Transatlantic editorial: The use of multiple arterial grafts for coronary revascularization in Europe and North America

Mario Gaudino, MD,^a Joanna Chikwe, MD,^b Volkmar Falk, MD,^{c,d,e,f} Jennifer S. Lawton, MD,^g John D. Puskas, MD,^h and David P. Taggart, MDⁱ

The use of multiple arterial grafts (MAGs) for coronary artery bypass grafting (CABG) is encouraged by all existing guidelines and recommendations from professional societies (Table 1).¹⁻³ However, it should be noted that the evidence basis in support of the use of MAGs is not definitive.

On one hand, a large body of observational evidence suggests that patients who receive MAGs for CABG have better postoperative outcomes and superior life expectancy.^{4,5} In addition, several randomized trials have reported that the midterm patency rate of arterial conduits, the radial artery (RA) in particular, is higher than that of the saphenous vein (Table 2).⁶⁻¹⁷

On the other hand, observational studies comparing different surgical interventions are open to treatment allocation bias¹⁸ so that hidden confounders, rather than true biological effect, may explain the observed differences (ie, the patients with the likeliest long-term longevity receive MAGs). In addition, although a pooled analysis of 6 randomized trials showed a lower risk of adverse cardiac events at 5 years of follow-up with the use of the RA instead of the saphenous vein for CABG,¹⁹ the intention-to-treat analysis of the large Arterial Revascularization Trial (ART) found

no difference in survival between patients receiving a single internal thoracic artery (SITA) and bilateral ITAs (BITAs) at 10 years of follow-up.⁶

ART reported a high (14%) crossover rate from the BITA group to the SITA graft group and a frequent use (>20%) of the RA in the control group. Both of these factors may have diluted the treatment effect of BITA grafting²⁰ and worked in favor of the null hypothesis. Indeed, a post hoc non-randomized comparison of patients who received MAG vs a single arterial graft (SAG) in the ART trial showed MAG was associated with a significant clinical benefit.⁶

Currently, a second large trial, Randomized comparison of the Outcome of single versus Multiple Arterial grafts (ROMA), comparing the use of MAGs (using a second ITA or RA) vs 1 ITA and vein is underway.²¹ The results of ROMA are expected in 2025; however, we here aim to report the attitude of the surgical community toward the use of MAGs in North America and in Europe.

PREVALENCE OF THE USE OF MAG

Data on the use of MAG are relatively limited for both North America and Europe (Table 3).²²⁻³⁰ In a review of The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery database including 1,493,470 patients undergoing CABG between 2004 and 2015, Schwann and colleagues²² reported a rate of MAG of 11.3%, with a significant decrease from 16% in 2004 to 9% in 2015. In another report from the STS database focused on low-risk patients most likely to benefit from MAG (age <70 years, no or mild chronic lung disease, body mass index <30 kg/m², and absence of diabetes), Lapar and colleagues³¹ reported a BITA use rate of 6%.

Goldstone and colleagues²³ analyzed a state-maintained clinical registry including all 126 nonfederal hospitals in California between 2006 and 2011 and found the percentage of MAG use was 9.9%, decreasing significantly from 10.7% to 9.1% over the study period. In the mandatory clinical New York State registry, a MAG rate of 20% was reported among patients who underwent CABG between the year 2005 and 2014 compared with 14% in the mandatory New Jersey clinical registry between 2005 and 2012.^{7,32}

Guru and colleagues²⁶ studied CABG patients in Ontario using the Cardiac Care Network database and reported an overall MAG rate of 12.1% between 1991 and 2003, having

From the ^aDepartment of Cardiothoracic Surgery, Weill Cornell Medicine, New York, NY; ^bDepartment of Cardiothoracic Surgery, Stony Brook School of Medicine, Stony Brook, NY; ^cDepartment of Cardiothoracic and Vascular Surgery, German Heart Center Berlin, Berlin, Germany; ^dDepartment of Cardiovascular Surgery, Charité Berlin, Berlin, Germany; ^eGerman Center of Cardiovascular Research, Partner Site Berlin, Berlin, Germany; ^fDepartment of Health Science and Technology, Swiss Federal Institute of Technology, Zurich, Switzerland; ^gDepartment of Surgery, Division of Cardiac Surgery, Johns Hopkins University School of Medicine, Baltimore, Md; ^hDepartment of Cardiovascular Surgery, Mount Sinai Saint Luke's, New York, NY; and ⁱDepartment of Cardiac Surgery, John Radcliffe Hospital, University of Oxford, Oxford, United Kingdom

This article has been copublished in *The Journal of Thoracic and Cardiovascular Surgery*, *The Annals of Thoracic Surgery*, and the *European Journal of Cardio-Thoracic Surgery*.

The American Association for Thoracic Surgery requests that this article be cited as: Gaudino M, Chikwe J, Falk V, Lawton JS, Puskas JD, Taggart DP. Transatlantic editorial: the use of multiple arterial grafts for coronary revascularization in Europe and North America. *J Thorac Cardiovasc Surg*. 2020;159:2254-9.

Reprints address: Mario Gaudino, MD, Department of Cardiothoracic Surgery, Weill Cornell Medicine, 525 E 68th St, New York, NY 10065 (E-mail: mfg9004@med.cornell.edu).

J Thorac Cardiovasc Surg 2020;159:2254-9
0022-5223/\$36.00

Copyright © 2020 Jointly between The Society of Thoracic Surgeons, The American Association for Thoracic Surgery, and the European Association for Cardio-Thoracic Surgery. Published by Elsevier Inc.

<https://doi.org/10.1016/j.jtcvs.2020.02.048>

TABLE 1. Summary of current guidelines on the use of multiple arterial grafts for coronary artery bypass grafting

Guideline	Summary
ACC/AHA, ¹ 2011	When anatomically and clinically suitable, use of a second IMA to graft the left circumflex or right coronary artery (when critically stenosed and perfusing LV myocardium) is reasonable to improve the likelihood of survival and to decrease reintervention (Class IIa, LOE B).
STS, ² 2016	As an adjunct to LITA, a second arterial graft (RITA or RA) should be considered in appropriate patients (COR IIa, LOE B). Use of BITAs should be considered in patients who do not have an excessive risk of sternal complications (COR IIa, LOE B). As an adjunct to LITA to LAD (or in patients with inadequate LITA grafts), use of a RA graft is reasonable when grafting coronary targets with severe stenoses (COR IIa, LOE B). The RGEA may be considered in patients with poor conduit options or as an adjunct to more complete arterial revascularization (COR IIb, LOE B). Use of arterial grafts (specific targets, number, and type) should be a part of the discussion of the heart team in determining the optimal approach for each patient (COR I, LOE C).
ESC/EACTS, ³ 2018	Additional arterial graft should be considered in appropriate patients (Class IIa, Level B). The use of the radial artery is recommended over the saphenous vein in patients with high grade coronary artery stenosis (Class I, Level B). BIMA grafting should be considered in patients who do not have a high risk of sternal wound infection (Class IIa, Level B). Multiple arterial grafting should be considered using the radial artery for high-grade stenosis and/or BIMA grafting for patients who do not have an increased risk of sternal wound infection.

ACC, American College of Cardiology; AHA, American Heart Association; IMA, internal mammary artery; LV, left ventricle; LOE, level of evidence; STS, The Society of Thoracic Surgeons; LITA, left internal thoracic artery; RITA, right internal thoracic artery; RA, radial artery; COR, class of recommendation; BITA, bilateral internal thoracic artery; LAD, left anterior descending; RGEA, right gastroepiploic artery; ESC, European Society of Cardiology; EACTS, European Association for Cardio-Thoracic Surgery; BIMA, bilateral internal mammary artery.

increased from 3.0% to 26.5%. Rocha and colleagues,²⁸ using the same registry, reported MAG in 22.4% of patients between 2008 and 2016. In another Canadian study, Pu and colleagues²⁷ studied patients in the province of British Columbia from 2000 to 2014 and reported a MAG rate of 27.8%, decreasing from 29% to 25% over the study period.

In Europe, Holm and colleagues³⁰ reported a BITA grafting rate of 34.2% in patients undergoing CABG in Finland, France, Germany, Italy, Sweden, and the United Kingdom from 2015 to 2017 using the European Multi-center Registry on Coronary Artery Bypass Grafting. Janiec and colleagues²⁹ reported a MAG rate of 3.9% using the Swedish Web System for Enhancement and Development of Evidence-Based Care in Heart Disease Evaluated According to Recommended Therapies (SWEDEHEART) registry. The Austrian Society for Cardiac and Thoracic-Vascular Surgery reported an overall MAG rate of 16.7% in the period from 2009 to 2018, increasing from 13.4% in 2009 to 25.0% in 2018. Recent data from Germany's Institute for Quality Assurance and Transparency in Healthcare for the years 2015 and 2016 show a BITA rate of 24.4% and 25.5%, respectively, and a use of the RA at approximately 9%.

POTENTIAL REASONS FOR THE SLOW ADOPTION OF MAG BY THE SURGICAL COMMUNITY

One route to understanding the reason for low rates of multiarterial revascularization in the United States (US) and Europe is to analyze the practice of individual surgeons. The national rates of multiarterial revascularization conceal

wide extremes of practice variation between individual providers.^{24,25} For example, in a recent analysis of 26,124 patients who underwent CABG in the US between 2005 and 2012, the prevalence of MAG was 14%; however, many surgeons performed MAG in fewer than 10% of patients, while a small minority of enthusiasts performed MAG in most patients (Figure 1).²³ Even wider practice variation was described within the ART trial, in which unplanned conversion rates from bilateral to SITA grafts ranged from 1.9% for one outlier to 100% in almost one-third of surgeons, suggesting ample variability in the level of confidence with the BITA procedure (Figure 2).^{6,33}

These extremes of practice may be explained in terms of evidence, expertise, and incentives. The absence of compelling evidence was cited by almost one-third of United Kingdom surgeons when asked in 2018 what issues limited use of BITA grafts in clinical practice.³⁴ As discussed, although a large body of observational data suggests that a second arterial conduit is associated with improved survival, graft patency, and freedom from reintervention, the findings of randomized studies have been equivocal.^{4-6,17,18,20-28,31}

For those surgeons convinced by the available evidence-base, an important factor limiting use of MAG may be technical expertise. The extent of and reason for this gap in practice are not apparent from simply analyzing surgeon case-volume and revascularization strategy. In 2 US registry studies, for example, no correlation was found between surgeon case-volume and MAG use: high volume surgeons were just as likely to prefer a SAG strategy as their low-volume counterparts.^{24,25}

TABLE 2. Summary of randomized control trials comparing graft conduits for coronary artery bypass grafting

Trial	Total patients (N)	Comparison	Mean follow-up (y)	Main findings
Arterial Revascularization Trial (ART) ⁶	1548	BITA vs SITA	10	Intention-to-treat analysis: mortality for BITA vs SITA: HR, 0.96; 95% CI, 0.82-1.12. As-treated analysis: mortality for BITA vs SITA: HR, 0.81; 95% CI, 0.68-0.95.
Petrovic ⁷	200	RA vs SV	8	No significant difference in survival between RA vs SV ($P = .979$). No difference in the composite of cardiac death, nonfatal myocardial infarction, and repeat revascularization between RA and SV ($P = .509$).
Radial Artery Patency and Clinical Outcomes (RAPCO) ⁸	649	Group 1: RITA vs RA (age <70) Group 2: RA vs SV (age >70)	5.5	Patencies were similar for either conduit in each group (log-rank $P = .06$ and $P = .54$, respectively).
Radial Artery Patency Study (RAPs) ⁹	510	RA vs SV	7.7 ± 1.5	Frequency of functional graft occlusion was lower in RA vs SV: 28 of 234 (12.0%) vs 46 of 234 (19.7%; $P = .03$). Frequency of total graft occlusion significantly lower in RA vs SV: 24 of 269 (8.9%) vs 50 of 269 (18.6%; $P = .002$).
Stand-in-Y ¹⁰	815	LITA + RA LITA + SV BITA	2.0 ± 0.81	Survival at 2 years was not different among groups ($P = .59$). Cardiac event-free survival was better in patients receiving 2 arterial grafts ($P < .0001$), even among elderly patients ($P = .02$).
Song ¹¹	60	RA vs SV	1	No difference in postoperative mortality, patency, and survival between RA and SV.
Goldman ¹²	757	RA vs SV	1	No significant difference in graft patency at 1 year after CABG for RA vs SV (adjusted OR, 0.99; 95% CI, 0.56-1.74; $P = .98$).
Saphenous VEIn versus Right Internal Thoracic Artery as a Y-Composite Graft trial (SAVE-RITA) ¹³	224	RITA vs SV	5.1 ± 0.4	No difference in graft occlusion rate ($P = .910$) between RITA vs SV. No difference in overall survival ($P = .439$) and freedom from major adverse cardiac and cerebrovascular event rates ($P = .354$) at 5 and 8 years between the 2 groups.
Muneretto ¹⁴	160	RA vs SV	1.3 ± 0.2	SV was an independent predictor for graft occlusion (OR, 1.11; 95% CI, 1.06-1.16) and angina recurrence (HR, 2.45; 95% CI, 1.67-3.19).
Radial artery versus Saphenous Vein Patency randomized trial (RVSP) ¹⁵	142	RA vs SV	5.6 ± 0.8	At 5 years, 98.3% of RA grafts and 86.4% of SV grafts were patent ($P = .04$). Graft narrowing occurred in 10% of patent RA grafts and in 23% of patent SV grafts ($P = .01$).
Glineur ¹⁶	210	RITA vs SV vs RGEA for the right coronary system	3	SV was associated with superior graft functionality compared with the other conduits (OR, 6.1; 95% CI, 2.4-15).
Gaudino ¹⁷	120	RA vs RITA vs SV in patients with in-stent restenosis	4.3 ± 0.7	SV grafts had a lower patency rate than arterial grafts and a high failure rate in patients with previous in-stent restenosis ($P = .001$).

BITA, Bilateral internal thoracic arteries; SITA, single internal thoracic artery; HR, hazard ratio; CI, confidence interval; RA, radial artery; SV, saphenous vein; LITA, left internal thoracic artery; CABG, coronary artery bypass grafting; OR, odds ratio; RITA, right internal thoracic artery; RGEA, right gastroepiploic artery.

Prospectively collected data on intraoperative decision-making influencing MAG vs SAG would be very beneficial. In this context, the data on unplanned conversion from BITA to a SITA graft in the ART trial are particularly important because it prospectively details the technical and clinical challenges that precluded BITA grafting by a group of surgeons specifically selected for their expertise in and enthusiasm for that approach.³³ The most common

reason, reported in 31% of cases, was that the conduit was “unsuitable”; specifically “damaged” in more than half such cases, with “poor flow” in one-third and “too short” in the rest.³³ It is notable that similar problems were reported in fewer than 1% of patients allocated to a SITA graft. Successful deployment of the right ITA requires greater technical facility, especially with composite and sequential grafts. Notably, this does not apply to the use

TABLE 3. Main series reporting the use of multiple arterial grafting in North America and Europe

Study	Registry	Variable	Percentage
United States and Canada			
Schwann, ²² 2018	The Society of Thoracic Surgeons Adult Cardiac Surgery Database	%MAG	11.3
Goldstone, ²³ 2018	California State registry	%MAG	9.9
Samadashvili, ²⁴ 2019	New York's Cardiac Surgery Reporting System and New York's Vital Statistics	%MAG	20.0
Chikwe, ²⁵ 2019	New Jersey Cardiac Catheterization Registry, New Jersey Discharge Data Collection System	%MAG	14.0
Guru, ²⁶ 2006	Cardiac Care Network database (Canada)	%MAG	12.1
Pu, ²⁷ 2017	Cardiac Services British Columbia registry (Canada)	%MAG	27.8
Rocha, ²⁸ 2018	CorHealth Registry (Canada)	%MAG	22.4
Europe			
Janiec, ²⁹ 2017	SWEDHEART registry	%MAG	3.9
Holm, ³⁰ 2019	European Multicenter Study on Coronary Artery Bypass Grafting registry	%BITA	34.2
Austrian Society for Cardiac and Thoracic-Vascular Surgery	Austrian Society for Cardiac and Thoracic-Vascular Surgery Registry	%MAG	16.7

MAG, Multiple arterial graft; SWEDHEART, Swedish Websystem for Enhancement of Evidence-Based Care in Heart Disease Evaluated According to Recommended Therapies; BITA, bilateral internal thoracic artery.

of the RA. In fact, in the quoted analysis of the STS database, Schwann and coauthors²² reported a clear volume-to-outcome relationship for BITA but not RA grafting. Finally, incentive is the third factor potentially driving the wider use of MAG and, specifically, the acceptance of the potential disadvantages of this strategy such as higher risk of sternal or forearm complications, bleeding, longer operative times, and the additional training and planning

associated in particular with BITA use.^{34,35} Increased sternal wound infection is a significant disincentive in the US health care setting, especially among diabetic patients, because providers may not receive reimbursement for the additional care associated with wound complications. It is important to note that even among diabetic patients, however, observational data suggest a mortality benefit for BITA over SITA grafting.³²

FIGURE 1. Rate of multiarterial revascularization by individual surgeon, stratified by annual coronary bypass case volume in a United States mandatory clinical registry. (From Chikwe J, Sun E, Hannan EL, et al. Outcomes of second arterial conduits in patients undergoing multivessel coronary artery bypass graft surgery. *J Am Coll Cardiol*. 2019;74:2238-48.)

FIGURE 2. Rate of unplanned conversion from bilateral to single internal mammary artery by individual surgeon, stratified by number of patients randomized in the Arterial Revascularization Trial. (From *New England Journal of Medicine*; Taggart DP, Benedetto U, Gerry S, Altman DG, Gray AM, Lees B, Gaudino M, Zamvar V, Bochenek A, Buxton B, Choong C, Clark S, Deja M, Desai J, Hasan R, Jasinski M, O’Keefe P, Moraes F, Pepper J, Seevanayagam S, Sudarshan C, Trivedi U, Wos S, Puskas J, Flather M; Arterial Revascularization Trial Investigators. Bilateral versus single internal-thoracic-artery grafts at 10 years; 380:437-46. Copyright © (2019) Massachusetts Medical Society. Reprinted with permission.)

Also, 30-day outcomes, including complications and patient satisfaction, are commonly publicly reported and may form part of managed care contracting criteria. There may be real concern that referrals could be targeted elsewhere on the basis of 30-day outcomes rather than putative late survival benefit.

STRATEGIES TO INCREASE MAG

On this basis, there are, in our opinion, 4 strategies that could potentially increase the appropriate use of MAG:

- Foster a cultural shift from the view of CABG as an entry-level operation for learners toward a specialist operation for experts. Update curricula and operative requirements for professional certification to include current best-practice in MAG with associated advanced training courses.
- Revise consensus guidelines to emphasize the role of targeted referral to expert providers offering a high likelihood of MAG and simultaneous low mortality in appropriate patients.
- Expand publicly reported CABG benchmarks, such as the STS quality bundle, to include MAG (or documentation of its contraindication) for young patients and compliance with evidence-based prophylactic sternal infection care bundles.
- Add appropriateness of intervention to public reporting for surgical revascularization.

In conclusion, a substantial body of evidence suggests that MAG may be associated with improved survival, graft patency, and freedom from reintervention. However, lack of clear level I evidence (in particular for BITA grafting), variable surgical expertise, and disincentives linked to

short-term outcomes impact public reporting and reimbursement and have led to extreme variation in the use of MAG even in the most appropriate patients. Disseminating consensus guidelines updated to reflect current best practice, especially in younger patients, and expanding quality benchmarks to include appropriateness of the revascularization strategy may help in addressing this knowledge and practice gaps.

The authors wish to thank the ÖG-HTG (Österreichische Gesellschaft für Herz und thorakale Gefäßchirurgie [Austrian Society for Cardiac and Thoracic-Vascular Surgery]) for their support.

References

- Hillis LD, Smith PK, Anderson JL, et al. 2011 ACCF/AHA guideline for coronary artery bypass graft surgery. A report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. Developed in collaboration with the American Association for Thoracic Surgery, Society of Cardiovascular Anesthesiologists, and Society of Thoracic Surgeons. *J Am Coll Cardiol*. 2011;58:e123-210.
- Aldea GS, Bakaeen FG, Pal J, et al. The Society of Thoracic Surgeons clinical practice guidelines on arterial conduits for coronary artery bypass grafting. *Ann Thorac Surg*. 2016;101:801-9.
- Sousa-Uva M, Neumann F-J, Ahlsson A, et al. 2018 ESC/EACTS guidelines on myocardial revascularization. *Eur J Cardiothorac Surg*. 2019;55:4-90.
- Gaudino M, Rahouma M, Abouarab A, et al. Radial artery versus saphenous vein as the second conduit for coronary artery bypass surgery: a meta-analysis. *J Thorac Cardiovasc Surg*. 2019;157:1819-25.e10.
- Buttar SN, Yan TD, Taggart DP, Tian DH. Long-term and short-term outcomes of using bilateral internal mammary artery grafting versus left internal mammary artery grafting: a meta-analysis. *Heart*. 2017;103:1419-26.
- Taggart DP, Benedetto U, Gerry S, et al. Bilateral versus single internal-thoracic-artery grafts at 10 years. *N Engl J Med*. 2019;380:437-46.
- Petrovic I, Neze D, Peric M, et al. Radial artery vs saphenous vein graft used as the second conduit for surgical myocardial revascularization: long-term clinical follow-up. *J Cardiothorac Surg*. 2015;10:127.
- Hayward PAR, Gordon IR, Hare DL, et al. Comparable patencies of the radial artery and right internal thoracic artery or saphenous vein beyond 5 years: results from the radial artery patency and clinical outcomes trial. *J Thorac Cardiovasc Surg*. 2010;139:60-5 [discussion: 65-7].
- Deb S, Cohen EA, Singh SK, Une D, Laupacis A, Fremes SE, RAPS Investigators. Radial artery and saphenous vein patency more than 5 years after coronary artery bypass surgery: results from RAPS (Radial Artery Patency Study). *J Am Coll Cardiol*. 2012;60:28-35.
- Nasso G, Coppola R, Bonifazi R, Piancone F, Bozzetti G, Speziale G. Arterial revascularization in primary coronary artery bypass grafting: direct comparison of 4 strategies—results of the Stand-in-Y Mammary study. *J Thorac Cardiovasc Surg*. 2009;137:1093-100.
- Song S-W, Sul S-Y, Lee H-J, Yoo KJ. Comparison of the radial artery and saphenous vein as composite grafts in off-pump coronary artery bypass grafting in elderly patients: a randomized controlled trial. *Korean Circ J*. 2012;42:107-12.
- Goldman S, Sethi GK, Holman W, et al. Radial artery grafts vs saphenous vein grafts in coronary artery bypass surgery: a randomized trial. *JAMA*. 2011;305:167-74.
- Kim M-S, Hwang HY, Kim JS, Oh SJ, Jang MJ, Kim KB. Saphenous vein versus right internal thoracic artery as a Y-composite graft: five-year angiographic and clinical results of a randomized trial. *J Thorac Cardiovasc Surg*. 2018;156:1424-33.e1.
- Muneretto C, Bisleri G, Negri A, et al. Left internal thoracic artery-radial artery composite grafts as the technique of choice for myocardial revascularization in elderly patients: a prospective randomized evaluation. *J Thorac Cardiovasc Surg*. 2004;127:179-84.
- Collins P, Webb CM, Chong CF, Moat NE, Radial Artery Versus Saphenous Vein Patency (RSVP) Trial Investigators. Radial artery versus saphenous vein patency randomized trial: five-year angiographic follow-up. *Circulation*. 2008;117:2859-64.
- Glineur D, D'hoore W, de Kerchove L, et al. Angiographic predictors of 3-year patency of bypass grafts implanted on the right coronary artery system: a prospective randomized comparison of gastroepiploic artery, saphenous vein, and right internal thoracic artery grafts. *J Thorac Cardiovasc Surg*. 2011;142:980-8.
- Gaudino M, Cellini C, Pragliola C, et al. Arterial versus venous bypass grafts in patients with in-stent restenosis. *Circulation*. 2005;112:1265-9.
- Gaudino M, Di Franco A, Rahouma M, et al. Unmeasured confounders in observational studies comparing bilateral versus single internal thoracic artery for coronary artery bypass grafting: a meta-analysis. *J Am Heart Assoc*. 2018;7:e008010.
- Gaudino M, Benedetto U, Fremes S, et al. Radial-artery or saphenous-vein grafts in coronary-artery bypass surgery. *N Engl J Med*. 2018;378:2069-77.
- Gaudino M, Fremes SE, Ruel M, et al. Prevalence and impact of treatment crossover in cardiac surgery randomized trials: a meta-epidemiologic study. *J Am Heart Assoc*. 2019;8:e013711.
- Gaudino M, Alexander JH, Bakaeen FG, et al. Randomized comparison of the clinical outcome of single versus multiple arterial grafts: the ROMA trial—rationale and study protocol. *Eur J Cardiothorac Surg*. 2017;52:1031-40.
- Schwann TA, Habib RH, Wallace A, et al. Operative outcomes of multiple-arterial versus single-arterial coronary bypass grafting. *Ann Thorac Surg*. 2018;105:1109-19.
- Goldstone AB, Chiu P, Baiocchi M, et al. Second arterial versus venous conduits for multivessel coronary artery bypass surgery in California. *Circulation*. 2018;137:1698-707.
- Samadashvili Z, Sundt TM, Wechsler A, et al. Multiple versus single arterial coronary bypass graft surgery for multivessel disease. *J Am Coll Cardiol*. 2019;74:1275-85.
- Chikwe J, Sun E, Hannan EL, et al. Outcomes of second arterial conduits in patients undergoing multivessel coronary artery bypass graft surgery. *J Am Coll Cardiol*. 2019;74:2238-48.
- Guru V, Fremes SE, Tu JV. How many arterial grafts are enough? A population-based study of midterm outcomes. *J Thorac Cardiovasc Surg*. 2006;131:1021-8.
- Pu A, Ding L, Shin J, et al. Long-term outcomes of multiple arterial coronary artery bypass grafting: a population-based study of patients in British Columbia, Canada. *JAMA*. 2017;318:1187-96.
- Rocha RV, Tam DY, Karkhanis R, et al. Multiple arterial grafting is associated with better outcomes for coronary artery bypass grafting patients. *Circulation*. 2018;138:2081-90.
- Janiec M, Dimberg A, Nazari Shafiti TZ, Lagerqvist B, Lindblom RPF. No improvements in long-term outcome after coronary artery bypass grafting with arterial grafts as a second conduit: a Swedish nationwide registry study. *Eur J Cardiothorac Surg*. 2018;53:448-54.
- Holm M, Biancari F, Khodabandeh S, et al. Bleeding in patients treated with ticagrelor or clopidogrel before coronary artery bypass grafting. *Ann Thorac Surg*. 2019;107:1690-8.
- LaPar DJ, Crosby IK, Rich JB, et al. Bilateral internal mammary artery use for coronary artery bypass grafting remains underutilized: a propensity-matched multi-institution analysis. *Ann Thorac Surg*. 2015;100:8-14; discussion: 14-5.
- Puskas JD, Sadiq A, Vassiliades TA, Kilgo PD, Lattouf OM. Bilateral internal thoracic artery grafting is associated with significantly improved long-term survival, even among diabetic patients. *Ann Thorac Surg*. 2012;94:710-5; discussion: 715-6.
- Benedetto U, Altman DG, Flather M, et al. Incidence and clinical implications of intraoperative bilateral internal thoracic artery graft conversion: insights from the arterial revascularization trial. *J Thorac Cardiovasc Surg*. 2018;155:2346-55.e6.
- Jayakumar S, Gasparini M, Treasure T, Burdett C, Cardiothoracic Trainees Research Collaborative. How do surgeons decide? Conduit choice in coronary artery bypass graft surgery in the UK. *Interact Cardiovasc Thorac Surg*. 2019;29:179-86.
- Mastrobuoni S, Gawad N, Price J, et al. Use of bilateral internal thoracic artery during coronary artery bypass graft surgery in Canada: the bilateral internal thoracic artery survey. *J Thorac Cardiovasc Surg*. 2012;144:874-9.