totally endoscopic CABG procedure assisted by the Da Vinci telemanipulation device for multivessel disease (either 2-vessel disease or as a hybrid procedure with concomitant percutaneous coronary intervention [PCI]) were excluded from the study (n 45 patients).'']	cardiologists to evaluate the freedom from angina, myocardial infarction, death from all causes, and cardiac-related deaths. Additionally, coronary angiography reports in patients who underwent repeated cardiac catheterization were obtained and evaluated. Late death was obtained from routine anniversary follow-up supplemented with the Social Security Death Index (Statistics Austria database).'']			cardiologists to evaluate the freedom from angina, myocardial infarction, death from all causes, and cardiac-related deaths. Additionally, coronary angiography reports in patients who underwent repeated cardiac catheterization were obtained and evaluated. Late death was obtained from routine anniversary follow-up supplemented with the Social Security Death Index (Statistics Austria database).'']		
Schwann et al[9] 9*	* = **truly representative.** [page 2: ''Our analysis included all multi-vessel coronary artery disease patients undergoing a LITA to left anterior descending coronary artery (LAD) CABG (1987–2011) who received a total of two or more coronary grafts. Patients were excluded in case of concomitant aortic, valvular, congenital cardiac surgery or those without an available US Social Security Number. Patients were retained in case of concurrent coronary and/or carotid endarterectomy. The final study population consisted of 8220 total patients divided to three grafting method sub-cohorts; 4484 received a	* = **drawn from the same community as the exposed cohort.** [page 2: ''Our analysis included all multi-vessel coronary artery disease patients undergoing a LITA to left anterior descending coronary artery (LAD) CABG (1987–2011) who received a total of two or more coronary grafts. Patients were excluded in case of concomitant aortic, valvular, congenital cardiac surgery or those without an available US Social Security Number. Patients were retained in case of concurrent coronary and/or carotid endarterectomy. The final study population consisted of 8220 total patients divided to three grafting method sub-cohorts;	* = **secure record.** [page 2: ''This investigation is a retrospective analysis of three cardiac surgery databases collected prospectively at the University of Toledo Medical Center (Hospital1, Toledo, Ohio), Mercy Saint Vincent Medical Center (Hospital2, Toledo, Ohio) and Yale New Haven Hospital (YNHH) (Hospital3, New Haven, Conn) in accordance with the STS National Adult Cardiac Surgery Database definitions and criteria. As the study period predated the development of the STS database, the earliest data were abstracted from an institutional database and chart review (YNHH).'']	* = **yes.**	** = **study controls for several variables (PSM study)**. [page 3: ''To minimize the confounding effect of these factors, we used propensity score matching to derive matched triplets with similar demographics, risk factor and operative parameters.'']	* = **record linkage.** [page 2: ''Long-term mortality data were secured from institutional followups, and from recurrent (twice annually, last November 2011) searches of the US Social Security Death Index (SSDI) database (http://ssdi.genealogy.rootsweb.com).'']	* = **yes.** [page 2: ''The available study followup period ranged between 3 and 189 mo'']	**no statement** (however, since ''Long-term mortality data were secured from institutional followups, and from recurrent (twice annually, last November 2011) searches of the US Social Security Death Index (SSDI) database,'' it is unlikely that a significant number of subjects was lost at follow-up)

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TABLE E4. Continued

Study, total score	Selection: Representativeness of the exposed cohort	Selection: Selection of the non-exposed cohort	Selection: Ascertainment of exposure	Selection: Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Outcome: Assessment of outcome	Outcome: Was follow-up long enough for outcomes to occur	Outcome: Adequacy of follow-up of cohorts
	single arterial (LITA) graft (SABG group), 3095 received a LITA with one or more radial artery grafts (RA-MABG group) and 641 received a LITA with an additional RITA graft (RITA-MABG group). Patients in the SABG, RA-MABG and RITA-MABG groups may have also received saphenous vein grafts (SVG).'']	4484 received a single arterial (LITA) graft (SABG group), 3095 received a LITA with one or more radial artery grafts (RA-MABG group) and 641 received a LITA with an additional RITA graft (RITA-MABG group). Patients in the SABG, RA-MABG and RITA-MABG groups may have also received saphenous vein grafts (SVG).'']						
Shi et al[10] 9*	* = **truly representative**. [page 2: ''We reviewed a multicenter database containing a total of 23,343 adult cardiac procedures performed from March 1, 1977, to December 31, 2010, across 7 centers affiliated with the University of Melbourne. These were Austin Hospital, Epworth Hospital Richmond, Epworth Eastern Hospital, Knox Hospital, Royal Melbourne Hospital, St Vincent's Hospital Melbourne, and Warringal Hospital.'']	* = **drawn from the same community as the exposed cohort.** [page 2: ''Patients were included even if they underwent incomplete revascularization for 3-vessel disease. As such, 6059 patients were identified. From this, a study cohort of 2821 patients was formed, with 912 (32%) receiving BITA and the remaining 1909 (68%) receiving a SITA.'']	* = **secure record.** [page 2: ''The database records detailed patient demography, preoperative risk factors, operative technique, postoperative hospital course, and clinical outcomes including 30-d or in-hospital morbidity and mortality. Data were collected prospectively. Survival status of patients was obtained from the National Death Index, which records all deaths within Australia.'']	* = **yes.**	** = **study controls for several variables (PSM study).** [page 3: ''Propensity score matching was performed to correct for the bias associated with the use of BITAs.'']	* = **record linkage.** [page 2: ''Our primary endpoint was long-term survival, and this was obtained using data from the Australian National Death Index.'']	* = **yes.** [page 3: ''Preoperative demographic and investigative data, operative variables and postoperative (30-d) mortality, morbidity, and 15-y survival were compared between SITA and BITA study groups.'']	**no statement** (however, since ''survival status of patients was obtained from the National Death Index, which records all deaths within Australia,'' it is unlikely that a significant number of subjects was lost at follow-up)
Tranbaugh et al[11] 9*	* = **truly representative.** [page 1: ''We performed a retrospective cohort study of our 2 affiliated institutions' experiences using either the RA or the RITA to bypass the circumflex coronary artery during primary isolated CABG using the LITA to bypass the left anterior descending artery from January 1995 to January 2009. Beth Israel Medical Center (BIMC) and St.	* = **drawn from the same community as the exposed cohort.** [page 2: ''RA use at BIMC was at first selective, with approximately 33% of CABG patients receiving a RA for indications of age younger than 65 y or unavailable venous conduit. Contraindications to RA use were hemodialysis or chronic renal insufficiency, Raynaud's disease, and, more recently,	* = **secure record.** [page 1: ''Both centers maintain an identical New York State–mandated, prospectively collected database.'']	* = **yes.**	** = **study controls for several variables (PSM study).** [page 2: ''A logistic propensity scoring model (based on the following significant predictors of treatment probability: age, sex, ethnicity, year of surgery, ejection fraction, priority, myocardial infarction, hypertension, chronic obstructive pulmonary disease [COPD], heart failure, number of grafts, number of	* = **record linkage.** [page 2: ''The Social Security Death Index (www.Genealogybank.com) was searched in October 2012 and was used to identify patients who died after hospital discharge...MAEs were collected prospectively and were defined by the Department of Health Cardiac Surgery Reporting System (http://www.health.ny.gov/statistics/diseases/	* = **yes.** [page 4: ''Long-term follow-up evaluation averaged 9.0 ± 4.3 y for the RA patients and 8.5 ± 4.6 y for the RITA patients, with a range 0.1 to 16 y.''	**no statement** (however, since ''the Social Security Death Index (www.Genealogybank.com) was searched in October 2012 and was used to identify patients who died after hospital discharge,'' it is unlikely that a significant number of subjects was lost at follow-up)

(Continued)

TABLE E4. Continued

	Selection					Outcome		
Study, total score	**Representativeness of the exposed cohort**	**Selection of the non-exposed cohort**	**Ascertainment of exposure**	**Demonstration that outcome of interest was not present at start of study**	**Comparability of cohorts on the basis of the design or analysis**	**Assessment of outcome**	**Was follow-up long enough for outcomes to occur**	**Adequacy of follow-up of cohorts**
	Luke's Roosevelt Hospital Center (SLR) are closely affiliated as part of Continuum Health Partners in New York, NY. Both centers maintain an identical New York State–mandated, prospectively collected database. BIMC used the RA as the primary second arterial conduit and SLR used the free RITA. Patients received additional SV grafts as needed.'']	radial artery catheterization. Overtime, use gradually increased. Currently, 75% of all patients receive a RA at BIMC using a liberalized age limit of younger than 80 y. Average total RA use was 43% over the past 17 y whereas RITA use at SLR has been consistently very high at near 60%. There are no age restrictions at SLR and there were no contraindications to using a RITA graft. These different institutional grafting strategies resulted in a much younger RA population at BIMC than the SLR RITA group, as seen in Table 1. A total of 6566 patients had isolated primary CABG using the LITA at BIMC (n ¼ 4385) and at SLR (n ¼ 2181) during the study period. Forty-one percent of these patients (2707) received a second arterial graft, whereas the other 3859 patients received a LITA and SV grafts (SITA).'']			arterial grafts, hemodialysis, and triple-vessel disease) was developed to summarize covariate information regarding treatment selection (RA vs RITA) into a single scalar value (propensity score [PS]) and subsequently was used in a nearest-neighbor, caliper-constrained matching technique.'']	cardiovascular/index.htmNYS).'']		
Tsuneyoshi et al[12] 9*	* = **truly representative.** [page 2: ''A total of 805 patients received elective isolated OPCAB at Kurashiki Central Hospital between January 2000 and December 2013. Of these patients, 232 received bilateral internal thoracic arteries (BITA) and 152 received single ITA plus the RA anastomosed to the aorta following the inclusion criteria.'']	* = **drawn from the same community as the exposed cohort.** [page 2: ''A total of 805 patients received elective isolated OPCAB at Kurashiki Central Hospital between January 2000 and December 2013. Of these patients, 232 received bilateral internal thoracic arteries (BITA) and 152 received single ITA plus the RA anastomosed to the aorta following the inclusion criteria.'']	**no description** (however, it is likely that a ''secure record'' was used – see page 2, ''Materials and methods'')	* = **yes.**	** = **study controls for several variables (PSM study).** [page 2: ''A propensity score-matched analysis was performed using a multivariate logistic regression model based on the variables, which revealed a *P* value of less than 0.2.'']	* = **record linkage.** [page 2: ''A follow-up was performed annually or more frequently at the outpatient clinic of our institution.'']	* = **yes.** [page 3: ''The mean follow-up was 6.1 and 7.8 y for groups BITA and LITA + RA, respectively ($P = .28$).'']	* = **subjects lost to follow-up unlikely to introduce bias.** [page 2: ''The follow-up rate was 91%.'']

TABLE E5. Outcomes definition for sternal wound complications and operative mortality in studies included in the primary analysis

Study	Sternal wound complications	Operative mortality
Navia et al[5]	Deep sternal wound infection was defined according to the evidence of mediastinitis during sternal reexploration	Hospital mortality
Pevni et al[6]	Deep sternal infection in this setting was defined as the presence of deep infection, in combination with late dehiscence requiring sternectomy	Within 30 d
Raja et al[7]	The incidence of superficial and deep sternal wound infection as defined by the Centers for Disease Control and Prevention	Within 30 d
Ruttmann et al[8]	Sternal dehiscence with a need for surgical intervention	Not defined
Schwann et al[9]	Deep sternal infection not defined	Within 30 d
Shi et al[10]	Deep sternal wound infection not defined	Within 30 d
Tranbaugh et al[11]	Deep sternal infection not defined	Within 30 d
Tsuneyoshi et al[12]	Deep sternal infection was defined as the presence of mediastinitis	Hospital mortality