The Society of Thoracic Surgeons Clinical Practice Guidelines on Arterial Conduits for Coronary Artery Bypass Grafting

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Internal thoracic arteries (ITAs) should be used to bypass the left anterior descending (LAD) artery when bypass of the LAD is indicated (class of recommendation [COR] I, level of evidence [LOE] B). As an adjunct to left internal thoracic artery (LITA), a second arterial graft (right ITA or radial artery [RA]) should be considered in appropriate patients (COR IIa, LOE B). Use of bilateral ITAs (BITAs) should be considered in patients who do not have an excessive risk of sternal complications (COR IIa, LOE B). To reduce the risk of sternal infection with BITA, skeletonized grafts should be considered (COR IIa, LOE B), smoking cessation is recommended (COR I, LOE C), glycemic control should be considered (COR IIa, LOE B), and enhanced sternal stabilization may be considered (COR IIb, LOE C). 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). When RA grafts are used, it is reasonable to use pharmacologic agents to reduce acute intraoperative and perioperative spasm (COR IIa, LOE C). The right gastroepiploic artery 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).

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REPORT

As the techniques of surgical and percutaneous coronary revascularization for coronary artery disease (CAD) continue to evolve, reassessing available data to inform decision making should take place periodically. This expert writing group was charged with developing balanced, patient-focused recommendations for clinical practice that aim to improve the quality of care, optimize individual patient outcomes, and favorably affect costs by focusing resources on the most effective strategies. Prior multi-society documents have focused on indications and outcomes of coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) in the treatment of multivessel CAD. This guideline assessed how the choice of arterial conduits can affect outcomes.

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In the past two decades, despite a decreasing rate of morbidity and mortality [1–3], the overall rate of CABG in North America has declined by more than 23%. An analysis of The Society of Thoracic Surgeons (STS) Adult Cardiac Surgical Database (ACSD) shows that isolated CABG procedures peaked in 1997 at 191,581 and declined to 146,947 procedures by 2012. When adjustments are made for the growing adult US population, a much more significant decline of nearly 38% for CABG is noted from 2001 to 2008 (from 1,742 to 1,081 CABG procedures per million adults per year; $p < 0.001$) [4, 5]. This decline may have been caused by (1) improvements in medical therapy and

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secondary prevention of stable angina [6], (2) improvements in stent technology and adjuvant medical therapy that have achieved intermediate-term outcomes similar to surgical revascularization, and (3) desire by patients to avoid the invasiveness and short-term risks of surgical intervention. Consequently, patients referred for a surgical procedure in the current era have more extensive coronary disease burden and coexisting morbidities such as diabetes, hypertension, chronic obstructive pulmonary disease (COPD), peripheral vascular disease, hyperlipidemia, and frailty [7–10]. Despite these higher-risk patients, surgeons are required to provide superior short-term surgical outcomes, minimal patient morbidity, and durable long-term outcomes and graft patency.

In the subset of patients who are candidates for either surgical or percutaneous interventions, older randomized trials failed to detect significant differences in short-term death and myocardial infarction (MI) rates, but they consistently observed higher rates of repeat revascularization after PCI compared with CABG [11, 12]. However, large registries that used propensity-matched analyses showed improved survival with CABG [13, 14]. In the more current SYNTAX (SYNergy Between PCI [percutaneous coronary intervention] With TAXUS and Cardiac Surgery) trial, differences between PCI and CABG were accentuated and continue to diverge over time in patients undergoing PCI with a high or intermediate SYNTAX score (less than 23) for repeat revascularization and for death and MI [15, 16]. In this population, favorable outcomes with CABG were attributed to more complete revascularization and improved graft patency.

In recent decades there has been dramatic evolution in PCI technologies, from balloon angioplasty to newer generations of drug-eluting stents, and periprocedural medical therapies that range from long-term dual antiplatelet therapy to the ubiquitous use of antistatins. In contrast, there has been little change in choice of conduits for CABG, and the use of multiple arterial grafting remains low. For the past few decades, most surgeons in the STS ACSD perform a single arterial bypass of the left internal thoracic artery (LITA) to the left anterior descending (LAD) and saphenous vein grafts (SVGs) to remaining targets. In the SYTNAX trial that compared CABG with PCI, almost all of the patients undergoing CABG (97.3%) received at least one arterial conduit bypass and 35.3% of patients received more than one arterial conduit [17]. The US sites had a significantly lower rate at 17% [18]. In the STS ACSD, the current incidence of a second arterial graft is less than 7% (1990 to 1999, 3.2%; 2000 to 2009, 11.6%; and 2010 to 2013, 6.7%) [19].

Because many studies have reported SVG failure rates of up to 10% to 20% after 1 year and an additional 5% failure rate for each subsequent year [20–22], it is logical to infer that if the surgical conduit failure rate can be ameliorated by safe, more judicious, and effective use of arterial grafts, long-term clinical outcomes may be significantly improved.

The most commonly reported coronary revascularization outcome measures are all-cause death and graft patency. All-cause death is a hard end point that can be reliably measured. Because there is no universally accepted definition (or assessment) of graft patency or failure, this end point is harder to report and compare.

Material and Methods

The STS Workforce on Evidence-Based Surgery assembled a task force in 2013 to address factors that guide the use of potential arterial and venous conduits in CABG procedures. All Task Force members were required to submit a disclosure form listing any potential conflict of interest from the period starting 36 months prior to initiating the guideline. The full responses are available as an Online Supplement. A systematic review was outlined, and searches were run in MEDLINE, Embase, and the Cochrane databases. Results were limited to papers published on human subjects in English since January 1, 2000. The following search terms were used to identify relevant studies: "coronary artery bypass graft," "CABG," "bilateral internal mammary artery," "bilateral internal thoracic artery," "left internal mammary artery," "right internal thoracic artery," "radial artery," "gastroepiploic artery," "patency," "overall survival," "mortality," "morbidity," "reoperation," "sternal infection and malunion."

We augmented our literature search by manually reviewing the identified studies. Abstracts were reviewed by at least two individuals for relevance. The initial approximately 1,500 results were reduced if they were case reports, had a primary focus of PCI, were population-based studies that covered incidence and risk factors for CABG, sought to identify potential secondary outcomes or markers, or included study populations of specific subgroups that will be a focus of subsequent STS guidelines. The remaining 103 relevant clinical studies were analyzed in the evidence and critical appraisal tables in the Appendix by three authors (S. Fremes, S. Firestone, and F. Bakaeen). Guideline recommendations were formulated and reviewed by all members of the writing group before approval by the Workforce on Evidence-Based Surgery and the STS Executive Committee.

The class of recommendation (COR) is an estimate of the size of the treatment effect that consider risks versus benefits in addition to evidence or agreement that a given treatment or procedure is or is not useful/effective. The level of evidence (LOE) is an estimate of the certainty or precision of the treatment effect (Table 1).

Bilateral ITA

The LITA is the gold standard conduit in CABG and has consistently shown to be associated with improved survival, graft patency, and freedom from cardiac events compared with SVG conduits. The LITA is used routinely to bypass the LAD artery when considerable disease is present, provided that contraindications to its use are not present (eg, poor LITA blood flow, extreme risk of sternal infection/malunion). This is thought to be because of the unique vascular biology of the internal thoracic artery and the large territorial run-off when the LITA is used to

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Table 1. Description of COR and LOE

	Description
COR	
Class I (benefit > > >risk)	Procedure/treatment *should* be performed/administered.
Class IIA (benefit >>risk)	Additional studies with focused objectives needed; *it is reasonable* to perform procedure/administer treatment
Class IIB (benefit > risk)	Additional studies with broad objectives needed; additional registry data would be helpful; procedure/treatment *may be considered*
Class III (no benefit)	Procedure/test: not helpful; treatment: no proven benefit
Class III (harm)	Procedure: without benefit or harmful; treatment: harmful to patients
LOE that best fits the recommendation	
Level A	Multiple populations evaluated; data derived from multiple randomized clinical trials or meta-analyses
Level B	Limited populations evaluated; data derived from a single randomized trial or nonrandomized studies
Level C	Very limited populations evaluated; only consensus opinion of experts, case studies, or standard of care are available

COR = classification of recommendation; LOE = level of evidence.

bypass the LAD. Data suggest that arterial grafts may also mitigate progression of native CAD [23].

CONDUIT HARVEST. The mammary pedicle may provide some protection for the artery at the expense of greater sternal ischemia [24, 25]. Alternatively, the internal thoracic arteries can be harvested in a skeletonized fashion or with a surrounding myofascial pedicle. Skeletonization was thought to potentially increase the likelihood of damage to the artery due to lack of surrounding soft tissue, but reported patency rates are similar between skeletonized and pedicle ITAs [26]. Several reports suggested that harvesting the ITA in the skeletonized fashion compared with pedicled grafts preserves sternal blood flow and, along with enhanced sternal reinforcement, significantly reduces the risk of wound infection [27, 28]. This is especially relevant in patients with diabetes mellitus (DM) with single ITA (SITA) and bilateral ITA (BITA) use [29].

BENEFITS OF BITA. Large nonrandomized risk-adjusted registry data and meta-analyses have reported safety and efficacy of BITA grafting [30–33]. The use of both ITAs was associated with decreased risk of death, reoperation, and PCI. A recent study found that BITA with the use of the right ITA (RITA) bypass to the LAD and the LITA to another left-sided coronary vessel has comparable outcomes with a BITA with LITA to the LAD and RITA to a left-sided coronary bypass (RITA late death hazard ratio [HR] 0.78, 95% confidence interval [CI]: 0.48 to 1.26; and repeat revascularization HR 0.83, 95% CI: 0.7 to 2.42) [34].

Three meta-analyses of retrospective studies compared SITA with BITA grafts and found HRs of 0.8 for overall survival and lower re-intervention rates, favoring BITA. The beneficial impacts of BITA compared with LITA grafting on survival and major adverse cardiac events may be delayed by as much as a 7 to 10 years but persist beyond that time period; thus, they may be less appreciated in older patients with coexistent morbidities with more limited life expectancy [35, 36]. In addition, certain subset of patients, specifically patients with DM, may derive specific survival benefits from BITA grafting [37].

STERNAL COMPLICATIONS. Although rates of surgical site infections are decreasing [38], mediastinitis and sternal malunion are associated with significant cost, morbidity, and death after CABG [39–41]. Known risks of sternal infection and malunion after SITA include nonelective procedure, age, pre-CABG hospital stay of more than 3 days, female sex, DM, obesity (body mass index greater than 40 kg/m^2), COPD, active smoking, use of intra-aortic balloon pump, the duration of surgical procedure, re-exploration for bleeding, immunosuppression regimen, and radiation mediastinal injury. Risks increase disproportionally when multiple factors are present [42–45]. Although graft patency and survival appears superior with BITA grafting, the main concern for surgeons is the potential increased risk of sternal wound infections compared with SITA. This increase in sternal mediastinitis may be secondary to a diminution of sternal blood supply after pedicled BITA [24, 46–48]. Although several investigators have reported an increased risk of sternal wound infections with BITA harvesting [49, 50], others have reported no significant difference in sternal wound complications, particularly after adjustment for other potentially confounding risk factors (such as sex, obesity, COPD and smoking) [51].

A major confounding factor for sternal wound infections is whether the diagnosis of DM is a risk factor or whether the risk is more closely associated with poor perioperative glycemic control. Although the importance of glycemic control in the perioperative period is well established, most reports classify patients only as having DM without further stratification of the level or effectiveness of glycemic control. Several reports suggest that poor preoperative glycemic control with glycosylated hemoglobin values greater than 7% were associated with worse outcomes [52]. The diagnosis of diabetes alone, independent of glycemic control, was not a predictor of outcomes in this study.

Current data suggest that BITA grafts can be performed safely in many, if not most, patients and is associated with improved graft patency and survival. There does appear to be an increased risk of sternal wound complications (nearly twofold to threefold) that may be mitigated by use of skeletonized graft harvest. Current data suggest that the survival benefit of BITA use appears in long-term follow-up of greater than 5 to 10 years, provided that the risk of postoperative mediastinitis is not increased.

LIMITATIONS. Definitive comparisons of single LITA use with BITA are limited by a paucity of sufficiently powered (for both benefit and risk), prospective, randomized trials with appropriate long-term follow-up (greater than 10 years). Analyses and interpretations of large nonrandomized series aim to control for bias in patient and conduit selection with propensity-matching techniques to adjust for varied patient profiles and risk, but cannot fully eliminate the possibility of selection bias affecting outcomes and survivals [30, 35]. Given the relatively low incidence of sternal infections, smaller studies are typically underpowered and are at risk of statistical type 2 errors when no difference in outcomes are reported.

A more definitive study about BITA versus SITA grafting (Arterial Revascularization Trial) is under way and has reported early outcomes [53]. More than 3,000 patients undergoing CABG were randomized to receive either SITA or BITA grafting. Early results were excellent and reveal similar operative and 1-year mortality rates. However, patients who received BITA grafts had a significantly higher risk of sternal wound complications (0.6% versus 1.9%, HR 3.2, 95% CI: 1.5 to 6.8). Long-term outcomes will be informative about graft patency, need for re-intervention, and survival, but they are yet to be reported.

RECOMMENDATIONS.

- The ITA should be used to bypass the LAD artery when bypass of the LAD is indicated (COR I, LOE B).
- As an adjunct to LITA, a second arterial graft (right internal thoracic artery or radial artery [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).
- To reduce the risk of sternal infection with BITA consider the following:
  - Skeletonized grafts should be considered (COR IIa, LOE B).
  - Smoking cessation is recommended (COR I, LOE C).
  - Glycemic control should be considered (COR IIa, LOE B).
  - Enhanced sternal stabilization may be considered (COR IIb, LOE C).

Radial Artery

RA conduits in CABG are typically used as part of a strategy of a multiple, more complete arterial revascularization strategy as an adjunct to a LITA to the LAD or BITA grafting. Unlike BITA, the use of a RA as an adjunct to LITA does not affect sternal vascular supply or increase risk of sternal healing or malunion. After an early controversy about poor graft patency and outcomes associated with RA grafts, the last two decades have produced data to support the safety and efficacy of RA conduits in patients undergoing CABG. This is most likely because of more appropriate patient and distal target selection and better pharmacologic perioperative therapy that aims to reduce RA graft spasm. According to a STS ACSD study, RA use peaked at 12.3% of all primary CABGs in 2002 and subsequently declined to 5.5% in 2009 [1].

CONDUIT HARVEST. The RA graft has the advantage of ease of harvest and ability to reach all coronary territories, making it an attractive option for a second or third arterial conduit. The RA is routinely harvested from the nondominant arm because of concerns about potential adverse impact of RA harvesting on hand sensory and motor function. The RA is usually not harvested if used previously and recently for angiography. Routine preoperative noninvasive vascular assessment of the palmar arch circulation to demonstrate a balanced radial and ulnar arterial circulation can allay concerns about hand ischemia. A properly conducted Allen's test is a useful first-line test to select patients for RA harvest, but the cutoff is controversial, and the test does not have a perfect sensitivity or specificity. Therefore, many surgeons choose to supplement the Allen's test with a second test such as dynamic Doppler ultrasound or measurement of digital pressure or pulse oximetry changes with RA occlusion [54]. Reassuringly, the incidence of forearm and hand ischemia is exceedingly low when such screening strategies are used [54–56].

Mild pain, paresthesia, weakness, and other neurologic symptoms in the harvest arm occur in up to one-third of patients in the early postoperative period, but they are usually transient and self-limiting [56, 57].

PHARMACOLOGIC MANAGEMENT. RAs are structurally and functionally different from ITAs. The RA is more muscular and is more susceptible to vasospasm; therefore, the use of pharmacologic prophylaxis against RA spasm is a common practice [58]. Multiple clinical studies have reported the efficacy of various pharmacologic agents in reducing spasm [59–61], although the impact their use has on overall survival and patency is unclear. Calcium channel blockers with or without nitrates are the most commonly used agents during bathing of the RA during graft preparation or for systemic administration intraoperatively and perioperatively when the RA may be the most vulnerable to spasm. Other less frequently used intraoperative antispasmodic agents evaluated include milrinone, papaverine, and phenoxybenzamine. The use of systemic agents may be limited by their hypotensive properties; therefore local application of antispasmodic agents is preferred. Beyond the perioperative period, calcium channel blockers are the mainstay therapy and are frequently continued for weeks or months after

discharge [58, 62]. However, little clinical data support long-term use (beyond the perioperative period), and some experienced centers have abandoned this routine [63]. A systematic review of the literature did not find a definitive benefit for prolonged administration of calcium channel blockers [64].

TARGET SELECTION. The "string sign," indicating diffuse narrowing or spasm of part or the entire length of the graft, is more common in RA grafts than in SVGs. It may be related to competitive flow or the perioperative use of alpha-adrenergic agonists [65] and was reported in as many as 7% of RA grafts [7]. Randomized trials that compared RA grafts with SVGs have consistently included a target vessel stenosis cutoff of greater than 70% as a criterion to minimize competitive flow [7]. Some investigators have reported a further threshold and step up in the risk of graft failure when comparing target vessels with proximal lesions of 70% to 89% to those greater than 90% [66].

The severity of target coronary stenosis is a main determinant of competitive flow, but the size of the target vessel needs to be considered as well. Existing American College of Cardiology/American Heart Association 2011 guidelines recommend against (class III, LOE C) arterial revascularization of the right coronary artery (typically larger than other potential targets) with less than 90% stenosis [67]. However, a recent systematic review suggested that graft failure of arterial grafts compared with SVGs to the right coronary artery is not significantly different without specification of a cutoff percentage for target vessel stenosis [68].

RA GRAFT VERSUS SV GRAFT. Seven randomized trials compared SVG with RA graft. Both the Radial Artery Patency Study [69] and the Radial Artery Versus Saphenous Vein Patency [70] studies showed the RA graft to have superior patency versus SVGs on 5-year angiographic follow-up. Two other studies, one that incorporated other arterial grafts to bypass coronaries with in-stent stenosis [71], and one that compared a composite LITA/RA total arterial revascularization with LITA/SVG CABG [72], favored RA patency beyond 1 year compared with SVG. In contrast, comparable patency rates between the RA graft and SVGs were found in the 1-year results from the Department of Veteran Affairs Cooperative Studies Program [73] and the midterm results from the Radial Artery Patency and Clinical Outcomes (RAPCO) study [74]. One trial reported overall superiority for the no-touch SVG patency over RA at a mean of 36 months; however, all RA-grafted coronary arteries with a stenosis of greater than 90% were patent [75].

Systematic reviews and meta-analyses sharing a similar core of randomized studies comparing RA and SV patency reported similar findings that selected patients with severe coronary stenosis may have superior RA angiographic outcomes at midterm [7, 27, 68].

Most observational data on this topic are derived from a few large single-center experiences, and many have reported favorable RA patency [76, 77]. Exceptions included reports that associated RA with reduced graft patency, but the studies were limited by small patient numbers [78, 79].

Two randomized control trials found a clinical benefit for RA on angina recurrence [72] and cardiac event-free survival compared with SVG [80]. A systematic review that included studies with follow-up that ranged from 1 to 6 years found no significant difference in mortality rates between the RA graft and SVG [81].

Large observational single-center studies associated the use of the RA to have improved long-term survival [82–84]; however, this was not replicated in any randomized trial or a large retrospective propensity-matched analysis to evaluate RAs in the context of arterial revascularization [85].

RA VERSUS RITA. The RA appears to have comparable graft patency to RITA. The RAPCO study included a RA and free RITA arm for patients older than 70 years that found 5-year patency rate of 89.8% in the RA group (95% CI: 71.0% to 100%) and 83.2% (95% CI: 54.1% to 100%) in the RITA group [74]. The remaining literature that compared RA and RITA patency is limited to retrospective studies with small patient numbers and inadequate long-term follow-up to guide care. The largest observational study (528 propensity-matched pairs) with a mean follow-up of 5.2 years showed similar graft patency rates for RA and RITA [86]. Other observational studies found superior RITA patency [79], including comparisons of LITA with RITA to LITA with RA composites [87].

No randomized trial to date has reported superior survival outcomes with the use of RITA compared with RA in patients undergoing CABG. Most observational studies showed no difference in major adverse cardiac events, but a few observational studies showed improvement with RITA [87–89]. The RAPCO study showed no difference in the event (death, MI, or revascularization) free survival between RITA and RA at a mean follow-up of 6 years.

Recently, the use of RA access for coronary angiography has increased. Because of concerns about injury to the RA caused by instrumentation and its potential impact on graft patency [90, 91], it is recommended that there should be a delay between transradial angiography and the use of the instrumented RA as a conduit for CABG. Clinical data are insufficient to designate a safe wait time, but histologic and flow dynamic data suggest that 3 months may be reasonable [90].

RECOMMENDATIONS.

- 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),
- When RA grafts are used, it is reasonable to use pharmacologic agents to reduce acute intraoperative and perioperative spasm (COR IIa, LOE C).

Right Gastroepiploic Artery

The right gastroepiploic artery (RGEA) is most often used in a similar fashion as the RA. Because it is also susceptible to spasm, it should only be used to bypass

severely stenotic coronaries, preferably the right coronary artery [92].

One-year patency of the RGEA is consistently reported to be 90% to 95% [93–95], with patency rapidly reducing to 80% to 85% and 62% at 5 and 10 years, respectively [93, 95, 96]. The GEA artery appears to be inferior to ITA grafts in terms of patency, whereas no significant differences are found between the GEA and RA or SVG conduits [79, 94, 96, 97]. In terms of clinical outcomes, no significant difference in event-free survival between the RGEA, RA, or SVG was reported [92, 98–102].

The abdominal incision and exposure required to harvest the RGEA (in addition to sternotomy with ITA or BITA harvest) may increase risk of sternal wound healing. For these reasons and for technical issues related to limited graft length, variation in size, and small distal diameter, the GEA is rarely used in North America and Europe [17]. Some centers in Asia still use gastroepiploic grafts and continue to report competitive outcomes associated with them [103].

RECOMMENDATIONS.

- The RGEA may be considered in patients with poor conduit options or as an adjunct to more complete arterial revascularization (COR IIb, LOE B).

Heart Team Approach

The latest European and American guidelines on myocardial revascularization recommend a formal collaborative interaction between the patient and the heart team comprised of noninterventional cardiologist, interventional cardiologist, cardiac surgeon, and other care providers [67, 104, 105]. With the use of evidence-based data of risk and benefit and appropriateness, this team aims to objectively inform and advise the patient of all treatment options to ensure a fully informed consent and shared decision making [67, 104]. Physicians and care providers engaged in this multidisciplinary decision-making process should have a common collective goal of facilitating patient-centered care that is based on (1) reviewing the patient's coronary anatomy and disease burden (including SYNTAX score); (2) reviewing the patient's coexisting medical morbidities that influence periprocedural and long-term outcome and survival; (3) proposing and integrating medical therapies and patient initiatives to address and mitigate long-term consequences for these conditions (eg, smoke cessation, exercise regimen, diet modification, and diabetes and lipid management); (4) assessment of individual patient's priorities and goals such as survival, angina relief, freedom from MI or repeat revascularizations; (5) balancing patient's goals with preferences to limit the invasiveness of the procedure and enhancing postprocedural recovery (convalescent) time; and (6) containing (societal) health care costs.

The heart team should acknowledge that particular patients will derive specific short- and long-term benefits from alternative treatments within subsets of strategies for percutaneous (eg, duration of dual antiplatelet therapy and type of stent) and surgical revascularization (eg, choice of conduits, off-pump CABG, and limited aortic manipulation). Because number, type, and specific targets of arterial grafts influence patient survival, quality of life, and durability of revascularization, these should be discussed as part of the heart team assessment and recommendation to the patient.

RECOMMENDATION.

- 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).

References

1. ElBardissi AW, Aranki SF, Sheng S, O'Brien SM, Greenberg CC, Gammie JS. Trends in isolated coronary artery bypass grafting: an analysis of the Society of Thoracic Surgeons adult cardiac surgery database. J Thorac Cardiovasc Surg 2012;143:273–81.
2. Movahed MR, Ramaraj R, Khoynezhad A, Hashemzadeh M, Hashemzadeh M. Declining in-hospital deaths in patients undergoing coronary bypass surgery in the United States irrespective of presence of type 2 diabetes or congestive heart failure. Clin Cardiol 2012;35:297–300.
3. Ferguson TB Jr, Hammill BG, Peterson ED, DeLong ER, Grover FL, STS National Database Committee. A decade of change–risk profiles and outcomes for isolated coronary artery bypass grafting procedures, 1990–1999: a report from the STS National Database Committee and the Duke Clinical Research Institute. Society of Thoracic Surgeons. Ann Thorac Surg 2002;73:480–9; discussion 489–90.
4. Epstein AJ, Polsky D, Yang F, Yang L, Groeneveld PW. Coronary revascularization trends in the United States, 2001–2008. JAMA 2011;305:1769–76.
5. Riley RF, Don CW, Powell W, Maynard C, Dean LS. Trends in coronary revascularization in the United States from 2001 to 2009: recent declines in percutaneous coronary intervention volumes. Circ Cardiovasc Qual Outcomes 2011;4:193–7.
6. Vedin O, Hagstrom E, Stewart R, et al. Secondary prevention and risk factor target achievement in a global, high-risk population with established coronary heart disease: baseline results from the STABILITY study. Eur J Prev Cardiol 2013;20:678–85.
7. Cao C, Manganas C, Horton M, et al. Angiographic outcomes of radial artery versus saphenous vein in coronary artery bypass graft surgery: a meta-analysis of randomized controlled trials. J Thorac Cardiovasc Surg 2013;146:255–61.
8. Aldea GS, Mokadam NA, Melford R Jr, et al. Changing volumes, risk profiles, and outcomes of coronary artery bypass grafting and percutaneous coronary interventions. Ann Thorac Surg 2009;87:1828–38.
9. Buth KJ, Gainer RA, Legare JF, Hirsch GM. The changing face of cardiac surgery: practice patterns and outcomes 2001–2010. Can J Cardiol 2014;30:224–30.
10. Mokadam NA, Melford RE Jr, Maynard C, et al. Prevalence and procedural outcomes of percutaneous coronary intervention and coronary artery bypass grafting in patients with diabetes and multivessel coronary artery disease. J Card Surg 2011;26:1–8.
11. Hlatky MA, Boothroyd DB, Bravata DM, et al. Coronary artery bypass surgery compared with percutaneous coronary interventions for multivessel disease: a collaborative analysis of individual patient data from ten randomised trials. Lancet 2009;373:1190–7.
12. Daemen J, Boersma E, Flather M, et al. Long-term safety and efficacy of percutaneous coronary intervention with stenting and coronary artery bypass surgery for multivessel coronary artery disease: a meta-analysis with 5-year

patient-level data from the ARTS, ERACI-II, MASS-II, and SoS trials. Circulation 2008;118:1146–54.
13. Hlatky MA, Boothroyd DB, Baker L, et al. Comparative effectiveness of multivessel coronary bypass surgery and multivessel percutaneous coronary intervention: a cohort study. Ann Intern Med 2013;158:727–34.
14. Weintraub WS, Grau-Sepulveda MV, Weiss JM, et al. Comparative effectiveness of revascularization strategies. N Engl J Med 2012;366:1467–76.
15. Kappetein AP, Feldman TE, Mack MJ, et al. Comparison of coronary bypass surgery with drug-eluting stenting for the treatment of left main and/or three-vessel disease: 3-year follow-up of the SYNTAX trial. Eur Heart J 2011;32:2125–34.
16. Mohr FW, Morice MC, Kappetein AP, et al. Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial. Lancet 2013;381:629–38.
17. Mohr FW, Rastan AJ, Serruys PW, et al. Complex coronary anatomy in coronary artery bypass graft surgery: impact of complex coronary anatomy in modern bypass surgery? Lessons learned from the SYNTAX trial after two years. J Thorac Cardiovasc Surg 2011;141:130–40.
18. Head SJ, Parasca CA, Mack MJ, et al. Differences in baseline characteristics, practice patterns and clinical outcomes in contemporary coronary artery bypass grafting in the United States and Europe: insights from the SYNTAX randomized trial and registry. Eur J Cardiothorac Surg 2015;46:400–8; discussion 408.
19. The Society of Thoracic Surgeons. Adult Cardiac Surgery Database. Chicago: The Society; 2014.
20. Goldman S, Zadina K, Moritz T, et al. Long-term patency of saphenous vein and left internal mammary artery grafts after coronary artery bypass surgery: results from a Department of Veterans Affairs Cooperative Study. J Am Coll Cardiol 2004;44:2149–56.
21. McLean RC, Nazarian SM, Gluckman TJ, et al. Relative importance of patient, procedural and anatomic risk factors for early vein graft thrombosis after coronary artery bypass graft surgery. J Cardiovasc Surg (Torino) 2011;52:877–85.
22. Halabi AR, Alexander JH, Shaw LK, et al. Relation of early saphenous vein graft failure to outcomes following coronary artery bypass surgery. Am J Cardiol 2005;96:1254–9.
23. Dimitrova KR, Hoffman DM, Geller CM, Dincheva G, Ko W, Tranbaugh RF. Arterial grafts protect the native coronary vessels from atherosclerotic disease progression. Ann Thorac Surg 2012;94:475–81.
24. Knobloch K, Lichtenberg A, Pichlmaier M, et al. Microcirculation of the sternum following harvesting of the left internal mammary artery. Thoracic Cardiovasc Surg 2003;51:255–9.
25. Lorberboym M, Medalion B, Bder O, et al. 99mTc-MDP bone SPECT for the evaluation of sternal ischaemia following internal mammary artery dissection. Nucl Med Commun 2002;23:47–52.
26. Ali E, Saso S, Ashrafian H, Athanasiou T. Does a skeletonized or pedicled left internal thoracic artery give the best graft patency? Interact Cardiovasc Thorac Surg 2010;10:97–104.
27. Hu X, Zhao Q. Skeletonized internal thoracic artery harvest improves prognosis in high-risk population after coronary artery bypass surgery for good quality grafts. Ann Thorac Surg 2011;92:48–58.
28. Sakic A, Chevtchik O, Kilo J, et al. Simple adaptations of surgical technique to critically reduce the risk of postoperative sternal complications in patients receiving bilateral internal thoracic arteries. Interact Cardiovasc Thorac Surg 2013;17:378–82.
29. Toumpoulis IK, Theakos N, Dunning J. Does bilateral internal thoracic artery harvest increase the risk of mediastinitis? Interact Cardiovasc Thorac Surg 2007;6:787–91.
30. Itagaki S, Cavallaro P, Adams DH, Chikwe J. Bilateral internal mammary artery grafts, mortality and morbidity: an analysis of 1 526 360 coronary bypass operations. Heart 2013;99:849–53.
31. Weiss AJ, Zhao S, Tian DH, Taggart DP, Yan TD. A meta-analysis comparing bilateral internal mammary artery with left internal mammary artery for coronary artery bypass grafting. Ann Cardiothorac Surg 2013;2:390–400.
32. Glineur D, D'Hoore W, Price J, et al. Survival benefit of multiple arterial grafting in a 25-year single-institutional experience: the importance of the third arterial graft. Eur J Cardiothorac Surg 2012;42:284–90; discussion 290–1.
33. Tatoulis J, Buxton BF, Fuller JA. The right internal thoracic artery: the forgotten conduit–5,766 patients and 991 angiograms. Ann Thorac Surg 2011;92:9–15; discussion 15–7.
34. Raja SG, Benedetto U, Husain M, et al. Does grafting of the left anterior descending artery with the in situ right internal thoracic artery have an impact on late outcomes in the context of bilateral internal thoracic artery usage? J Thorac Cardiovasc Surg 2014;148:1275–81; Erratum in: J thorac Cardiovasc Surg 2015;149:947.
35. Kieser TM, Lewin AM, Graham MM, et al. Outcomes associated with bilateral internal thoracic artery grafting: the importance of age. Ann Thorac Surg 2011;92:1269–75; discussion 1275–6.
36. Mohammadi S, Dagenais F, Doyle D, et al. Age cut-off for the loss of benefit from bilateral internal thoracic artery grafting. Eur J Cardiothorac Surg 2008;33:977–82.
37. Raza S, Sabik JF 3rd, Masabni K, Ainkaran P, Lytle BW, Blackstone EH. Surgical revascularization techniques that minimize surgical risk and maximize late survival after coronary artery bypass grafting in patients with diabetes mellitus. J Thorac Cardiovasc Surg 2014;148:1257–64; discussion 1264–6.
38. Alasmari FA, Tleyjeh IM, Riaz M, et al. Temporal trends in the incidence of surgical site infections in patients undergoing coronary artery bypass graft surgery: a population-based cohort study, 1993 to 2008. Mayo Clin Proc 2012;87:1054–61.
39. Speir AM, Kasirajan V, Barnett SD, Fonner E Jr. Additive costs of postoperative complications for isolated coronary artery bypass grafting patients in Virginia. Ann Thorac Surg 2009;88:40–5; discussion 45–6.
40. Braxton JH, Marrin CA, McGrath PD, et al. 10-year follow-up of patients with and without mediastinitis. Semin Thorac Cardiovasc Surg 2004;16:70–6.
41. Graf K, Ott E, Vonberg RP, Kuehn C, Haverich A, Chaberny IF. Economic aspects of deep sternal wound infections. Eur J Cardiothorac Surg 2010;37:893–6.
42. Berrios-Torres SI, Mu Y, Edwards JR, Horan TC, Fridkin SK. Improved risk adjustment in public reporting: coronary artery bypass graft surgical site infections. Infect Control Hosp Epidemiol 2012;33:463–9.
43. Shahian DM, O'Brien SM, Filardo G, et al. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 3–valve plus coronary artery bypass grafting surgery. Ann Thorac Surg 2009;88:S43–62.
44. Fowler VG Jr, O'Brien SM, Muhlbaier LH, Corey GR, Ferguson TB, Peterson ED. Clinical predictors of major infections after cardiac surgery. Circulation 2005;112:I358–65.
45. Hemo E, Mohr R, Uretzky G, et al. Long-term outcomes of patients with diabetes receiving bilateral internal thoracic artery grafts. J Thorac Cardiovasc Surg 2013;146:586–92.
46. Takami Y, Tajima K, Masumoto H. Near-infrared spectroscopy for noninvasive evaluation of chest wall ischemia immediately after left internal thoracic artery harvesting. Gen Thorac Cardiovasc Surg 2008;56:281–7.
47. Boodhwani M, Lam BK, Nathan HJ, et al. Skeletonized internal thoracic artery harvest reduces pain and dysesthesia and improves sternal perfusion after coronary artery bypass surgery: a randomized, double-blind, within-patient comparison. Circulation 2006;114:766–73.
48. Tang GH, Maganti M, Weisel RD, Borger MA. Prevention and management of deep sternal wound infection. Semin Thorac Cardiovasc Surg 2004;16:62–9.

49. Pusca SV, Kilgo PD, Vega JD, et al. Propensity-score analysis of early outcomes after bilateral versus single internal thoracic artery grafting. Innovations (Phila) 2008;3:19–24.
50. Gansera B, Schmidtler F, Gillrath G, et al. Does bilateral ITA grafting increase perioperative complications? Outcome of 4462 patients with bilateral versus 4204 patients with single ITA bypass. Eur J Cardiothorac Surg 2006;30:318–23.
51. Momin AU, Deshpande R, Potts J, et al. Incidence of sternal infection in diabetic patients undergoing bilateral internal thoracic artery grafting. Ann Thorac Surg 2005;80:1765–72; discussion 1772.
52. Halkos ME, Thourani VH, Lattouf OM, Kilgo P, Guyton RA, Puskas JD. Preoperative hemoglobin a1c predicts sternal wound infection after coronary artery bypass surgery with bilateral versus single internal thoracic artery grafts. Innovations (Phila) 2008;3:131–8.
53. Taggart DP, Altman DG, Gray AM, et al. Randomized trial to compare bilateral vs. single internal mammary coronary artery bypass grafting: 1-year results of the Arterial Revascularisation Trial (ART). Eur Heart J 2010;31:2470–81.
54. Ronald A, Patel A, Dunning J. Is the Allen's test adequate to safely confirm that a radial artery may be harvested for coronary arterial bypass grafting? Interact Cardiovasc Thorac Surg 2005;4:332–40.
55. Meharwal ZS, Trehan N. Functional status of the hand after radial artery harvesting: results in 3,977 cases. Ann Thorac Surg 2001;72:1557–61.
56. Holman WL, Davies JE, Lin JY, et al. Consequences of radial artery harvest: results of a prospective, randomized, multicenter trial. JAMA Surg 2013;148:1020–3.
57. Denton TA, Trento L, Cohen M, et al. Radial artery harvesting for coronary bypass operations: neurologic complications and their potential mechanisms. J Thorac Cardiovasc Surg 2001;121:951–6.
58. Myers MG, Fremes SE. Prevention of radial artery graft spasm: a survey of Canadian surgical centres. Can J Cardiol 2003;19:677–81.
59. Yoshizaki T, Tabuchi N, Toyama M. Verapamil and nitroglycerin improves the patency rate of radial artery grafts. Asian Cardiovasc Thorac Ann 2008;16:396–400.
60. Kulik A, Rubens FD, Gunning D, Bourke ME, Mesana TG, Ruel M. Radial artery graft treatment with phenoxybenzamine is clinically safe and may reduce perioperative myocardial injury. Ann Thorac Surg 2007;83:502–9.
61. Mussa S, Guzik TJ, Black E, Dipp MA, Channon KM, Taggart DP. Comparative efficacies and durations of action of phenoxybenzamine, verapamil/nitroglycerin solution, and papaverine as topical antispasmodics for radial artery coronary bypass grafting. J Thorac Cardiovasc Surg 2003;126:1798–805.
62. Athanasiou T, Saso S, Rao C, et al. Radial artery versus saphenous vein conduits for coronary artery bypass surgery: forty years of competition–which conduit offers better patency? A systematic review and meta-analysis. Eur J Cardiothorac Surg 2011;40:208–20.
63. Achouh P, Isselmou KO, Boutekadjirt R, et al. Reappraisal of a 20-year experience with the radial artery as a conduit for coronary bypass grafting. Eur J Cardiothorac Surg 2012;41:87–92.
64. Patel A, Asopa S, Dunning J. Should patients receiving a radial artery conduit have post-operative calcium channel blockers? Interact Cardiovasc Thorac Surg 2006;5:251–7.
65. Miwa S, Desai N, Koyama T, et al. Radial artery angiographic string sign: clinical consequences and the role of pharmacologic therapy. Ann Thorac Surg 2006;81:112–8; discussion 119.
66. Desai ND, Cohen EA, Naylor CD, Fremes SE. Radial Artery Patency Study Investigators. A randomized comparison of radial-artery and saphenous-vein coronary bypass grafts. N Engl J Med 2004;351:2302–9.
67. 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. Circulation 2011;124:e652–735.
68. Athanasiou T, Ashrafian H, Mukherjee D, Harling L, Okabayashi K. Are arterial grafts superior to vein grafts for revascularisation of the right coronary system? A systematic review. Heart 2013;99:835–42.
69. Deb S, Cohen EA, Singh SK, et al. 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.
70. 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.
71. Gaudino M, Cellini C, Pragliola C, et al. Arterial versus venous bypass grafts in patients with in-stent restenosis. Circulation 2005;112:I265–9.
72. 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.
73. 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.
74. Hayward PA, 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.
75. Dreifaldt M, Mannion JD, Bodin L, Olsson H, Zagozdzon L, Souza D. The no-touch saphenous vein as the preferred second conduit for coronary artery bypass grafting. Ann Thorac Surg 2013;96:105–11.
76. Schwann TA, Zacharias A, Riordan CJ, Durham SJ, Shah AS, Habib RH. Sequential radial artery grafts for multivessel coronary artery bypass graft surgery: 10-year survival and angiography results. Ann Thorac Surg 2009;88:31–9.
77. Tranbaugh RF, Dimitrova KR, Friedmann P, et al. Coronary artery bypass grafting using the radial artery: clinical outcomes, patency, and need for reintervention. Circulation 2012;126:S170–5.
78. Khot UN, Friedman DT, Pettersson G, Smedira NG, Li J, Ellis SG. Radial artery bypass grafts have an increased occurrence of angiographically severe stenosis and occlusion compared with left internal mammary arteries and saphenous vein grafts. Circulation 2004;109:2086–91.
79. Fukui T, Tabata M, Manabe S, Shimokawa T, Takanashi S. Graft selection and one-year patency rates in patients undergoing coronary artery bypass grafting. Ann Thorac Surg 2010;89:1901–5.
80. 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.
81. Hu X, Zhao Q. Systematic comparison of the effectiveness of radial artery and saphenous vein or right internal thoracic artery coronary bypass grafts in non-left anterior descending coronary arteries. J Zhejiang Univ Sci B 2011;12:273–9.
82. Tranbaugh RF, Dimitrova KR, Friedmann P, et al. Radial artery conduits improve long-term survival after coronary artery bypass grafting. Ann Thorac Surg 2010;90:1165–72.
83. Schwann TA, Engoren M, Bonnell M, Clancy C, Habib RH. Comparison of late coronary artery bypass graft survival effects of radial artery versus saphenous vein grafting in male and female patients. Ann Thorac Surg 2012;94:1485–91.

84. Zacharias A, Habib RH, Schwann TA, Riordan CJ, Durham SJ, Shah A. Improved survival with radial artery versus vein conduits in coronary bypass surgery with left internal thoracic artery to left anterior descending artery grafting. Circulation 2004;109:1489–96.
85. Locker C, Schaff HV, Dearani JA, et al. Multiple arterial grafts improve late survival of patients undergoing coronary artery bypass graft surgery: analysis of 8622 patients with multivessel disease. Circulation 2012;126:1023–30.
86. Tranbaugh RF, Dimitrova KR, Lucido DJ, et al. The second best arterial graft: a propensity analysis of the radial artery versus the free right internal thoracic artery to bypass the circumflex coronary artery. J Thorac Cardiovasc Surg 2014;147:133–40.
87. Cho WC, Yoo DG, Kim JB, et al. Left internal thoracic artery composite grafting with the right internal thoracic versus radial artery in coronary artery bypass grafting. J Card Surg 2011;26:579–85.
88. Navia D, Vrancic M, Piccinini F, et al. Is the second internal thoracic artery better than the radial artery in total arterial off-pump coronary artery bypass grafting? A propensity score-matched follow-up study. J Thorac Cardiovasc Surg 2014;147:632–8.
89. Ruttmann E, Fischler N, Sakic A, et al. Second internal thoracic artery versus radial artery in coronary artery bypass grafting: a long-term, propensity score-matched follow-up study. Circulation 2011;124:1321–9.
90. Lim LM, Galvin SD, Javid M, Matalanis G. Should the radial artery be used as a bypass graft following radial access coronary angiography. Interact Cardiovasc Thorac Surg 2014;18:219–24.
91. Kamiya H, Ushijima T, Kanamori T, et al. Use of the radial artery graft after transradial catheterization: is it suitable as a bypass conduit? Ann Thorac Surg 2003;76:1505–9.
92. Glineur D, D'hoore W, El Khoury G, et al. Angiographic predictors of 6-month patency of bypass grafts implanted to the right coronary artery a prospective randomized comparison of gastroepiploic artery and saphenous vein grafts. J Am Coll Cardiol 2008;51:120–5.
93. Suma H, Isomura T, Horii T, Sato T. Late angiographic result of using the right gastroepiploic artery as a graft. J Thorac Cardiovasc Surg 2000;120:496–8.
94. Takemura H, Watanabe G, Takahashi M, Tomita S, Higashidani K. Beating heart coronary artery bypass grafting: results from 402 patients and the usefulness of gastroepiploic artery composite grafting. Jpn J Thorac Cardiovasc Surg 2003;51:173–7.
95. Yie K, Na CY, Oh SS, Kim JH, Shinn SH, Seo HJ. Angiographic results of the radial artery graft patency according to the degree of native coronary stenosis. Eur J Cardiothorac Surg 2008;33:341–8.
96. Hirose H, Amano A, Takanashi S, Takahashi A. Coronary artery bypass grafting using the gastroepiploic artery in 1,000 patients. Ann Thorac Surg 2002;73:1371–9.
97. Kim KB, Cho KR, Choi JS, Lee HJ. Right gastroepiploic artery for revascularization of the right coronary territory in off-pump total arterial revascularization: strategies to improve patency. Ann Thorac Surg 2006;81:2135–41.
98. Di Mauro M, Contini M, Iaco AL, et al. Bilateral internal thoracic artery on the left side: a propensity score-matched study of impact of the third conduit on the right side. J Thorac Cardiovasc Surg 2009;137:869–74.
99. Esaki J, Koshiji T, Okamoto M, Tsukashita M, Ikuno T, Sakata R. Gastroepiploic artery grafting does not improve the late outcome in patients with bilateral internal thoracic artery grafting. Ann Thorac Surg 2007;83:1024–9.
100. Pevni D, Uretzky G, Yosef P, et al. Revascularization of the right coronary artery in bilateral internal thoracic artery grafting. Ann Thorac Surg 2005;79:564–9.
101. Lev-Ran O, Mohr R, Uretzky G, et al. Graft of choice to right coronary system in left-sided bilateral internal thoracic artery grafting. Ann Thorac Surg 2003;75:88–92.
102. Jeong DS, Kim YH, Lee YT, et al. Revascularization for the right coronary artery territory in off-pump coronary artery bypass surgery. Ann Thorac Surg 2013;96:778–85; discussion 785.
103. Suma H, Tanabe H, Takahashi A, et al. Twenty years experience with the gastroepiploic artery graft for CABG. Circulation 2007;116:I188–91.
104. Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS); European Association for Percutaneous Cardiovascular Iinterventions (EAPCI), et al. Guidelines on myocardial revascularization. Eur J Cardiothorac Surg 2010;38 Suppl:S1–52.
105. Kolh P, Windecker S, Alfonso F, et al. 2014 ESC/EACTS Guidelines on myocardial revascularization: the Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS). Developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI). Eur J Cardiothorac Surg 2014;46:517–92.