Systematic Review

A meta-analysis comparing bilateral internal mammary artery with left internal mammary artery for coronary artery bypass grafting

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Background: Increasing evidence continues to demonstrate a survival advantage for bilateral internal mammary artery (BIMA) over left internal mammary artery (LIMA) for coronary artery bypass grafting (CABG). We performed an updated meta-analysis of published studies comparing BIMA versus LIMA in CABG operations and assessed differences in long-term survival.

Methods: Electronic searches for studies comparing BIMA versus LIMA were performed using three databases from 1972 to December 2012. Studies with at least four years of follow-up and at least 100 patients in each group were included for review. We used a random-effect model and pooled hazard ratios from across all included studies.

Results: No randomized controlled trials and 27 observational studies totaling 79,063 patients (19,277 BIMA, 59,786 LIMA) were included for final analysis. The BIMA group demonstrated significantly better long-term survival than the LIMA group [hazard ratio, 0.78; confidence interval, 0.72-0.84; P<0.00001].

Conclusions: In an updated meta-analysis, we demonstrate an increase in long-term survival in patients receiving BIMA as a primary grafting strategy over those receiving a LIMA. Although no randomized controlled trials were included in this meta-analysis, the survival benefit seen with a BIMA cannot be overlooked when determining which operation to perform in CABG patients. Until the long-term results of the ART trial are published, we offer best available evidence in favor of BIMA over LIMA for CABG surgery.

Keywords: Internal mammary artery, bilateral, coronary artery bypass, meta-analysis

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Introduction

Coronary artery bypass grafting (CABG) still remains the most common open cardiac surgery procedure performed worldwide today. The gold standard for CABG is the left internal mammary artery (LIMA) to the left anterior descending artery (LAD), as this conduit selection provides increased survival and freedom from myocardial infarction, symptoms, and reinterventions compared to a saphenous vein graft (SVG) to the same artery (1). Additionally, angiographic studies have shown late occlusion of the LIMA to LAD to be far less than that of a SVG to the LAD (2,3). The proposed mechanism for this increased patency and subsequent improved clinical outcome is due to the inherent characteristics of the internal mammary artery endothelium and improved run-off of the LAD territory (4-6).

Often patients need more than one graft during a CABG procedure to bypass extensive disease in other coronary

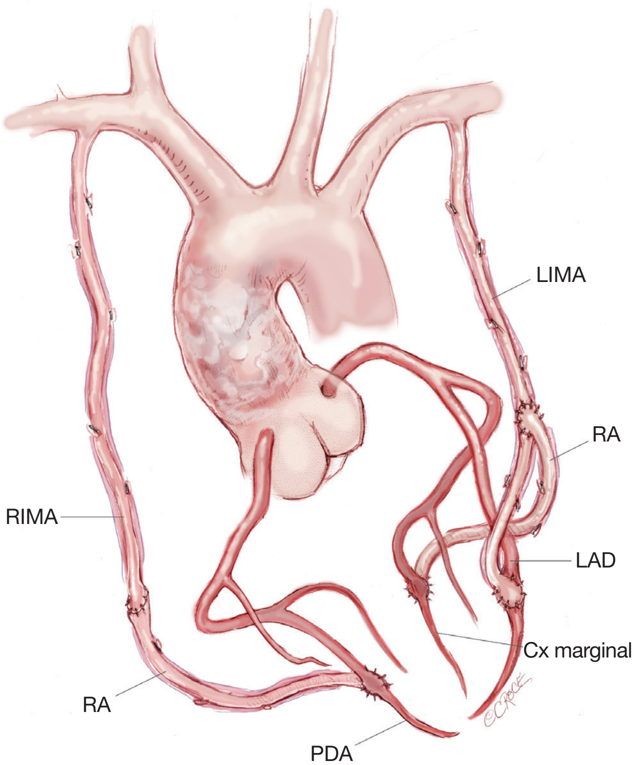

Figure 1 Illustration of bilateral internal mammary artery grafts. RIMA, right internal mammary artery; LIMA, left internal mammary artery; LAD, left anterior descending artery; PDA, posterior descending artery; Cx, circumflex; RA, radial artery

arteries. Given to the clearly demonstrated benefits of the LIMA on clinical and angiographic outcomes, the advantages and disadvantages of the bilateral internal mammary artery (BIMA) technique (*Figure 1*) have been rigorously studied through multiple retrospective and prospective cohort studies. A meta-analysis of seven observational studies that included 15,962 patients (11,269 LIMA and 4,693 BIMA) was performed in 2001 by Taggart *et al*. (7). In this landmark meta-analysis, the BIMA group demonstrated significantly better survival than the LIMA group [hazard ratio (HR), 0.81; 95% confidence interval (CI), 0.70-0.94]. This sparked an even greater number of non-randomized studies investigating long-term outcomes of BIMA versus LIMA in the general population of CABG patients as well as specific subpopulations.

Yet there still remains doubt as to whether BIMA is the better choice for patients in the long-term as the only randomized controlled trial (ART Trial) to date evaluating long-term survival is still ongoing (8). Additionally, only 4-12% of CABGs performed today use BIMA over a LIMA plus SVG, so clearly this is an example where evidence has not being translated into clinical practice (9,10). An updated meta-analysis was therefore undertaken as the studies included in the previous meta-analysis are few compared to the published literature to date and may have been confounded by patient selection bias as early use of the BIMA technique was often employed only in the young and low-risk patient populations.

We aimed to identify studies reporting clinical outcomes with BIMA versus LIMA to determine whether the use of BIMA has an increased long-term survival over other conduits. The primary outcome measured in this meta-analysis was survival.

Methods

Literature search strategy

Electronic searches were performed in three databases from January 1972 to December 2012: Medline (between 1972-2012), Embase (between 1980-2012), and the Cochrane Central Register of Controlled Trials (inception-2012). The final search was conducted on January 21, 2013. To achieve the maximum sensitivity of the search strategy and identify all studies, we searched the databases for publications containing the words: coronary, mammary or thoracic and artery; single, double, multiple, bilateral, unilateral, total or complete; and graft, bypass, revascularization, or reconstruction. These search terms included all search terms used in the original meta-analysis by Taggart *et al*. (7), plus additional keywords decided upon by the authors. Terms were searched in isolation or in combination with alternate forms, synonyms, abbreviations, or database indexing terms. All identified articles were systematically reviewed using the inclusion and exclusion criteria. Additionally, references from the final included studies were reviewed for further identification of potentially relevant studies that were missed in the original search.

Selection criteria

The same inclusion and exclusion criteria were used as in the original meta-analysis published by Taggart *et al*. (7). Eligible studies for this meta-analysis included those in which patient cohorts underwent CABG surgery utilizing the BIMA approach and the LIMA approach. We included published studies that investigated at least 100 patients in the BIMA cohort and 100 patients in the LIMA cohort. Furthermore, only those studies with a follow-up greater than 4 years were included. If multiple studies were published from the same center, only the last recorded publication with the most complete results was included. All non-English studies, duplicated studies, review articles, case reports, abstracts, conference presentations, editorials, and expert opinions were excluded.

The same endpoints and definition of endpoints were used as in the original publication. The primary outcome assessed was long-term survival and was defined as time from operation to death from any cause.

Data extraction and critical appraisal

Two authors (AJW and SZ) independently reviewed each article and determined inclusion of the studies for final analysis. All data were extracted from the relevant article texts, tables, and figures (AJW and SZ). Discrepancies between the two reviewers were resolved by discussion and consensus with a third author (TDY). A fourth author (DPT) confirmed the final results.

Statistical analysis

We used a random-effect meta-analysis. If a study did not report a specific variable it was not included in the overall average for that variable reported in this meta-analysis: mean follow-up (2,11-15), sex (16), diabetes (17), age (2), and ejection fraction (2,11,12,16-25). The HR and CI were extracted from all studies and included in the final analysis. This was accomplished through methods described in the previous meta-analysis (26). Specifically, the HR and CI of the following studies were derived from their total occurrence numbers and log-rank P-value: Joo *et al*. (27), Bonacchi *et al*. (28), and Danzer *et al*. (29); the HR and CI of the following studies were derived from their Kaplan-Meier survival projections along with initial population sizes assuming a fixed rate of censoring: Pick *et al*. (30), Berreklouw *et al*. (19), Lytle *et al*. (20), Jones *et al*. (17), Tarelli *et al*. (31), Dewar *et al*. (11), and Hirotani *et al*. (13) The overall study results by Dewar *et al*. (11) were obtained through a weighted average between the less than 60 years old patient group and greater than 60 years old patient group as described previously. In all cases where the prior meta-analysis yielded the latest HR and CI, the derivations were compared and no significant differences were detected as a result of the specified HR and CI that were used. For the remainder of the studies, the HR and CI were provided. Finally, the LN (HR) and standard error (SE) of LN (HR) were obtained from the HR and CI explicitly based on the same method used within the original meta-analysis.

Evidence of publication bias was sought using the methods of Egger *et al*. (32) and Begg *et al*. (33). A contour-enhanced funnel plot was performed to aid in interpreting the funnel plot (34). If studies appear to be missing in areas of low statistical significance, then it is possible that the asymmetry is due to publication bias. If studies appear to be missing in areas of high statistical significance, then publication bias is a less likely cause of funnel asymmetry. Intercept significance was determined by the t-test suggested by Egger *et al*. (32). $P<0.05$ was considered representative of statistically significant publication bias. All statistical analyses were conducted with Review Manager version 5.2.1 (Cochrane Collaboration, Software Update, Oxford, United Kingdom) or STATA version 11.0 (Stata Corporation, College Station, TX).

Results

Literature search

A total of 3,762 publications were identified through three electronic database searches (*Figure 2*). After exclusion of duplicate or irrelevant publications, 92 studies were retrieved. One additional study [Parsa *et al*. (15)] published after the final search was added as the authors felt its importance warranted inclusion. A thorough evaluation of all 93 studies resulted in 27 being included in the present meta-analysis (*Table 1*). Of these 27 studies, 25 were retrospective cohort studies and 2 were prospective cohort studies. No randomized controlled trials were eligible for inclusion in this meta-analysis. Out of the 7 studies included in the original meta-analysis by Taggart *et al*., 4 were included in this updated publication (the 3 studies that were not included were updated with more recent publications from the same center). The 27 studies included a total of 79,063 patients, of which 19,277 were BIMA and 59,786 were LIMA patients.

Demographics

The studies consisted of on-pump CABG (n=11), off-pump CABG (n=2), and mixed (n=8) as the primary means for performing the operation. Six studies did not report how the procedure was performed (*Table 1*). Six of the 27 studies

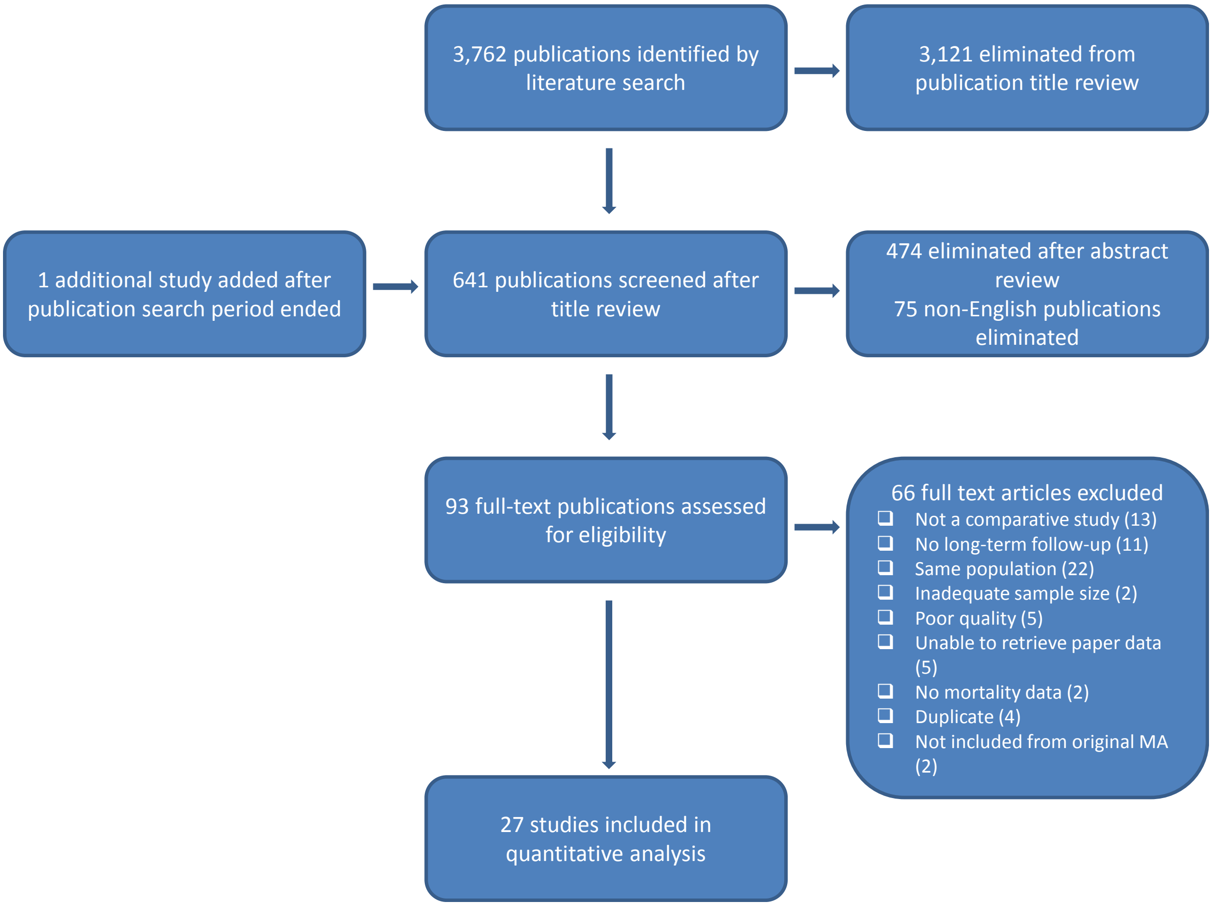

Figure 2 Flowchart of the method for selecting the studies included in the meta-analysis (MA)

Table 1 List of studies comparing BIMA versus LIMA included in the meta-analysis

Study	Year of publication	Study period	Type of study	Patient population	On *vs.* off pump	Exclusion criteria
Naunheim (18)	1992	1972-1975	Retrospective pair matched cohort	General	On	Age >60, left ventricular function >15, LAD stenosis <70%
Dewar (11)	1995	1984-1992	Retrospective pair matched cohort	General	On	NR
Pick (30)	1997	1983-1986	Retrospective cohort	General	On	Single vessel disease, alternate venous or arterial conduits, endarterectomies, reoperations
Buxton (12)	1998	1985-1995	Retrospective cohort	General	On	None
Jones (17)	2000	1986-1996	Retrospective cohort	>65 years	On	None
Berreklouw (19)	2001	1985-1990	Retrospective matched cohort	General	On	Free IMA or GEA grafts used, reoperations, concomitant procedures
Danzer (29)	2001	1983-1989	Retrospective cohort	General	On	None
Endo (2)	2001	1985-1998	Retrospective cohort	General	NR	Non-elective, reoperations, concomitant procedures, long-term dialysis patients

Table 1 (*continued*)

Table 1 (continued)

Study	Year of publication	Study period	Type of study	Patient population	On *vs.* off pump	Exclusion criteria
Tarelli (31)	2001	1988-1990	Retrospective cohort	General	On	Single vessel disease, no LIMA grafted, presence of ventricular aneurysm
Hirotani (13)	2003	1991-2003	Retrospective cohort	Diabetic	On	Concomitant procedures, congenital heart disease, post-infarct VSD
Calafiore (35)	2004	1986-1999	Propensity matched prospective cohort	General	Mix	Patients older than 75
Lytle (20)	2004	1971-1989	Propensity matched retrospective cohort	General	NR	Non-IMA arterial grafts used
Stevens (36)	2004	1985-1995	Retrospective cohort	General	NR	Single or double CABG performed, concomitant procedure, reoperation, use of GEA graft
Bonacchi (28)	2006	1997-2003	Retrospective cohort	Unstable angina	On	Elective operations
Toumpoulis (21)	2006	1992-2002	Propensity matched retrospective cohort	Diabetic	Mix	Non-diabetic patients
Mohammadi (22)	2008	1992-2005	Retrospective cohort	General	NR	None
Carrier (23)	2009	1995-2007	Retrospective cohort	General	NR	Reoperations, concomitant surgery
Kurlansky (24)	2010	1972-1994	Retrospective cohort	General	On	Use of only SVG, concomitant procedures, only one distal anastomosis
Kieser (16)	2011	1995-2008	Retrospective cohort	General	NR	Reoperation, concomitant procedure, non-Alberta residents, patients with incomplete data
Glineur (37)	2012	1985-1995	Propensity matched retrospective cohort	General	Mix	None
Grau (38)	2012	1994-2010	Propensity matched retrospective cohort	General	Mix	Reoperation, concomitant procedure, use of radial artery, only one graft
Joo (27)	2012	2000-2009	Propensity matched retrospective cohort	RIMA to RCA	Off	On-pump CABGs, off-pump CABGs without IMA graft
Kelly (25)	2012	1995-2009	Retrospective cohort	General	Mix	Fewer than 2 grafts, reoperation, no IMA used
Kinoshita (39)	2012	2002-2010	Propensity matched retrospective cohort	Elderly	Off	Preoperative percutaneous CPB, age <70, only one graft, on-pump CABG
Locker (40)	2012	1993-2009	Propensity matched retrospective cohort	General	Mix	Concomitant procedures, reoperation, congenital cardiac anomalies, single vessel disease,
Puskas (14)	2012	2002-2010	Retrospective cohort	General	Mix	Emergency cases, only one graft, no IMA used
Parsa (15)	2013	1984-2009	Prospective cohort	General	Mix	None

LAD, left anterior descending artery; NR, not reported; IMA, internal mammary artery; GEA, gastroepiploic artery; VSD, ventricular septal defect; CABG, coronary artery bypass graft; SVG, saphenous vein graft; CPB, cardiopulmonary bypass; BIMA, bilateral internal mammary artery; LIMA, left internal mammary artery

Table 2 Study demographics

Study	Number of patients		Length of follow up (yrs)		Total follow up	Age (yrs)		Male (%)		Diabetes (%)		Ejection fraction (mean)	
	BIMA	LIMA	BIMA	LIMA	(yrs)	BIMA	LIMA	BIMA	LIMA	BIMA	LIMA	BIMA	LIMA
Naunheim (18)	100	100	14	14	NR	50	51	83	87	4	3	NR	NR
Dewar (11)	377	765	NR	NR	4†	61	62	85	83	18	19	NR	NR
Pick (30)	160	161	9.8	9.8	NR	60	62	82	80	17	27	60.0	60.0
Buxton (12)	1,269	1,557	NR	NR	4.3	59	65	89	78	7	20	NR	NR
Jones (17)	172	338	5	5	NR	69.2	69.7	80.8	90.2	NR	NR	NR	NR
Berreklouw (19)	249	233	9.7	10	NR	53.7	56	89.6	83.7	6	7.4	NR	NR
Danzer (29)	382	139	10	10	NR	59.8	57.1	88	89.9	13.6	13	57.0	61.0
Endo (2)	443	688	NR	NR	6.2†	61†	62†	90.3	80.8	42.9	40.3	54.0†	54.0†
Tarelli (31)	150	150	9.2	9.1	NR	56.5	59.3	92.7	82.7	17	37	57.2	54.5
Hirotani (13)	179	124	NR	NR	12	64.8	63.9	77	75	100	100	48.2	48.8
Calafiore (35)	570	570	7.1	7.5	NR	60.7	60.8	80.7	82.5	24.2	24.2	59.4	59.3
Lytle (20)	1152	1152	16.2	16.3	NR	57.5	57.8	88	86	12	12	NR	NR
Stevens (36)	1,808	2,498	8	12	NR	57	63	88	75	12	18	NR	NR
Bonacchi (28)	320	332	5.6	5.6	NR	59	63	82	80	30	34	NR	NR
Toumpoulis (21)	490	490	4.7	4.7	NR	63.6	64.5	55.1	56.1	100	100	NR	NR
Mohammadi (22)	1,388	9,566	6.6	5.5	NR	55	63.7	89.3	76.6	10.9	31	NR	NR
Carrier (23)	1,235	5,420	6	6	NR	61	68	84	71	21	31	NR	NR
Kurlansky (24)	2,215	2,369	12.7	11.1	NR	62.9	67.5	85.1	74.3	20.8	27.3	NR	NR
Kieser (16)	1,038	4,029	6.4	7.1	NR	58	67.6	NR	NR	27.8	26.2	NR	NR
Glineur (37)	297	291	16.3	15.1	NR	57	61	89	89	16	27	56.0	53.0
Grau (38)	928	928	9	9	NR	60.9	62.1	89.2	89.3	10.8	10.9	52.0	51.0
Joo (27)	366	366	7	7	NR	60.7	60.1	76.2	78.7	37.8	39.3	56.9	55.9
Kelly (25)	1,079	6,554	5.4	4.6	NR	58.4	65	82	75	26	37	NR	NR
Kinoshita (39)	217	217	4.3	4.3	NR	76.1	76.3	78.3	76.5	44.2	48.8	53.0	52.0
Locker (40)	1,153	1,153	7.6	7.6	NR	59	59	74.8	73.8	18.5	19.2	58.0	58.0
Puskas (14)	812	2,715	NR	NR	8	58.4	63.9	83.9	67	28.6	44.7	51.7	49.7
Parsa (15)	728	16,881	NR	NR	25	59	64	80.2	71.5	14.7	29.9	51.0	52.0
Weighted average			8.8	7.1		59.4	64.4	84.2	72.2	21.5	30.3	55	52

†median; BIMA, bilateral internal mammary artery; LIMA, left internal mammary artery; NR, not reported

consisted of patient subsets, including: diabetic patients only (n=2), elderly patients only (n=2), unstable angina patients only (n=1), and right coronary artery anastomoses only (n=1). The exclusion criteria for each study are reported in *Table 1*. *Table 2* details BIMA and LIMA demographics for all included studies. The majority of patients in these studies were male (76.8%): the BIMA group (84.2%) and the LIMA group (74.4%). The average age for all patients included was 63.2 years (BIMA 59.4 *vs.* LIMA 64.4 years). Diabetes was present in 28.1% of the entire population (BIMA 21.5% *vs.* LIMA 30.3%). Although not presented in 15 out of the 27 studies, the mean ejection fraction (EF) for the studies that did report this number was 0.53 (BIMA 0.55 *vs.* LIMA 0.52). The overall average length of follow-up for all studies that reported this result was 7.6 years: 8.8 years for BIMA patients and 7.1 years for LIMA patients.

Outcomes

Figure 3 presents the individual HRs for survival for all

Study or Subgroup	log[Hazard Ratio]	SE	BIMA Total	LIMA Total	Weight	Hazard Ratio IV, Random, 95% CI	Year
Naunheim	-0.288	0.265	100	100	1.7%	0.75 [0.45, 1.26]	1992
Dewar	0.01	0.272	377	765	1.6%	1.01 [0.59, 1.72]	1995
Pick	-0.198	0.247	160	161	1.9%	0.82 [0.51, 1.33]	1997
Buxton	-0.342	0.127	1269	1557	4.9%	0.71 [0.55, 0.91]	1998
Jones	-0.288	0.181	172	338	3.1%	0.75 [0.53, 1.07]	2000
Tarelli	0.02	0.349	150	150	1.0%	1.02 [0.51, 2.02]	2001
Berreklouw	-0.274	0.301	249	233	1.4%	0.76 [0.42, 1.37]	2001
Endo	-0.051	0.179	443	688	3.1%	0.95 [0.67, 1.35]	2001
Danzer	-1.347	0.639	382	139	0.3%	0.26 [0.07, 0.91]	2001
Hirotani	-1.386	0.805	179	124	0.2%	0.25 [0.05, 1.21]	2003
Stevens	-0.431	0.106	1808	2498	5.8%	0.65 [0.53, 0.80]	2004
Calafiore	0.642	0.367	570	570	1.0%	1.90 [0.93, 3.90]	2004
Lytle	-0.301	0.071	1152	1152	7.9%	0.74 [0.64, 0.85]	2004
Toumpoulis	-0.117	0.126	490	490	4.9%	0.89 [0.69, 1.14]	2006
Bonacchi	-0.58	0.306	320	332	1.3%	0.56 [0.31, 1.02]	2006
Mohammadi	-3.912	1.528	1388	9566	0.1%	0.02 [0.00, 0.40]	2008
Carrier	-0.431	0.119	1235	5420	5.2%	0.65 [0.51, 0.82]	2009
Kurlansky	-0.186	0.047	2215	2369	9.3%	0.83 [0.76, 0.91]	2010
Kieser	-0.117	0.103	1038	4029	6.0%	0.89 [0.73, 1.09]	2011
Locker	-0.315	0.107	1153	1153	5.8%	0.73 [0.59, 0.90]	2012
Puskas	-0.431	0.155	812	2715	3.8%	0.65 [0.48, 0.88]	2012
Kinoshita	-0.58	0.291	217	217	1.4%	0.56 [0.32, 0.99]	2012
Kelly	-0.198	0.096	1079	6554	6.4%	0.82 [0.68, 0.99]	2012
Joo	-0.01	0.169	366	366	3.4%	0.99 [0.71, 1.38]	2012
Grau	-0.4	0.115	928	928	5.4%	0.67 [0.54, 0.84]	2012
Glineur	-0.301	0.127	297	291	4.9%	0.74 [0.58, 0.95]	2012
Parsa	-0.051	0.065	728	16881	8.2%	0.95 [0.84, 1.08]	2013
Total (95% CI)			**19277**	**59786**	**100.0%**	**0.78 [0.72, 0.84]**	

Heterogeneity: Tau² = 0.01; Chi² = 47.10, df = 26 (P = 0.007); I² = 45%

Test for overall effect: Z = 6.61 (P < 0.00001)

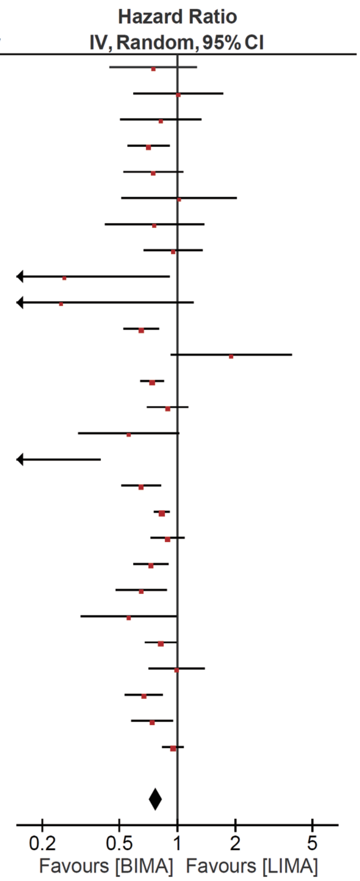

Figure 3 Forest plot of the hazard ratio (HR) of survival in BIMA versus LIMA studies. The estimate of the HR of each trial corresponds to the middle of the squares, and the horizontal line shows the 95% confidence interval (CI). On each line, the inverse variance and study size is shown. The sum of the statistics is represented by the middle of the solid diamond. A test of heterogeneity between the trials within a subgroup is given below the summary statistics. IV, inverse variance; BIMA, bilateral internal mammary artery; LIMA, left internal mammary artery

studies comparing BIMA versus LIMA. Of the 27 studies included in this meta-analysis, 13 had a statistically significant HR below unity. One study reported a statistically significant harmful effect for patients receiving a BIMA operation (35). However, after recalculating the results from this study we concluded that this was only a trend and not statistically significant (see *Figure 3* Calafiore 2004). The results of the studies combined indicated a statistically significant benefit in survival for patients receiving BIMA versus LIMA for CABG (HR 0.78, CI: 0.72-0.84, I^2=45%, P<0.00001).

Begg's funnel plot and Egger's test were performed to assess publication bias in the literature. All 27 included studies yielded a Begg's test score of P=0.692 and an Egger's test score of P=0.286, while inspection of the contour-enhanced funnel plot (*Figure 4*) showed no significant asymmetry. These results suggest that publication bias was not an influencing factor.

Discussion

The use of the internal mammary artery (IMA) for conduit selection has changed greatly since its initial introduction in the 1950s and 1960s. Initially, conduit choice favored SVGs over the IMA until seminal work by Loop *et al.* (1) in 1986 showed a distinct clinical advantage in favor of the LIMA. This led to the LIMA-LAD anastomosis to become the gold standard for CABG patients. With the survival benefit demonstrated by the LIMA-LAD, a small number of centers began using BIMAs more often as a grafting strategy since it was thought that the same benefit from the LIMA could be extrapolated to BIMA. Following this idea,

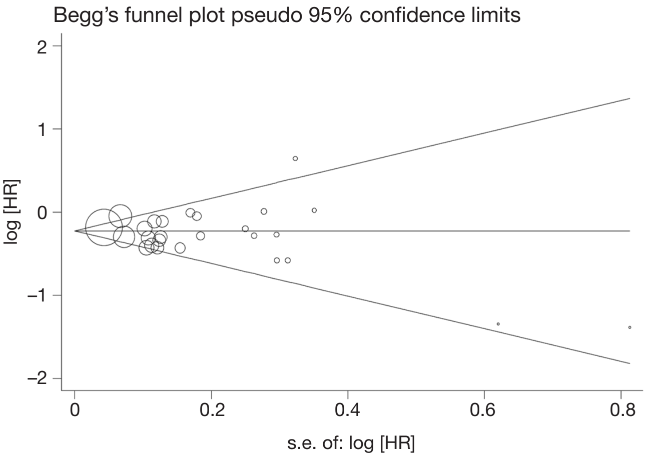

Figure 4 Funnel plot for the meta-analysis of mortality comparing BIMA versus LIMA in all 27 included studies. The log of hazard ratio (HR) comparing mortality (vertical axis) is presented against the standard error (SE) of the log of HR (horizontal axis). The SE inversely corresponds to the study size. Asymmetry of the plot can indicate publication bias. BIMA, bilateral internal mammary artery; LIMA, left internal mammary artery

a number of retrospective studies (12,20,36) demonstrated a survival advantage in patients receiving a BIMA. In this updated meta-analysis involving 27 observational studies comparing patients receiving BIMA versus LIMA grafts, we also show a statistically significant reduction in long-term mortality in the BIMA group.

This finding is in agreement with the previous meta-analysis by Taggart *et al*., who also demonstrated a survival benefit, albeit with only 7 studies and one-fifth of the 79,000 patients included in this current version. The studies that were included in this meta-analysis averaged almost 8 years of follow-up, with the longest study having follow-up at 25 years (15). Simply put, patients are living longer on average than ever before, and thus, it is important that they are given the additional benefit in long-term survival seen with a BIMA operation. Additionally, there was a combination of both on-pump and off-pump CABG procedures performed in the included studies. Two studies in this meta-analysis only included off-pump CABG patients, with one finding a statistically significant reduction in mortality and the other showing no difference (27,39). Although the debate about on-pump versus off-pump surgery is beyond the scope of this meta-analysis, it is interesting to note that the BIMA operation can be performed safely and possibly advantageously both ways.

In this meta-analysis, patients who received a BIMA as their primary graft strategy were on average younger, male, and non-diabetic. BIMA patients also had a slightly better mean EF (0.55 *vs*. 0.52) than those who only received a LIMA. The patient demographics of the original meta-analysis by Taggart *et al*. reflected surgical practice at the time, where BIMA was mostly performed in non-diabetic young patients. Our current study reflects a more state-of-the-art practice since close to one-third of all patients were diabetic, a risk factor often cited as a reason to preclude a BIMA. Despite this, the BIMA technique still demonstrated increased survival.

So with increasing evidence that shows long-term survival advantage for patients receiving BIMAs, why are so few patients undergoing this operation? The most often cited reason reported by cardiac surgeons is the belief that BIMA is associated with increased early morbidity and mortality (41,42), specifically the occurrence of deep sternal wound infection (DSWI) and the well-documented increased risk of death that accompanies it. DSWI has been reported to occur in as low as 0.3% and as high as 14% of BIMA procedures and is thought to be a result of the decreased sternal perfusion exacerbated by bilateral versus unilateral harvest of the IMA (38,43).

Additionally, due to referral patterns and changing patient demographics, more patients with diabetes, a risk factor often cited for DSWI, are undergoing CABG surgery than ever before. However, in diabetic patients, increased use of skeletonized harvesting techniques when performing a BIMA operation along with other infection prevention strategies have shown a reduction in DSWIs comparable to that seen in LIMA patients (44). The same reduction did not occur in BIMA operations performed through a pedicled harvest (44). Therefore, although the complexity of the operation increases with a skeletonized versus a pedicled harvest, the benefits of a BIMA operation can be realized while still maintaining a similar rate of DSWI seen in LIMA harvests.

While the success of the LIMA to LAD graft is well established, the decision as to where the right internal mammary artery (RIMA) should be used (right coronary artery versus circumflex) and how the RIMA should be used (*in situ vs*. free graft *vs*. 'Y' graft) has proven to be less straightforward. Traditionally, inferior rates of RIMA patency versus LIMA patency have been documented regardless of choice of graft site (45). A recent report by Kurlansky *et al*. demonstrated no difference in patients receiving an *in situ* RIMA to the left or right coronary system (46). Despite this, most surgeons will agree that if a RIMA is used in addition to a LIMA, the target vessel should have a significant stenosis with a good runoff in order to maintain long-term conduit patency.

Currently, the majority of patients still receive only LIMA, despite the fact that the best available evidence shows increased survival in patients receiving BIMAs. Although mostly speculative, and touched upon further in this issue by Lytle *et al.*, the incentives for long-term prognosis often take a backseat to the more tightly regulated short-term morbidity and mortality. The BIMA operation is by all accounts a more arduous operation that requires more patience and surgical skill. In addition, the intense scrutiny of immediate patient outcomes following CABG surgery may force the surgeon to perform an operation that may be less beneficial in the long term but less risky in the short term. Lastly, the BIMA operation, along with total arterial revascularization strategies, are not easily taught as social and political pressures force the eldest, most experienced surgeon to perform the surgery instead of allowing younger surgeons to gain the required repetition necessary for excellence.

The present meta-analysis is limited by the nature of the studies included. No randomized controlled trials have yet to be reported with full long-term follow up and thus, only retrospective and prospective cohort studies were included in the final analysis. Whether taken singular or combined in a meta-analysis, observational studies suffer from a lack of control of confounding factors. The long-term results of the ART trial should provide more definitive answers, as it will be the first randomized controlled trial with long-term results comparing the outcomes between BIMA and LIMA patients. Additionally, as stated earlier, the group of patients that received BIMA grafting strategies tended to be younger, male, and non-diabetic, thus possibly biasing towards a better prognosis.

In conclusion, we demonstrate an increased survival among patients receiving BIMA versus those receiving LIMA for CABG surgery in a meta-analysis of 27 studies involving over 79,000 patients. Although it is important to tailor the operation to each individual patient, the benefit from this operative strategy can no longer be ignored and with decreasing rates of short-term morbidity (i.e., DSWI) via improved operative techniques, BIMA bypass grafting for patients needs to become a first-line option for patients receiving revascularization.

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