2011 ACCF/AHA Guideline for Coronary Artery Bypass Graft Surgery: Executive Summary

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

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Preamble

The medical profession should play a central role in evaluating the evidence related to drugs, devices, and procedures for the detection, management, and prevention of disease. When properly applied, expert analysis of available data on the benefits and risks of these therapies and procedures can improve the quality of care, optimize patient outcomes, and favorably affect costs by focusing resources on the most effective strategies. An organized and directed approach to a thorough review of evidence has resulted in the production of clinical practice guidelines that assist physicians in selecting the best management strategy for an individual patient. Moreover, clinical practice guidelines can provide a foundation for other applications, such as performance measures, appropriate use criteria, and both quality improvement and clinical decision support tools.

The American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA) have jointly produced guidelines in the area of cardiovascular disease since 1980. The ACCF/AHA Task Force on Practice Guidelines (Task Force), charged with developing, updating, and revising practice guidelines for cardiovascular diseases and procedures, directs and oversees this effort. Writing committees are charged with regularly reviewing and evaluating all available evidence to develop balanced, patient-centric recommendations for clinical practice.

Experts in the subject under consideration are selected by the ACCF and AHA to examine subject-specific data and write guidelines in partnership with representatives from other medical organizations and specialty groups. Writing

Table 1. Applying Classification of Recommendations and Level of Evidence

ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT	SIZE OF TREATMENT EFFECT: 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* or CLASS III *Harm* Procedure/Test / Treatment COR III: No benefit — Not Helpful / No Proven Benefit COR III: Harm — Excess Cost w/o Benefit or Harmful / Harmful to Patients
LEVEL A Multiple populations evaluated* Data derived from multiple randomized clinical trials or meta-analyses	■ Recommendation that procedure or treatment is useful/effective ■ Sufficient evidence from multiple randomized trials or meta-analyses	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Sufficient evidence from multiple randomized trials or meta-analyses
LEVEL B Limited populations evaluated* Data derived from a single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is useful/effective ■ Evidence from single randomized trial or nonrandomized studies	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Evidence from single randomized trial or nonrandomized studies
LEVEL C Very limited populations evaluated* Only consensus opinion of experts, case studies, or standard of care	■ Recommendation that procedure or treatment is useful/effective ■ Only expert opinion, case studies, or standard of care	■ Recommendation in favor of treatment or procedure being useful/effective ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation's usefulness/efficacy less well established ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Only expert opinion, case studies, or standard of care
Suggested phrases for writing recommendations	should is recommended is indicated is useful/effective/beneficial	is reasonable can be useful/effective/beneficial is probably recommended or indicated	may/might be considered may/might be reasonable usefulness/effectiveness is unknown/unclear/uncertain or not well established	COR III: No Benefit: is not recommended; is not indicated; should not be performed/ administered/ other; is not useful/ beneficial/ effective COR III: Harm: potentially harmful; causes harm; associated with excess morbidity/mortality; should not be performed/ administered/ other
Comparative effectiveness phrases†	treatment/strategy A is recommended/indicated in preference to treatment B treatment A should be chosen over treatment B	treatment/strategy A is probably recommended/indicated in preference to treatment B it is reasonable to choose treatment A over treatment B		

A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials.

Although randomized trials are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

*Data available from clinical trials or registries about the usefulness/efficacy in different subpopulations, such as sex, age, history of diabetes, history of prior myocardial infarction, history of heart failure, and prior aspirin use.

†For comparative effectiveness recommendations (Class I and IIa; Level of Evidence A and B only), studies that support the use of comparator verbs should involve direct comparisons of the treatments or strategies being evaluated.

committees are asked to perform a formal literature review; weigh the strength of evidence for or against particular tests, treatments, or procedures; and include estimates of expected outcomes where such data exist. Patient-specific modifiers, comorbidities, and issues of patient preference that may influence the choice of tests or therapies are considered. When available, information from studies on cost is considered, but data on efficacy and outcomes constitute the primary basis for the recommendations contained herein.

In analyzing the data and developing recommendations and supporting text, the writing committee uses evidence-based methodologies developed by the Task Force.[1] The Class of Recommendation (COR) is an estimate of the size of the treatment effect considering risks versus benefits in addition to evidence and/or agreement that a given treatment or procedure is or is not useful/effective or in some situations may cause harm. The Level of Evidence (LOE) is an estimate of the certainty or precision of the treatment effect. The writing committee reviews and ranks evidence supporting each recommendation with the weight of evidence ranked as LOE A, B, or C according to specific definitions that are included in Table 1. Studies are identified as observational, retrospective, prospective, or randomized where appropriate. For certain conditions for which inadequate data are available, recommendations are based on expert consensus and clinical experience and are ranked as LOE C. When recommendations at LOE C are supported by historical clinical data, appropriate references (including clinical reviews) are cited if available. For issues for which sparse data are available, a survey of current practice among the clinicians on

the writing committee is the basis for LOE C recommendations, and no references are cited. The schema for COR and LOE is summarized in Table 1, which also provides suggested phrases for writing recommendations within each COR. A new addition to this methodology is separation of the Class III recommendations to delineate if the recommendation is determined to be of "no benefit" or is associated with "harm" to the patient. In addition, in view of the increasing number of comparative effectiveness studies, comparator verbs and suggested phrases for writing recommendations for the comparative effectiveness of one treatment or strategy versus another have been added for COR I and IIa, LOE A or B only.

In view of the advances in medical therapy across the spectrum of cardiovascular diseases, the Task Force has designated the term *guideline–directed medical therapy (GDMT)* to represent optimal medical therapy as defined by ACCF/AHA guideline–recommended therapies (primarily Class I). This new term, GDMT, will be used herein and throughout all future guidelines.

Because the ACCF/AHA practice guidelines address patient populations (and healthcare providers) residing in North America, drugs that are not currently available in North America are discussed in the text without a specific COR. For studies performed in large numbers of subjects outside North America, each writing committee reviews the potential influence of different practice patterns and patient populations on the treatment effect and relevance to the ACCF/AHA target population to determine whether the findings should inform a specific recommendation.

The ACCF/AHA practice guidelines are intended to assist healthcare providers in clinical decision making by describing a range of generally acceptable approaches to the diagnosis, management, and prevention of specific diseases or conditions. The guidelines attempt to define practices that meet the needs of most patients in most circumstances. The ultimate judgment regarding the care of a particular patient must be made by the healthcare provider and patient in light of all the circumstances presented by that patient. As a result, situations may arise for which deviations from these guidelines may be appropriate. Clinical decision making should involve consideration of the quality and availability of expertise in the area where care is provided. When these guidelines are used as the basis for regulatory or payer decisions, the goal should be improvement in quality of care. The Task Force recognizes that situations arise in which additional data are needed to inform patient care more effectively; these areas will be identified within each respective guideline when appropriate.

Prescribed courses of treatment in accordance with these recommendations are effective only if followed. Because lack of patient understanding and adherence may adversely affect outcomes, physicians and other healthcare providers should make every effort to engage the patient's active participation in prescribed medical regimens and lifestyles. In addition, patients should be informed of the risks, benefits, and alternatives to a particular treatment and be involved in shared decision making whenever feasible, particularly for COR IIa and IIb, where the benefit-to-risk ratio may be lower.

The Task Force makes every effort to avoid actual, potential, or perceived conflicts of interest that may arise as a result of industry relationships or personal interests among the members of the writing committee. All writing committee members and peer reviewers of the guideline are required to disclose all such current relationships, as well as those existing 12 months previously. In December 2009, the ACCF and AHA implemented a new policy for relationships with industry and other entities (RWI) that requires the writing committee chair plus a minimum of 50% of the writing committee to have no *relevant* RWI (Appendix 1 for the ACCF/AHA definition of relevance). These statements are reviewed by the Task Force and all members during each conference call and meeting of the writing committee and are updated as changes occur. All guideline recommendations require a confidential vote by the writing committee and must be approved by a consensus of the voting members. Members are not permitted to write, and must rescue themselves from voting on, any recommendation or section to which their RWI apply. Members who recused themselves from voting are indicated in the list of writing committee members, and section recusals are noted in Appendix 1. Authors' and peer reviewers' RWI pertinent to this guideline are disclosed in Appendixes 1 and 2, respectively. Additionally, to ensure complete transparency, writing committee members' comprehensive disclosure information—including RWI not pertinent to this document—is available as an online supplement. Comprehensive disclosure information for the Task Force is also available online at www.cardiosource.org/ACC/About-ACC/Leadership/Guidelines-and-Documents-Task-Forces.aspx. The work of the writing committee was supported exclusively by the ACCF and AHA without commercial support. Writing committee members volunteered their time for this activity.

In an effort to maintain relevance at the point of care for practicing physicians, the Task Force continues to oversee an ongoing process improvement initiative. As a result, in response to pilot projects, evidence tables (with references linked to abstracts in PubMed) have been added.

In April 2011, the Institute of Medicine released 2 reports: *Finding What Works in Health Care: Standards for Systematic Reviews* and *Clinical Practice Guidelines We Can Trust*.[2,3] It is noteworthy that the ACCF/AHA guidelines are cited as being compliant with many of the proposed standards. A thorough review of these reports and of our current methodology is under way, with further enhancements anticipated.

The recommendations in this guideline are considered current until they are superseded by a focused update or the full-text guideline is revised. Guidelines are official policy of both the ACCF and AHA.

Alice K. Jacobs, MD, FACC, FAHA
Chair, ACCF/AHA Task Force on Practice Guidelines

1. Introduction

1.1. Methodology and Evidence Review

Whenever possible, the recommendations listed in this document are evidence based. Articles reviewed in this guideline revision covered evidence from the past 10 years through January 2011, as well as selected other references through

April 2011. Searches were limited to studies, reviews, and evidence conducted in human subjects that were published in English. Key search words included but were not limited to: *analgesia, anastomotic techniques, antiplatelet agents, automated proximal clampless anastomosis device, asymptomatic ischemia, Cardica C-port, cost effectiveness, depressed left ventricular (LV) function, distal anastomotic techniques, direct proximal anastomosis on aorta, distal anastomotic devices, emergency coronary artery bypass graft (CABG) and ST-elevation myocardial infarction (STEMI), heart failure, interrupted sutures, LV systolic dysfunction, magnetic connectors, PAS-Port automated proximal clampless anastomotic device, patency, proximal connectors, renal disease, sequential anastomosis, sternotomy, symmetry connector, symptomatic ischemia, proximal connectors, sequential anastomosis, T grafts, thoracotomy, U-clips, Ventrica Magnetic Vascular Port system, Y grafts*. Additionally, the committee reviewed documents related to the subject matter previously published by the ACCF and AHA. References selected and published in this document are representative but not all-inclusive.

The guideline is focused on the safe, appropriate, and efficacious performance of CABG. The STEMI, percutaneous coronary intervention (PCI), and CABG guidelines were written concurrently, with additional collaboration from the Stable Ischemic Heart Disease (SIHD) guideline writing committee. This allowed greater collaboration among the different writing committees on topics such as PCI in STEMI and revascularization strategies in patients with coronary artery disease (CAD) (including unprotected left main PCI, multivessel disease revascularization, and hybrid procedures).

In accordance with the direction of the Task Force and feedback from readers, in this iteration of the guideline, the amount of text has been shortened, and emphasis has been placed on summary statements rather than detailed discussion of numerous individual trials. Online supplemental evidence and summary tables have been created to document the studies and data considered for new or changed guideline recommendations.

Because the executive summary contains only the recommendations, the reader is encouraged to consult the full-text guideline[4] for additional detail on the recommendations and guidance on the care of the patient undergoing CABG.

1.2. Organization of the Writing Committee

The committee was composed of acknowledged experts in CABG, interventional cardiology, general cardiology, and cardiovascular anesthesiology. The committee included representatives from the ACCF, AHA, American Association for Thoracic Surgery, Society of Cardiovascular Anesthesiologists, and Society of Thoracic Surgeons (STS).

1.3. Document Review and Approval

This document was reviewed by 2 official reviewers, each nominated by both the ACCF and the AHA, as well as 1 reviewer each from the American Association for Thoracic Surgery, Society of Cardiovascular Anesthesiologists, and STS, as well as members from the ACCF/AHA Task Force on Data Standards, ACCF/AHA Task Force on Performance Measures, ACCF Surgeons' Scientific Council, ACCF Interventional Scientific Council, and Southern Thoracic Surgical Association. All information on reviewers' RWIs was distributed to the writing committee and is published in this document (Appendix 2). This document was approved for publication by the governing bodies of the ACCF and the AHA and endorsed by the American Association for Thoracic Surgery, Society of Cardiovascular Anesthesiologists, and STS.

2. Procedural Considerations: Recommendations

2.1. Anesthetic Considerations

Class I

1. **Anesthetic management directed toward early postoperative extubation and accelerated recovery of low- to medium-risk patients undergoing uncomplicated CABG is recommended.[5–7] *(Level of Evidence: B)***
2. **Multidisciplinary efforts are indicated to ensure an optimal level of analgesia and patient comfort throughout the perioperative period.[8–12] *(Level of Evidence: B)***
3. **Efforts are recommended to improve interdisciplinary communication and patient safety in the perioperative environment (eg, formalized checklist-guided multidisciplinary communication).[13–16] *(Level of Evidence: B)***
4. **A fellowship-trained cardiac anesthesiologist (or experienced board-certified practitioner) credentialed in the use of perioperative transesophageal echocardiography is recommended to provide or supervise anesthetic care of patients who are considered to be at high risk.[17–19] *(Level of Evidence: C)***

Class IIa

1. **Volatile anesthestic-based regimens can be useful in facilitating early extubation and reducing patient recall.[6,20–22] *(Level of Evidence: A)***

Class IIb

1. **The effectiveness of high thoracic epidural anesthesia/analgesia for routine analgesic use is uncertain.[23–26] *(Level of Evidence: B)***

Class III: HARM

1. **Cyclooxygenase-2 inhibitors are not recommended for pain relief in the postoperative period after CABG.[27,28] *(Level of Evidence: B)***
2. **Routine use of early extubation strategies in facilities with limited backup for airway emergencies or advanced respiratory support is potentially harmful. *(Level of Evidence: C)***

2.2. Bypass Graft Conduit

Class I

1. **If possible, the left internal mammary artery (LIMA) should be used to bypass the left anterior**

descending (LAD) artery when bypass of the LAD artery is indicated.[29–32] *(Level of Evidence: B)*

Class IIa

1. The right internal mammary artery is probably indicated to bypass the LAD artery when the LIMA is unavailable or unsuitable as a bypass conduit. *(Level of Evidence: C)*
2. When anatomically and clinically suitable, use of a second internal mammary artery 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.[33–37] *(Level of Evidence: B)*

Class IIb

1. Complete arterial revascularization may be reasonable in patients less than or equal to 60 years of age with few or no comorbidities. *(Level of Evidence: C)*
2. Arterial grafting of the right coronary artery may be reasonable when a critical (≥90%) stenosis is present.[32,36,38] *(Level of Evidence: B)*
3. Use of a radial artery graft may be reasonable when grafting left-sided coronary arteries with severe stenoses (>70%) and right-sided arteries with critical stenoses (≥90%) that perfuse LV myocardium.[39–44] *(Level of Evidence: B)*

Class III: HARM

1. An arterial graft should not be used to bypass the right coronary artery with less than a critical stenosis (<90%).[32] *(Level of Evidence: C)*

2.3. Intraoperative Transesophageal Echocardiography

Class I

1. Intraoperative transesophageal echocardiography should be performed for evaluation of acute, persistent, and life-threatening hemodynamic disturbances that have not responded to treatment.[45,46] *(Level of Evidence: B)*
2. Intraoperative transesophageal echocardiography should be performed in patients undergoing concomitant valvular surgery.[45,47] *(Level of Evidence: B)*

Class IIa

1. Intraoperative transesophageal echocardiography is reasonable for monitoring of hemodynamic status, ventricular function, regional wall motion, and valvular function in patients undergoing CABG.[46,48–53] *(Level of Evidence: B)*

2.4. Preconditioning/Management of Myocardial Ischemia

Class I

1. Management targeted at optimizing the determinants of coronary arterial perfusion (eg, heart rate, diastolic or mean arterial pressure, and right ventricular or LV end-diastolic pressure) is recommended to reduce the risk of perioperative myocardial ischemia and infarction.[54–58] *(Level of Evidence: B)*

Class IIa

1. Volatile-based anesthesia can be useful in reducing the risk of perioperative myocardial ischemia and infarction.[59–62] *(Level of Evidence: A)*

Class IIb

1. The effectiveness of prophylactic pharmacological therapies or controlled reperfusion strategies aimed at inducing preconditioning or attenuating the adverse consequences of myocardial reperfusion injury or surgically induced systemic inflammation is uncertain.[63–70] *(Level of Evidence: A)*
2. Mechanical preconditioning might be considered to reduce the risk of perioperative myocardial ischemia and infarction in patients undergoing off-pump CABG.[71–73] *(Level of Evidence: B)*
3. Remote ischemic preconditioning strategies using peripheral-extremity occlusion/reperfusion might be considered to attenuate the adverse consequences of myocardial reperfusion injury.[74–76] *(Level of Evidence: B)*
4. The effectiveness of postconditioning strategies to attenuate the adverse consequences of myocardial reperfusion injury is uncertain.[77,78] *(Level of Evidence: C)*

2.5. Clinical Subsets

2.5.1. CABG in Patients With Acute Myocardial Infarction

Class I

1. Emergency CABG is recommended in patients with acute myocardial infarction (MI) in whom 1) primary PCI has failed or cannot be performed, 2) coronary anatomy is suitable for CABG, and 3) persistent ischemia of a significant area of myocardium at rest and/or hemodynamic instability refractory to nonsurgical therapy is present.[79–83] *(Level of Evidence: B)*
2. Emergency CABG is recommended in patients undergoing surgical repair of a postinfarction mechanical complication of MI, such as ventricular septal rupture, mitral valve insufficiency because of papillary muscle infarction and/or rupture, or free wall rupture.[84–88] *(Level of Evidence: B)*
3. Emergency CABG is recommended in patients with cardiogenic shock and who are suitable for CABG irrespective of the time interval from MI to onset of shock and time from MI to CABG.[82,89–91] *(Level of Evidence: B)*
4. Emergency CABG is recommended in patients with life-threatening ventricular arrhythmias (believed to be ischemic in origin) in the presence of left main stenosis greater than or equal to 50% and/or 3-vessel CAD.[92] *(Level of Evidence: C)*

Class IIa

1. **The use of CABG is reasonable as a revascularization strategy in patients with multivessel CAD with recurrent angina or MI within the first 48 hours of STEMI presentation as an alternative to a more delayed strategy.[79,81,83,93] *(Level of Evidence: B)***
2. **Early revascularization with PCI or CABG is reasonable for selected patients greater than 75 years of age with ST-segment elevation or left bundle branch block who are suitable for revascularization irrespective of the time interval from MI to onset of shock.[94–98] *(Level of Evidence: B)***

Class III: HARM

1. **Emergency CABG should not be performed in patients with persistent angina and a small area of viable myocardium who are stable hemodynamically. *(Level of Evidence: C)***
2. **Emergency CABG should not be performed in patients with noreflow (successful epicardial reperfusion with unsuccessful microvascular reperfusion). *(Level of Evidence: C)***

2.5.2. Life-Threatening Ventricular Arrhythmias

Class I

1. **CABG is recommended in patients with resuscitated sudden cardiac death or sustained ventricular tachycardia thought to be caused by significant CAD (≥50% stenosis of left main coronary artery and/or ≥70% stenosis of 1, 2, or all 3 epicardial coronary arteries) and resultant myocardial ischemia.[92,99,100] *(Level of Evidence: B)***

Class III: HARM

1. **CABG should not be performed in patients with ventricular tachycardia with scar and no evidence of ischemia. *(Level of Evidence: C)***

2.5.3. Emergency CABG After Failed PCI

Class I

1. **Emergency CABG is recommended after failed PCI in the presence of ongoing ischemia or threatened occlusion with substantial myocardium at risk.[101,102] *(Level of Evidence: B)***
2. **Emergency CABG is recommended after failed PCI for hemodynamic compromise in patients without impairment of the coagulation system and without a previous sternotomy.[101,103,104] *(Level of Evidence: B)***

Class IIa

1. **Emergency CABG is reasonable after failed PCI for retrieval of a foreign body (most likely a fractured guidewire or stent) in a crucial anatomic location. *(Level of Evidence: C)***
2. **Emergency CABG can be beneficial after failed PCI for hemodynamic compromise in patients with impairment of the coagulation system and without previous sternotomy. *(Level of Evidence: C)***

Class IIb

1. **Emergency CABG might be considered after failed PCI for hemodynamic compromise in patients with previous sternotomy. *(Level of Evidence: C)***

Class III: HARM

1. **Emergency CABG should not be performed after failed PCI in the absence of ischemia or threatened occlusion. *(Level of Evidence: C)***
2. **Emergency CABG should not be performed after failed PCI if revascularization is impossible because of target anatomy or a no-reflow state. *(Level of Evidence: C)***

2.5.4. CABG in Association With Other Cardiac Procedures

Class I

1. **CABG is recommended in patients undergoing noncoronary cardiac surgery with greater than or equal to 50% luminal diameter narrowing of the left main coronary artery or greater than or equal to 70% luminal diameter narrowing of other major coronary arteries. *(Level of Evidence: C)***

Class IIa

1. **The use of the LIMA is reasonable to bypass a significantly narrowed LAD artery in patients undergoing noncoronary cardiac surgery. *(Level of Evidence: C)***
2. **CABG of moderately diseased coronary arteries (>50% luminal diameter narrowing) is reasonable in patients undergoing noncoronary cardiac surgery. *(Level of Evidence: C)***

3. CAD Revascularization: Recommendations

Recommendations and text in this section are the result of extensive collaborative discussions between the PCI and CABG writing committees as well as key members of the SIHD and Unstable Angina/Non–ST-Elevation Myocardial Infarction (UA/NSTEMI) writing committees. Certain issues, such as older versus more contemporary studies, primary analyses versus subgroup analyses, and prospective versus post hoc analyses, have been carefully weighed in designating COR and LOE; they are addressed in the appropriate corresponding text.[4]

The goals of revascularization for patients with CAD are to 1) to improve survival and 2) to relieve symptoms. The following text contains recommendations for revascularization to improve survival and symptoms. These recommendations are summarized in Tables 2 and 3.

Revascularization recommendations in this section are predominantly based on studies of patients with symptomatic SIHD and should be interpreted in this context. As discussed later in this section, recommendations on the type of revascularization are, in general, applicable to patients with UA/NSTEMI. In some cases (eg, unprotected left main CAD), specific recommendations are made for patients with UA/NSTEMI or STEMI.

Table 2. Revascularization to Improve Survival Compared With Medical Therapy

Anatomic Setting	COR	LOE	References
UPLM or complex CAD			
CABG and PCI	I—Heart Team approach recommended	C	105–107
CABG and PCI	IIa—Calculation of the STS and SYNTAX scores	B	107–114
UPLM*			
CABG	I	B	115–121
PCI	IIa—For SIHD when *both* of the following are present: • Anatomic conditions associated with a low risk of PCI procedural complications and a high likelihood of good long-term outcome (eg, a low SYNTAX score of ≤22, ostial or trunk left main CAD) • Clinical characteristics that predict a significantly increased risk of adverse surgical outcomes (eg, STS-predicted risk of operative mortality ≥5%)	B	108, 110, 111, 122–140, 168
	IIa—For UA/NSTEMI if not a CABG candidate	B	111, 127, 129–131, 136, 137, 139, 140, 142
	IIa—For STEMI when distal coronary flow is TIMI flow grade 3 and PCI can be performed more rapidly and safely than CABG	C	124, 143, 144
	IIb—For SIHD when *both* of the following are present: • Anatomic conditions associated with a low to intermediate risk of PCI procedural complications and Intermediate to high likelihood of good long-term outcome (eg, low-intermediate SYNTAX score of <33, bifurcation left main CAD) • Clinical characteristics that predict an increased risk of adverse surgical outcomes (eg, moderate-severe COPD, disability from prior stroke, or prior cardiac surgery; STS-predicted risk of operative mortality >2%)	B	108, 110, 111, 122–137, 139, 145
	III: Harm—For SIHD in patients (versus performing CABG) with unfavorable anatomy and for PCI and who are good candidates for CABG	B	108, 110, 111, 115–123
3-vessel disease with or without proximal LAD artery disease*			
CABG	I	B	117, 121, 146–149
	IIa—It is reasonable to choose CABG over PCI in patients with complex 3-vessel CAD (eg, SYNTAX >22) who are good candidates for CABG	B	123, 138, 148, 164–165
PCI	IIb—Of uncertain benefit	B	117, 146, 148, 176
2-vessel disease with proximal LAD artery disease*			
CABG	I	B	117, 121, 146–149
PCI	IIb—Of uncertain benefit	B	117, 146, 148, 176
2-vessel disease without proximal LAD artery disease*			
CABG	IIa—With extensive ischemia	B	153–156
	IIb—Of uncertain benefit without extensive ischemia	C	148
PCI	IIb—Of uncertain benefit	B	117, 146, 148, 176
1-vessel proximal LAD artery disease			
CABG	IIa—With LIMA for long-term benefit	B	30, 31, 121, 148
PCI	IIb—of uncertain benefit	B	117, 146, 148, 176
1-vessel disease without proximal LAD artery Involvement			
CABG	III: Harm	B	121, 146, 153, 154, 188–192
PCI	III: Harm	B	121, 146, 153, 154, 188–192
LV dysfunction			
CABG	IIa—EF 35% to 50%	B	121, 157–161
CABG	IIb—EF <35% without significant left main CAD	B	121, 157–161, 177, 178
PCI	Insufficient data		
Survivors of sudden cardiac death with presumed ischemia-mediated VT			
CABG	I	B	99, 150, 152
PCI	I	C	150
No anatomic or physiological criteria for revascularization			
CABG	III: Harm	B	121, 146, 153, 154, 188–192
PCI	III: Harm	B	121, 146, 153, 154, 188–192

*In patients with multivessel disease who also have diabetes, it is reasonable to choose CABG (with LIMA) over PCI[155,168–175] (*Class IIa/LOE: B*).

CABG indicates coronary artery bypass graft; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; COR, class of recommendation; EF, ejection fraction; LAD, left anterior descending; LIMA, left internal mammary artery; LOE, level of evidence; LV, left ventricular; N/A, not applicable; PCI, percutaneous coronary intervention; SIHD, stable ischemic heart disease; STEMI, ST-elevation myocardial infarction; STS, Society of Thoracic Surgeons; SYNTAX, Synergy between percutaneous coronary intervention with TAXUS and cardiac surgery; TIMI, Thrombolysis in Myocardial Infarction; UA/NSTEMI, unstable angina/non–ST-elevation myocardial infarction; UPLM, unprotected left main; and VT, ventricular tachycardia.

Table 3. Revascularization to Improve Symptoms With Significant Anatomic (≥50% Left Main or ≥70% Non–Left Main CAD) or Physiological (FFR ≤0.80) Coronary Artery Stenoses

Clinical Setting	COR	LOE	References
≥1 significant stenoses amenable to revascularization and unacceptable angina despite GDMT	I—CABG I—PCI	A	176, 193–202
≥1 significant stenoses and unacceptable angina in whom GDMT cannot be implemented because of medication contraindications, adverse effects, or patient preferences	IIa—CABG IIa—PCI	C	N/A
Previous CABG with ≥1 significant stenoses associated with ischemia and unacceptable angina despite GDMT	IIa—PCI	C	180, 183, 186
	IIb—CABG	C	187
Complex 3-vessel CAD (eg, SYNTAX score >22) with or without involvement of the proximal LAD artery and a good candidate for CABG	IIa—CABG preferred over PCI	B	123, 138, 148, 164–165
Viable ischemic myocardium that is perfused by coronary arteries that are not amenable to grafting	IIb—TMR as an adjunct to CABG	B	203–207
No anatomic or physiologic criteria for revascularization	III: Harm—CABG III: Harm—PCI	C	N/A

CABG indicates coronary artery bypass graft; CAD, coronary artery disease; COR, class of recommendation; FFR, fractional flow reserve; GDMT, guideline-directed medical therapy; LOE, level of evidence; N/A, not applicable; PCI, percutaneous coronary intervention; SYNTAX, Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery; and TMR, transmyocardial laser revascularization.

3.1. Heart Team Approach to Revascularization Decisions

Class I

1. **A Heart Team approach to revascularization is recommended in patients with unprotected left main or complex CAD.[105–107] *(Level of Evidence: C)***

Class IIa

1. **Calculation of the STS and SYNTAX (Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery) scores is reasonable in patients with unprotected left main and complex CAD.[107–114] *(Level of Evidence: B)***

3.2. Revascularization to Improve Survival

Left Main CAD Revascularization

Class I

1. **CABG to improve survival is recommended for patients with significant (≥50% diameter stenosis) left main coronary artery stenosis.[115–121] *(Level of Evidence: B)***

Class IIa

1. **PCI to improve survival is reasonable as an alternative to CABG in selected stable patients with significant (≥50% diameter stenosis) unprotected left main CAD with: 1) anatomic conditions associated with a low risk of PCI procedural complications and a high likelihood of good long-term outcome (eg, a low SYNTAX score [≤22], ostial or trunk left main CAD); and 2) clinical characteristics that predict a significantly increased risk of adverse surgical outcomes (eg, STS-predicted risk of operative mortality ≥5%).[108,110,111,122–140,168] *(Level of Evidence: B)***
2. **PCI to improve survival is reasonable in patients with UA/NSTEMI when an unprotected left main coronary artery is the culprit lesion and the patient is not a candidate for CABG.[111,127,129–131,136,137,139,140,142] *(Level of Evidence: B)***
3. **PCI to improve survival is reasonable in patients with acute STEMI when an unprotected left main coronary artery is the culprit lesion, distal coronary flow is less than Thrombolysis In Myocardial Infarction grade 3, and PCI can be performed more rapidly and safely than CABG.[124,143,144] *(Level of Evidence: C)***

Class IIb

1. **PCI to improve survival may be reasonable as an alternative to CABG in selected stable patients with significant (≥50% diameter stenosis) unprotected left main CAD with: 1) anatomic conditions associated with a low to intermediate risk of PCI procedural complications and an intermediate to high likelihood of good long-term outcome (eg, low–intermediate SYNTAX score of <33, bifurcation left main CAD); and 2) clinical characteristics that predict an increased risk of adverse surgical outcomes (eg, moderate–severe chronic obstructive pulmonary disease, disability from previous stroke, or previous cardiac surgery; STS-predicted risk of operative mortality >2%).[108,110,111,122–140,145] *(Level of Evidence: B)***

Class III: HARM

1. **PCI to improve survival should not be performed in stable patients with significant (≥50% diameter stenosis) unprotected left main CAD who have unfavorable anatomy for PCI and who are good candidates for CABG.[108,110,111,115–123] *(Level of Evidence: B)***

Non–Left Main CAD Revascularization

Class I

1. **CABG to improve survival is beneficial in patients with significant (≥70% diameter) stenoses in 3 major coronary arteries (with or without involvement of the proximal LAD artery) or in the proximal LAD plus 1 other major coronary artery.[117,121,146–149] *(Level of Evidence: B)***

2. CABG or PCI to improve survival is beneficial in survivors of sudden cardiac death with presumed ischemia-mediated ventricular tachycardia caused by significant (≥70% diameter) stenosis in a major coronary artery. *(CABG Level of Evidence: B[99,150,152]; PCI Level of Evidence: C[150])*

Class IIa

1. CABG to improve survival is reasonable in patients with significant (≥70% diameter) stenoses in 2 major coronary arteries with severe or extensive myocardial ischemia (eg, high-risk criteria on stress testing, abnormal intracoronary hemodynamic evaluation, or >20% perfusion defect by myocardial perfusion stress imaging) or target vessels supplying a large area of viable myocardium.[153–156] *(Level of Evidence: B)*
2. CABG to improve survival is reasonable in patients with mild–moderate LV systolic dysfunction (ejection fraction 35% to 50%) and significant (≥70% diameter stenosis) multivessel CAD or proximal LAD coronary artery stenosis, when viable myocardium is present in the region of intended revascularization.[121,157–161] *(Level of Evidence: B)*
3. CABG with a LIMA graft to improve survival is reasonable in patients with significant (≥70% diameter) stenosis in the proximal LAD artery and evidence of extensive ischemia.[30,31,121,148] *(Level of Evidence: B)*
4. It is reasonable to choose CABG over PCI to improve survival in patients with complex 3-vessel CAD (eg, SYNTAX score >22), with or without involvement of the proximal LAD artery, who are good candidates for CABG.[123,138,148,164,165] *(Level of Evidence: B)*
5. CABG is probably recommended in preference to PCI to improve survival in patients with multivessel CAD and diabetes mellitus, particularly if a LIMA graft can be anastomosed to the LAD artery.[155,168–175] *(Level of Evidence: B)*

Class IIb

1. The usefulness of CABG to improve survival is uncertain in patients with significant (≥70%) stenoses in 2 major coronary arteries not involving the proximal LAD artery and without extensive ischemia.[148] *(Level of Evidence: C)*
2. The usefulness of PCI to improve survival is uncertain in patients with 2- or 3-vessel CAD (with or without involvement of the proximal LAD artery) or 1-vessel proximal LAD disease.[117,146,148,176] *(Level of Evidence: B)*
3. CABG might be considered with the primary or sole intent of improving survival in patients with SIHD with severe LV systolic dysfunction (ejection fraction <35%) whether or not viable myocardium is present.[121,157–161,177,178] *(Level of Evidence: B)*
4. The usefulness of CABG or PCI to improve survival is uncertain in patients with previous CABG and extensive anterior wall ischemia on noninvasive testing.[179–187] *(Level of Evidence: B)*

Class III: HARM

1. CABG or PCI should not be performed with the primary or sole intent to improve survival in patients with SIHD with 1 or more coronary stenoses that are not anatomically or functionally significant (eg, <70% diameter non–left main coronary artery stenosis, fractional flow reserve >0.80, no or only mild ischemia on noninvasive testing), involve only the left circumflex or right coronary artery, or subtend only a small area of viable myocardium.[121,146, 153,154,188–192] *(Level of Evidence: B)*

3.3. Revascularization to Improve Symptoms

Class I

1. CABG or PCI to improve symptoms is beneficial in patients with 1 or more significant (≥70% diameter) coronary artery stenoses amenable to revascularization and unacceptable angina despite GDMT.[176,193–202] *(Level of Evidence: A)*

Class IIa

1. CABG or PCI to improve symptoms is reasonable in patients with 1 or more significant (≥70% diameter) coronary artery stenoses and unacceptable angina for whom GDMT cannot be implemented because of medication contraindications, adverse effects, or patient preferences. *(Level of Evidence: C)*
2. PCI to improve symptoms is reasonable in patients with previous CABG, 1 or more significant (≥70% diameter) coronary artery stenoses associated with ischemia, and unacceptable angina despite GDMT.[180,183,186] *(Level of Evidence: C)*
3. It is reasonable to choose CABG over PCI to improve symptoms in patients with complex 3-vessel CAD (eg, SYNTAX score >22), with or without involvement of the proximal LAD artery, who are good candidates for CABG.[123,138,148,164,165] *(Level of Evidence: B)*

Class IIb

1. CABG to improve symptoms might be reasonable for patients with previous CABG, 1 or more significant (≥70% diameter) coronary artery stenoses not amenable to PCI, and unacceptable angina despite GDMT.[187] *(Level of Evidence: C)*
2. Transmyocardial laser revascularization performed as an adjunct to CABG to improve symptoms may be reasonable in patients with viable ischemic myocardium that is perfused by arteries that are not amenable to grafting.[203–207] *(Level of Evidence: B)*

Class III: HARM

1. CABG or PCI to improve symptoms should not be performed in patients who do not meet anatomic (≥50% left main or ≥70% non–left main stenosis)

or physiological (eg, abnormal fractional flow reserve) criteria for revascularization. *(Level of Evidence: C)*

3.4. Clinical Factors That May Influence the Choice of Revascularization

3.4.1. Dual Antiplatelet Therapy Compliance and Stent Thrombosis

Class III: HARM

1. **PCI with coronary stenting (bare-metal stent or drug-eluting stent) should not be performed if the patient is not likely to be able to tolerate and comply with dual antiplatelet therapy for the appropriate duration of treatment based on the type of stent implanted.[208–211] *(Level of Evidence: B)***

3.5. Hybrid Coronary Revascularization

Class IIa

1. **Hybrid coronary revascularization (defined as the planned combination of LIMA-to-LAD artery grafting and PCI of ≥1 non-LAD coronary arteries) is reasonable in patients with 1 or more of the following[212–220] *(Level of Evidence: B)*:**
   a. **Limitations to traditional CABG, such as heavily calcified proximal aorta or poor target vessels for CABG (but amenable to PCI);**
   b. **Lack of suitable graft conduits;**
   c. **Unfavorable LAD artery for PCI (ie, excessive vessel tortuosity or chronic total occlusion).**

Class IIb

1. **Hybrid coronary revascularization (defined as the planned combination of LIMA-to-LAD artery grafting and PCI of ≥1 non-LAD coronary arteries) may be reasonable as an alternative to multivessel PCI or CABG in an attempt to improve the overall risk–benefit ratio of the procedures. *(Level of Evidence: C)***

4. Perioperative Management: Recommendations

4.1. Preoperative Antiplatelet Therapy

Class I

1. **Aspirin (100 mg to 325 mg daily) should be administered to CABG patients preoperatively.[221–223] *(Level of Evidence: B)***
2. **In patients referred for elective CABG, clopidogrel and ticagrelor should be discontinued for at least 5 days before surgery[224–226] *(Level of Evidence: B)* and prasugrel for at least 7 days *(Level of Evidence: C)* to limit blood transfusions.**
3. **In patients referred for urgent CABG, clopidogrel and ticagrelor should be discontinued for at least 24 hours to reduce major bleeding complications.[225,227–229] *(Level of Evidence: B)***
4. **In patients referred for CABG, short-acting intravenous glycoprotein IIb/IIIa inhibitors (eptifibatide or tirofiban) should be discontinued for at least 2 to 4 hours before surgery[230,231] and abciximab for at least 12 hours beforehand[232] to limit blood loss and transfusions. *(Level of Evidence: B)***

Class IIb

1. **In patients referred for urgent CABG, it may be reasonable to perform surgery less than 5 days after clopidogrel or ticagrelor has been discontinued and less than 7 days after prasugrel has been discontinued. *(Level of Evidence: C)***

4.2. Postoperative Antiplatelet Therapy

Class I

1. **If aspirin (100 mg to 325 mg daily) was not initiated preoperatively, it should be initiated within 6 hours postoperatively and then continued indefinitely to reduce the occurrence of saphenous vein graft closure and adverse cardiovascular events.[223,233,234] *(Level of Evidence: A)***

Class IIa

1. **For patients undergoing coronary artery bypass grafting, clopidogrel 75 mg daily is a reasonable alternative in patients who are intolerant of or allergic to aspirin. *(Level of Evidence: C)***

4.3. Management of Hyperlipidemia

Class I

1. **All patients undergoing CABG should receive statin therapy, unless contraindicated.[235–247,247a] *(Level of Evidence: A)***
2. **In patients undergoing CABG, an adequate dose of statin should be used to reduce low-density lipoprotein cholesterol to less than 100 mg/dL *and* to achieve at least a 30% lowering of low-density lipoprotein cholesterol.[235–239,247a] *(Level of Evidence: C)***

Class IIa

1. **In patients undergoing CABG, it is reasonable to treat with statin therapy to lower the low-density lipoprotein cholesterol to less than 70 mg/dL in very high-risk* patients.[236–238,247a,248–250] *(Level of Evidence: C)***
2. **For patients undergoing urgent or emergency CABG who are not taking a statin, it is reasonable to initiate high-dose statin therapy immediately.[250a] *(Level of Evidence: C)***

Class III: HARM

1. **Discontinuation of statin or other dyslipidemic therapy is not recommended before or after CABG in patients without adverse reactions to therapy.[251–253] *(Level of Evidence: B)***

*Presence of established cardiovascular disease plus 1) multiple major risk factors (especially diabetes), 2) severe and poorly controlled risk factors (especially continued cigarette smoking), 3) multiple risk factors of the metabolic syndrome (especially high triglycerides ≥200 mg/dL plus non–high-density lipoprotein cholesterol ≥130 mg/dL with low high-density lipoprotein cholesterol [<40 mg/dL]), and 4) acute coronary syndromes.

4.4. Hormonal Manipulation

Class I

1. **Use of continuous intravenous insulin to achieve and maintain an early postoperative blood glucose concentration less than or equal to 180 mg/dL while avoiding hypoglycemia is indicated to reduce the incidence of adverse events, including deep sternal wound infection, after CABG.[254–256] *(Level of Evidence: B)***

Class IIb

1. **The use of continuous intravenous insulin designed to achieve a target intraoperative blood glucose concentration less than 140 mg/dL has uncertain effectiveness.[257–259] *(Level of Evidence: B)***

Class III: HARM

1. **Postmenopausal hormonal therapy (estrogen/prosgesterone) should not be administered to women undergoing CABG.[260–262] *(Level of Evidence: B)***

4.5. Perioperative Beta Blockers

Class I

1. **Beta blockers should be administered for at least 24 hours before CABG to all patients without contraindications to reduce the incidence or clinical sequelae of postoperative AF.[263–267,267a–267c] *(Level of Evidence: B)***
2. **Beta blockers should be reinstituted as soon as possible after CABG in all patients without contraindications to reduce the incidence or clinical sequelae of AF.[263–267,267a–267c] *(Level of Evidence: B)***
3. **Beta blockers should be prescribed to all CABG patients without contraindications at the time of hospital discharge. *(Level of Evidence: C)***

Class IIa

1. **Preoperative use of beta blockers in patients without contraindications, particularly in those with an LV ejection fraction (LVEF) greater than 30%, can be effective in reducing the risk of in-hospital mortality.[268–270] *(Level of Evidence: B)***
2. **Beta blockers can be effective in reducing the incidence of perioperative myocardial ischemia.[271–274] *(Level of Evidence: B)***
3. **Intravenous administration of beta blockers in clinically stable patients unable to take oral medications is reasonable in the early postoperative period.[275] *(Level of Evidence: B)***

Class IIb

1. **The effectiveness of preoperative beta blockers in reducing inhospital mortality rate in patients with LVEF less than 30% is uncertain.[268,276] *(Level of Evidence: B)***

4.6. Angiotensin-Converting Enzyme Inhibitors and Angiotensin-Receptor Blockers

Class I

1. **Angiotensin-converting enzyme (ACE) inhibitors and angiotensin-receptor blockers given before CABG should be reinstituted postoperatively once the patient is stable, unless contraindicated.[277–279] *(Level of Evidence: B)***
2. **ACE inhibitors or angiotensin-receptor blockers should be initiated postoperatively and continued indefinitely in CABG patients who were not receiving them preoperatively, who are stable, and who have an LVEF less than or equal to 40%, hypertension, diabetes mellitus, or chronic kidney disease, unless contraindicated.[278,279a,279b] *(Level of Evidence: A)***

Class IIa

1. **It is reasonable to initiate ACE inhibitors or angiotensin-receptor blockers postoperatively and to continue them indefinitely in all CABG patients who were not receiving them preoperatively and are considered to be at low risk (ie, those with a normal LVEF in whom cardiovascular risk factors are well controlled), unless contraindicated.[278–282] *(Level of Evidence: B)***

Class IIb

1. **The safety of the preoperative administration of ACE inhibitors or angiotensin-receptor blockers in patients on chronic therapy is uncertain.[283–288] *(Level of Evidence: B)***
2. **The safety of initiating ACE inhibitors or angiotensin-receptor blockers before hospital discharge is not well established.[278,280,282,289] *(Level of Evidence: B)***

4.7. Smoking Cessation

Class I

1. **All smokers should receive in-hospital educational counseling and be offered smoking cessation therapy during CABG hospitalization.[291–293,293a] *(Level of Evidence: A)***

Class IIb

1. **The effectiveness of pharmacological therapy for smoking cessation offered to patients before hospital discharge is uncertain. *(Level of Evidence: C)***

4.8. Emotional Dysfunction and Psychosocial Considerations

Class IIa

1. **Cognitive behavior therapy or collaborative care for patients with clinical depression after CABG can be beneficial to reduce objective measures of depression.[294–298] *(Level of Evidence: B)***

4.9. Cardiac Rehabilitation

Class I

1. **Cardiac rehabilitation is recommended for all eligible patients after CABG.[299–301,301a–301d] *(Level of Evidence: A)***

4.10. Perioperative Monitoring

4.10.1. Electrocardiographic Monitoring

Class I

1. **Continuous monitoring of the electrocardiogram for arrhythmias should be performed for at least 48 hours in all patients after CABG.[265,302,303] *(Level of Evidence: B)***

Class IIa

1. **Continuous ST-segment monitoring for detection of ischemia is reasonable in the intraoperative period for patients undergoing CABG.[56,304–306] *(Level of Evidence: B)***

Class IIb

1. **Continuous ST-segment monitoring for detection of ischemia may be considered in the early postoperative period after CABG.[272,302,307–310] *(Level of Evidence: B)***

4.10.2. Pulmonary Artery Catheterization

Class I

1. **Placement of a pulmonary artery catheter is indicated, preferably before the induction of anesthesia or surgical incision, in patients in cardiogenic shock undergoing CABG. *(Level of Evidence: C)***

Class IIa

1. **Placement of a pulmonary artery catheter can be useful in the intraoperative or early postoperative period in patients with acute hemodynamic instability.[311–316] *(Level of Evidence: B)***

Class IIb

1. **Placement of a pulmonary artery catheter may be reasonable in clinically stable patients undergoing CABG after consideration of baseline patient risk, the planned surgical procedure, and the practice setting.[311–316] *(Level of Evidence: B)***

4.10.3. Central Nervous System Monitoring

Class IIb

1. **The effectiveness of intraoperative monitoring of the processed electroencephalogram to reduce the possibility of adverse recall of clinical events or for detection of cerebral hypoperfusion in CABG patients is uncertain.[449–451] *(Level of Evidence: B)***
2. **The effectiveness of routine use of intraoperative or early postoperative monitoring of cerebral oxygen saturation via near-infrared spectroscopy to detect cerebral hypoperfusion in patients undergoing CABG is uncertain.[317–319] *(Level of Evidence: B)***

5. CABG-Associated Morbidity and Mortality: Occurrence and Prevention: Recommendations

5.1. Public Reporting of Cardiac Surgery Outcomes

Class I

1. **Public reporting of cardiac surgery outcomes should use risk-adjusted results based on clinical data.[320–327] *(Level of Evidence: B)***

5.1.1. Use of Outcomes or Volume as CABG Quality Measures

Class I

1. **All cardiac surgery programs should participate in a state, regional, or national clinical data registry and should receive periodic reports of their risk-adjusted outcomes. *(Level of Evidence: C)***

Class IIa

1. **When credible risk-adjusted outcomes data are not available, volume can be useful as a structural metric of CABG quality.[328–342] *(Level of Evidence: B)***

Class IIb

1. **Affiliation with a high-volume tertiary center might be considered by cardiac surgery programs that perform fewer than 125 CABG procedures annually. *(Level of Evidence: C)***

5.2. Use of Epiaortic Ultrasound Imaging to Reduce Stroke Rates

Class IIa

1. **Routine epiaortic ultrasound scanning is reasonable to evaluate the presence, location, and severity of plaque in the ascending aorta to reduce the incidence of atheroembolic complications.[343–345] *(Level of Evidence: B)***

5.3. The Role of Preoperative Carotid Artery Noninvasive Screening in CABG Patients

Class I

1. **A multidisciplinary team approach (consisting of a cardiologist, cardiac surgeon, vascular surgeon, and neurologist) is recommended for patients with clinically significant carotid artery disease for whom CABG is planned. *(Level of Evidence: C)***

Class IIa

1. **Carotid artery duplex scanning is reasonable in selected patients who are considered to have high-risk features (ie, age >65 years, left main coronary stenosis, peripheral artery disease, history of cerebrovascular disease [transient ischemic attack, stroke, etc.], hypertension, smoking, and diabetes mellitus).[346,347] *(Level of Evidence: C)***
2. **In the CABG patient with a previous transient ischemic attack or stroke and a significant (50% to**

99%) carotid artery stenosis, it is reasonable to consider carotid revascularization in conjunction with CABG. In such an individual, the sequence and timing (simultaneous or staged) of carotid intervention and CABG should be determined by the patient's relative magnitudes of cerebral and myocardial dysfunction. *(Level of Evidence: C)*

Class IIb

1. In the patient scheduled to undergo CABG who has no history of transient ischemic attack or stroke, carotid revascularization may be considered in the presence of bilateral severe (70% to 99%) carotid stenoses or a unilateral severe carotid stenosis with a contralateral occlusion. *(Level of Evidence: C)*

5.4. Mediastinitis/Perioperative Infection

Class I

1. Preoperative antibiotics should be administered to all patients to reduce the risk of postoperative infection.[348–353] *(Level of Evidence: A)*
2. A second-generation cephalosporin is recommended for prophylaxis in patients without methicillin-resistant *Staphylococcus aureus* colonization.[353–361] *(Level of Evidence: A)*
3. Vancomycin alone or in combination with other antibiotics to achieve broader coverage is recommended for prophylaxis in patients with proven or suspected methicillin-resistant *S. aureus* colonization.[356,362–364] *(Level of Evidence: B)*
4. A deep sternal wound infection should be treated with aggressive surgical debridement in the absence of complicating circumstances. Primary or secondary closure with muscle or omental flap is recommended.[365–367] Vacuum therapy in conjunction with early and aggressive debridement is an effective adjunctive therapy.[368–377] *(Level of Evidence: B)*
5. Use of a continuous intravenous insulin protocol to achieve and maintain an early postoperative blood glucose concentration less than or equal to 180 mg/dL while avoiding hypoglycemia is indicated to reduce the risk of deep sternal wound infection.[256,259,378–381] *(Level of Evidence: B)*

Class IIa

1. When blood transfusions are needed, leukocyte-filtered blood can be useful to reduce the rate of overall perioperative infection and in-hospital death.[382–385] *(Level of Evidence: B)*
2. The use of intranasal mupirocin is reasonable in nasal carriers of *S. aureus*.[386,387] *(Level of Evidence: A)*
3. The routine use of intranasal mupirocin is reasonable in patients who are not carriers of *S. aureus*, unless an allergy exists. *(Level of Evidence: C)*

Class IIb

1. The use of bilateral internal mammary arteries in patients with diabetes mellitus is associated with an increased risk of deep sternal wound infection, but it may be reasonable when the overall benefit to the patient outweighs this increased risk. *(Level of Evidence: C)*

5.5. Renal Dysfunction

Class IIb

1. In patients with preoperative renal dysfunction (creatinine clearance <60 mL/min), off-pump CABG may be reasonable to reduce the risk of acute kidney injury.[388–392] *(Level of Evidence: B)*
2. In patients with preexisting renal dysfunction undergoing on-pump CABG, maintenance of a perioperative hematocrit greater than 19% and mean arterial pressure greater than 60 mm Hg may be reasonable. *(Level of Evidence: C)*
3. In patients with preexisting renal dysfunction, a delay of surgery after coronary angiography may be reasonable until the effect of radiographic contrast material on renal function is assessed.[393–395] *(Level of Evidence: B)*
4. The effectiveness of pharmacological agents to provide renal protection during cardiac surgery is uncertain.[396–418] *(Level of Evidence: B)*

5.6. Perioperative Myocardial Dysfunction

Class IIa

1. In the absence of severe, symptomatic aorto-iliac occlusive disease or peripheral artery disease, the insertion of an intra-aortic balloon is reasonable to reduce mortality rate in CABG patients who are considered to be at high risk (eg, those who are undergoing reoperation or have LVEF <30% or left main CAD).[419–424] *(Level of Evidence: B)*
2. Measurement of biomarkers of myonecrosis (eg, creatine kinase-MB, troponin) is reasonable in the first 24 hours after CABG.[425] *(Level of Evidence: B)*

5.6.1. Transfusion

Class I

1. Aggressive attempts at blood conservation are indicated to limit hemodilutional anemia and the need for intraoperative and perioperative allogeneic red blood cell transfusion in CABG patients.[426–429] *(Level of Evidence: B)*

5.7. Perioperative Dysrhythmias

Class I

1. Beta blockers should be administered for at least 24 hours before CABG to all patients without contraindications to reduce the incidence or clinical sequelae of postoperative AF.[263–267,267a–267c] *(Level of Evidence: B)*
2. Beta blockers should be reinstituted as soon as possible after CABG in all patients without contraindications to reduce the incidence or clinical sequelae of AF.[263–267,267a–267c] *(Level of Evidence: B)*

Class IIa

1. **Preoperative administration of amiodarone to reduce the incidence of postoperative AF is reasonable for patients at high risk for postoperative AF who have contraindications to beta blockers.[430] *(Level of Evidence: B)***
2. **Digoxin and nondihydropyridine calcium channel blockers can be useful to control the ventricular rate in the setting of AF but are not indicated for prophylaxis.[265] *(Level of Evidence: B)***

5.8. Perioperative Bleeding/Transfusion

Class I

1. **Lysine analogues are useful intraoperatively and postoperatively in patients undergoing on-pump CABG to reduce perioperative blood loss and transfusion requirements.[431–438] *(Level of Evidence: A)***
2. **A multimodal approach with transfusion algorithms, point-of-care testing, and a focused blood conservation strategy should be used to limit the number of transfusions.[439–444] *(Level of Evidence: A)***
3. **In patients taking thienopyridines (clopidogrel or prasugrel) or ticagrelor in whom elective CABG is planned, clopidogrel and ticagrelor should be withheld for at least 5 days[224,225,227,228,445–451] *(Level of Evidence: B)* and prasugrel for at least 7 days[452] *(Level of Evidence: C)* before surgery.**
4. **It is recommended that surgery be delayed after the administration of streptokinase, urokinase, and tissue-type plasminogen activators until hemostatic capacity is restored, if possible. The timing of recommended delay should be guided by the pharmacodynamic half-life of the involved agent. *(Level of Evidence: C)***
5. **Tirofiban or eptifibatide should be discontinued at least 2 to 4 hours before CABG and abciximab at least 12 hours before CABG.[230–232,436,437,453–457] *(Level of Evidence: B)***

Class IIa

1. **It is reasonable to consider off-pump CABG to reduce perioperative bleeding and allogeneic blood transfusion.[458–464] *(Level of Evidence: A)***

6. Specific Patient Subsets: Recommendations

6.1. Anomalous Coronary Arteries

Class I

1. **Coronary revascularization should be performed in patients with:**
   a. **A left main coronary artery that arises anomalously and then courses between the aorta and pulmonary artery.[465–467] *(Level of Evidence: B)***
   b. **A right coronary artery that arises anomalously and then courses between the aorta and pulmonary artery with evidence of myocardial ischemia.[465–468] *(Level of Evidence: B)***

Class IIb

1. **Coronary revascularization may be reasonable in patients with a LAD coronary artery that arises anomalously and then courses between the aorta and pulmonary artery. *(Level of Evidence: C)***

6.2. Patients With Chronic Obstructive Pulmonary Disease/Respiratory Insufficiency

Class IIa

1. **Preoperative intensive inspiratory muscle training is reasonable to reduce the incidence of pulmonary complications in patients at high risk for respiratory complications after CABG.[469] *(Level of Evidence: B)***

Class IIb

1. **After CABG, noninvasive positive pressure ventilation may be reasonable to improve pulmonary mechanics and to reduce the need for reintubation.[470,471] *(Level of Evidence: B)***
2. **High thoracic epidural analgesia may be considered to improve lung function after CABG.[472,473] *(Level of Evidence: B)***

6.3. Patients With End-Stage Renal Disease on Dialysis

Class IIb

1. **CABG to improve survival rate may be reasonable in patients with end-stage renal disease undergoing CABG for left main coronary artery stenosis of greater than or equal to 50%.[474] *(Level of Evidence: C)***
2. **CABG to improve survival rate or to relieve angina despite GDMT may be reasonable for patients with end-stage renal disease with significant stenoses (≥70%) in 3 major vessels or in the proximal LAD artery plus 1 other major vessel, regardless of LV systolic function.[475] *(Level of Evidence: B)***

Class III: HARM

1. **CABG should not be performed in patients with end-stage renal disease whose life expectancy is limited by noncardiac issues. *(Level of Evidence: C)***

6.4. Patients With Concomitant Valvular Disease

Class I

1. **Patients undergoing CABG who have at least moderate aortic stenosis should have concomitant aortic valve replacement.[476–479] *(Level of Evidence: B)***
2. **Patients undergoing CABG who have severe ischemic mitral valve regurgitation not likely to resolve with revascularization should have concomitant mitral valve repair or replacement at the time of CABG.[480–485] *(Level of Evidence: B)***

Class IIa

1. **In patients undergoing CABG who have moderate ischemic mitral valve regurgitation not likely to resolve with revascularization, concomitant mitral**

valve repair or replacement at the time of CABG is reasonable.[480–485] *(Level of Evidence: B)*

Class IIb

1. **Patients undergoing CABG who have mild aortic stenosis may be considered for concomitant aortic valve replacement when evidence (eg, moderate–severe leaflet calcification) suggests that progression of the aortic stenosis may be rapid and the risk of the combined procedure is acceptable. *(Level of Evidence: C)***

6.5. Patients With Previous Cardiac Surgery

Class IIa

1. **In patients with a patent LIMA to the LAD artery and ischemia in the distribution of the right or left circumflex coronary arteries, it is reasonable to recommend reoperative CABG to treat angina if GDMT has failed and the coronary stenoses are not amenable to PCI.[186,486] *(Level of Evidence: B)***

Staff

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KEY WORDS: AHA Scientific Statements ■ acute coronary syndromes ■ anticoagulants ■ antiplatelet agents ■ arrhythmias, cardiac ■ coronary angiography ■ coronary artery revascularization ■ interventions: stents ■ drug therapy ■ heart diseases ■ myocardial revascularization ■ platelet aggregation inhibitor ■ ultrasound

Appendix 1. Author Relationships With Industry and Other Entities (Relevant)—2011 ACCF/AHA Guideline for Coronary Artery Bypass Graft Surgery

Committee Member	Employer/Title	Consultant	Speaker's Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness	Voting Recusals by Section Numbers*
L. David Hillis (*Chair*)	University of Texas Health Science Center at San Antonio—Professor and Chair of the Department of Medicine	None	None	None	None	None	None	None
Peter K. Smith (*Vice Chair*)	Duke University Medical Center: Private Diagnostic Clinic—Professor of Surgery; Chief of Thoracic Surgery	• Eli Lilly • Baxter BioSurgery	None	None	None	None	None	2.2.3 4.1 4.2 5.2.6
Jeffrey L. Anderson	Intermountain Medical Center—Associate Chief of Cardiology	• BMS/sanofi-aventis	None	None	• Toshiba‡ • Gilead Pharma • AstraZeneca	None	None	2.1.6 2.2.3 4.1 4.2 4.3 5.2.6
John A. Bittl	Ocala Heart Institute Munroe Regional Medical Center—Interventional Cardiologist	None	None	None	None	None	None	None
Charles R. Bridges	University of Pennsylvania Medical Center—Chief of Cardiothoracic Surgery	• Baxter BioSurgery‡ • Zymogenetics	• Bayer Pharmaceuticals	None	None	None	• Plaintiff, alleged mitral valve dysfunction, 2009 • Defendant, retinal artery occlusion (stroke) after CABG, 2009 • Defendant, timely insertion of IABP after CABG, 2009 • Defendant, timely transport after acute aortic dissection, 2009 • Plaintiff, unexpected intra-abdominal hemorrhage and death after AVR, 2009	2.2.3 4.1 4.2 5.2.6
John G. Byrne	Vanderbilt University Medical Center: Division of Cardiac Surgery—Chairman of Cardiac Surgery	None	None	None	None	None	None	None
Joaquin E. Cigarroa	Oregon Health and Science University—Associate Professor of Medicine	None	None	None	None	None	None	None
Verdi J. DiSesa	John Hopkins Hospital, Division of Cardiac Surgery—Clinical Associate	None	None	None	None	None	None	None
Loren F. Hiratzka	Cardiac, Vascular and Thoracic Surgeons, Inc.—Medical Director of Cardiac Surgery	None	None	None	None	None	None	None
Adolph M. Hutter Jr	Massachusetts General Hospital—Professor of Medicine	None	None	None	None	None	None	None

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Appendix 1. Continued

Committee Member	Employer/Title	Consultant	Speaker's Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness	Voting Recusals by Section Numbers*
Michael E. Jessen	UT Southwestern Medical Center—Professor of Cardiothoracic Surgery	• Quest Medical‡	None	None	None	None	None	2.1.8
Ellen C. Keeley	University of Virginia—Associate Professor of Internal Medicine	None	None	None	None	None	None	None
Stephen J. Lahey	University of Connecticut—Professor and Chief of Cardiothoracic Surgery	None	None	None	None	None	• Defendant, mitral valve replacement, 2009	None
Richard A. Lange	University of Texas Health Science Center at San Antonio—Professor of Medicine	None	None	None	None	None	None	None
Martin J. London	University of California San Francisco, Veterans Affairs Medical Center—Professor of Clinical Anesthesia	None	None	None	None	None	None	None
Michael J. Mack	The Heart Hospital Baylor Plano—Cardiovascular Surgery, Medical Director	• Cordis • Marquett • Medtronic • Edwards Lifesciences‡	None	None	None	None	None	2.1.3 2.2.1 5.2.1.1 5.2.1.2
Manesh R. Patel	Duke University Medical Center—Associate Professor of Medicine	None	None	None	None	None	None	None
John D. Puskas	Emory University/Emory Healthcare—Chief of Cardiac Surgery	• Marquett • Medtronic	None	None	• Marquett† • Medtronic†	None	None	2.1.3 2.2.1 2.2.2
Joseph F. Sabik	Cleveland Clinic Foundation—Professor of Surgery	• Edwards Lifesciences • Medtronic	None	None	None	None	None	2.2.2 5.2.1.1 5.2.1.2
Ola Selnes	John Hopkins Hospital, Department of Neurology—Professor of Neurology	None	None	None	None	None	None	None
David M. Shahian	Massachusetts General Hospital—Professor of Surgery	None	None	None	None	None	None	None
Jeffrey C. Trost	John Hopkins School of Medicine—Assistant Professor of Medicine	None	None	None	• Toshiba†	None	None	2.1.7 3.5 4.10 4.10.1 4.10.2 4.10.3 5.2.1.1.1 5.2.1.1.2

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Appendix 1. Continued

Committee Member	Employer/Title	Consultant	Speaker's Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness	Voting Recusals by Section Numbers*
Michael D. Winniford	University of Mississippi Medical Center—Professor of Medicine	None	None	None	None	None	None	None

This table represents the relationships of committee members with industry and other entities that were determined to be relevant to this document. These relationships were reviewed and updated in conjunction with all meetings and/or conference calls of the writing committee during the document development process. The table does not necessarily reflect relationships with industry at the time of publication. A person is deemed to have a significant interest in a business if the interest represents ownership of ≥5% of the voting stock or share of the business entity, or ownership of ≥$10 000 of the fair market value of the business entity; or if funds received by the person from the business entity exceed 5% of the person's gross income for the previous year. Relationships that exist with no financial benefit are also included for the purpose of transparency. Relationships in this table are modest unless otherwise noted.

According to the ACCF/AHA, a person has a *relevant* relationship IF: (a) The *relationship or interest* relates to the same or similar subject matter, intellectual property or asset, topic, or issue addressed in the *document*; or (b) the *company/entity* (with whom the relationship exists) makes a drug, drug class, or device addressed in the *document,* or makes a competing drug or device addressed in the *document*; or (c) the *person or a member of the person's household,* has a reasonable potential for financial, professional or other personal gain or loss as a result of the issues/content addressed in the document.

*Writing committee members are required to recuse themselves from voting on sections to which their specific relationships with industry and other entities may apply. Section numbers apply to the full-text guideline.

†Significant relationship.

‡No financial benefit.

AVR indicates aortic valve replacement; CABG, coronary artery bypass graft surgery; and IABP, intra-aortic balloon pump.

Appendix 2. Reviewer Relationships With Industry and Other Entitites (Relevant)—2011 ACCF/AHA Guideline for Coronary Artery Bypass Graft Surgery

Peer Reviewer	Representation	Consultant	Speaker's Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Robert Guyton	Official Reviewer—ACCF/ AHA Task Force on Practice Guidelines	None	None	None	• Edwards Lifesciences	None	None
Jeffrey Jacobs	Official Reviewer—ACCF/ AHA Task Force on Data Standards	None	None	None	None	None	None
L. Kristin Newby	Official Reviewer—AHA	• AstraZeneca	None	None	• Eli Lilly* • GlaxoSmithKline†	None	None
Eric D. Peterson	Official Reviewer—ACCF/ AHA Task Force on Performance Measures	• AstraZeneca	None	None	• BMS/ sanofi-aventis† • Eli Lilly†	None	None
Richard J. Shemin	Official Reviewer—AHA	• Edwards Lifesciences	None	None	None	None	None
Hector Ventura	Official Reviewer—ACCF Board of Governors	None	• Actelion • Gilead	None	None	None	None
Thad F. Waites	Official Reviewer—ACCF Board of Trustees	None	None	None	None	None	None
T. Bruce Ferguson, Jr	Organizational Reviewer—STS	None	None	None	None	None	None
Stephen E. Fremes	Organizational Reviewer—AATS	None	None	None	None	Merck	• Defendant, leaking thoracic aortic aneurysm, 2009 • Defendant, aortic dissection, 2009
Colleen G. Koch	Organizational Reviewer—SCA	None	None	None	None	None	None
Harold L. Lazar	Organizational Reviewer—AATS	None	None	None	None	None	None
Walter H. Merrill	Organizational Reviewer—STS	None	None	None	None	None	None
Stanton K. Shernan	Organizational Reviewer—SCA	None	• Philips Healthcare	None	None	None	• Plaintiff, communication of echocardiography results, 2010
Joseph S. Alpert	Content Reviewer	• Bayer • Sanofi-aventis	None	None	None	None	None
Robert M. Califf	Content Reviewer	• AstraZeneca • Daiichi-Sankyo • GlaxoSmithKline • Medtronic • Sanofi-aventis	None	None	• Eli Lilly† • Bayer	None	None
Robbin G. Cohen	Content Reviewer	None	None	None	None	None	• Defendant, death after minimally invasive heart surgery, 2011 • Defendant, diagnosis of aortic dissection, 2010 • Plaintiff, renal failure and Aprotinin, 2010
Mark A. Creager	Content Reviewer—ACCF/ AHA Task Force on Practice Guidelines	• AstraZeneca • Genzyme • Merck • Roche • Vascutek	None	None	• Merck	None	• Plaintiff, Fasudil Development: *Asahi Pharma v Actelion,* 2010
Steven M. Ettinger	Content Reviewer—ACCF/ AHA Task Force on Practice Guidelines	None	None	None	• Medtronic	None	None
David P. Faxon	Content Reviewer	• Sanofi-aventis	None	None	None	None	• Defendant, cath vascular access site complication, 2009

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Appendix 2. Continued

Peer Reviewer	Representation	Consultant	Speaker's Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Kirsten E. Fleischmann	Content Reviewer	None	None	None	None	None	None
Lee Fleisher	Content Reviewer	None	None	None	• Pfizer	• AstraZeneca†	• Defendant, perioperative stroke, 2009
Anthony P. Furnary	Content Reviewer—ACCF Surgeons' Scientific Council	None	None	None	None	None	• Defendant, Bayer Corp. Trasylol litigation, 2009 to 2011
Valentin Fuster	Content Reviewer	None	None	None	None	None	None
John W. Hirshfeld, Jr	Content Reviewer	• GlaxoSmithKline	None	None	None	None	None
Judith S. Hochman	Content Reviewer—ACCF/ AHA Task Force on Practice Guidelines	• Eli Lilly • GlaxoSmithKline	None	None	None	None	None
James L. Januzzi, Jr	Content Reviewer	• Roche	None	None	• Roche	None	None
Frederick G. Kushner	Content Reviewer—Vice Chair, 2012 STEMI Guideline Writing Committee	None	None	None	None	None	None
Glenn Levine	Content Reviewer—Chair, 2011 PCI Guideline Writing Committee	None	None	None	None	None	None
Donald Likosky	Content Reviewer	None	None	None	• Maquet† • Medtronic†	None	None
James J. Livesay	Content Reviewer—Southern Thoracic Surgical Association	None	None	None	None	None	• Defendant, acute aortic dissection, 2011 • Defendant, cardiac mortality review, 2010 • Defendant, heparin induced thrombocytopenia, 2010
Bruce W. Lytle	Content Reviewer—2004 CABG Guideline Writing Committee	None	None	None	None	None	None
Robert A. Marlow	Content Reviewer—2004 CABG Guideline Writing Committee	None	None	None	None	None	None
Rick A. Nishimura	Content Reviewer—ACCF Board of Trustees	None	None	None	None	None	None
Patrick O'Gara	Content Reviewer—Chair, 2012 STEMI Guideline Writing Committee	None	None	None	None	None	None
E. Magnus Ohman	Content Reviewer—ACCF/ AHA Task Force on Practice Guidelines	• AstraZeneca • Bristol-Myers Squibb • Boehringer Ingelheim • Gilead Sciences • Merck • Pozen • Sanofi-aventis	• Boehringer Ingelheim • Gilead Sciences	None	• Daiichi-Sankyo • Datascope • Eli Lilly	None	None
John D. Rutherford	Content Reviewer	None	None	None	None	None	None
George A. Stouffer	Content Reviewer	None	None	None	None	None	• Defendant, review of malpractice claim, 2010

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Peer Reviewer	Representation	Consultant	Speaker's Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Mathew Williams	Content Reviewer—ACCF Interventional Scientific Council	• Edwards Lifesciences • Medtronic	None	None	None	None	None

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