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ACC/AHA Pocket Guideline

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines

Coronary Artery Bypass Graft Surgery

March 2005

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Developed in Collaboration With the American Association for Thoracic Surgery and the Society of Thoracic Surgeons

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The following article was adapted from the ACC/AHA *Guideline Update for Coronary Artery Bypass Graft Surgery (Journal of the American College of Cardiology* 2004;44:1146-54 and *Circulation* 2004:110:1168-1176). For a copy of the full report or published summary article, visit our Web sites at *www.acc.org* or *www.americanheart.org*, or call the ACC Resource Center at 1-800-253-4636, ext 694.

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I. Introduction

The full text of the guidelines is available on the World Wide Web sites of the American College of Cardiology (*www.acc.org*) and the American Heart Association (*www.americanheart.org*). The summary article is published in the September 1, 2004, issue of the *Journal of the American College of Cardiology* and the August 31, 2004, issue of *Circulation*.

This pocket guide provides rapid prompts for appropriate patient management, which is outlined in much greater detail in the full-text guidelines. It is not intended as a replacement for understanding the caveats and rationales that are stated carefully in the full-text guidelines. Users should consult the full-text document for more information.

Coronary artery bypass graft (CABG) surgery is among the most common operations performed in the world and accounts for more resources expended in cardiovascular medicine than any other single

procedure. Since the original guidelines were published in 1991, there has been considerable evolution in the surgical approach to coronary disease, and at the same time there have been advances in preventive, medical, and percutaneous catheter approaches to therapy. This revised pocket guideline is based on an initial computerized search of the English literature on CABG since 1999, a manual search of final articles, and expert opinion. Special attention was devoted to identification of randomized controlled trials published since 1999.

As with other American College of Cardiology/American Heart Association (ACC/AHA) guidelines, this document uses ACC/AHA classification of recommendations and level of evidence as described on pages 4 and 5. In the 1999 update, the writing committee did not rank the available scientific evidence in an A, B, or C fashion. The level of evidence is now provided.

Table 1. Applying Classification of Recommendations and Level of Evidence in ACC/AHA Format

ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT	SIZE OF TREATMENT EFFECT: CLASS I *Benefit >>> Risk* Procedure/Treatment **SHOULD** be performed/ administered	SIZE OF TREATMENT EFFECT: CLASS IIa *Benefit >> Risk* *Additional studies with focused objectives needed* **IT IS REASONABLE** to perform procedure/administer treatment
LEVEL A Multiple (3-5) population risk strata evaluated* General consistency of direction and magnitude of effect	■ 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
LEVEL B Limited (2-3) population risk strata evaluated*	■ Recommendation that procedure or treatment is useful/effective ■ Limited 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
LEVEL C Very limited (1-2) population risk strata evaluated*	■ 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
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

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

CLASS IIb	CLASS III
Benefit ≥ Risk *Additional studies with broad objectives needed; additional registry data would be helpful* **Procedure/Treatment MAY BE CONSIDERED**	*Risk ≥ Benefit* *No additional studies needed* **Procedure/Treatment should NOT be performed/administered SINCE IT IS NOT HELPFUL AND MAY BE HARMFUL**
■ 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
■ 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 ■ Limited evidence from single randomized trial or nonrandomized studies
■ 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

may/might be considered	is not recommended
may/might be reasonable	is not indicated
usefulness/effectiveness is unknown/unclear/uncertain or not well established	should not is not useful/effective/beneficial may be harmful

II. Outcomes: Mortality

A. Hospital Outcomes

Seven core variables are the most consistent predictors of mortality after coronary artery surgery:

- Priority of operation
- Prior heart surgery
- Left ventricular ejection fraction (LVEF)
- Number of major coronary arteries with significant stenoses
- Advanced age
- Gender
- Percent stenosis of left main coronary artery

The greatest risk is correlated with the urgency of operation, advanced age, and prior coronary bypass surgery. *Table 2* shows a method by which other key patient variables may be used to predict an individual patient's operative risk of death, stroke, or mediastinitis.

Table 2. Preoperative Estimation of Risk of Mortality, Cerebrovascular Accident, and Mediastinitis

For use only in isolated CABG surgery

Directions: Locate outcome of interest, e.g., mortality. Use the score in that column for each relevant preoperative variable; then sum these scores to get the total score. Take the total score and look up the approximate preoperative risk in the table on page 8.

Patient or Disease Characteristic	Mortality Score	CVA Score	Mediastinitis Score
Age 60–69	1.5	1.5	1
Age 70–79	2.5	2.5	1.5
Age ≥ 80	6.5	3	2
Female sex	2	1.5	
Obesity (BMI 31–36)			2
Severe Obesity (BMI ≥ 37)			4.5
Diabetes	1	1.5	1.5
COPD	2		2
PVD	1.5	1.5	
Dialysis	4	2	3
Creatinine ≥ 2	2	2	
MI ≤ 7 days	1.5		
Prior CABG	2.5		
LVEF < 40%	2	1.5	1.5
3-Vessel Disease	1.5		
LM 50–89%	1.5		
LM 90%	2		
WBC > 12K	2.5		
Urgent surgery	2	1.5	2
Emergency surgery	5	3.5	2
Total Score			

Table 2 continued

Preoperative Risk

Total Score	Mortality %	CVA %	Mediastinitis %
0	0.2	0.4	0.3
1	0.2		0.3
2	0.3	0.6	0.4
3	0.3	0.9	0.5
4	0.5	1.3	0.7
5	0.7	1.4	0.9
6	1.0	2.0	1.3
7	1.3	2.7	1.7
8	1.8	3.4	2.5
9	2.3	4.2	3.2
10	3.0	5.9	4.2
11	4.0	7.6	5.6
12	5.3	≥ 10.0	≥ 7.3
13	6.9		
14	8.8		
15	11.5		
16	14.1		
17	18.7		
18	≤ 23.0		

Calculation of Mortality Risk: An 80-year-old female, with an LVEF < 40% who is having elective CABG surgery, has had no prior CABG surgery and has no other risk factors. Her total score = 6.5 (age greater than or equal to 80) + 2 (Female) + 2 (LVEF less than 40%) = 10.5. Since her total score equals 10.5 round up to 11, her predicted risk of mortality = 4.0%.

Definitions:

Obesity: Find the approximate height and weight in the table on page 10 to classify the person as obese or severely obese.

Obesity: BMI 31 - 36. **Severe obesity:** BMI greater than or equal to 37.

Example: A patient 5'7" and weighing 200 lbs. is classified obese. If the patient weighed 233 lbs. or more, he/she would be classified severely obese.

Diabetes: Currently treated with oral medications or insulin.

COPD (chronic obstructive pulmonary disease): Treated with bronchodilators or steroids.

PVD (peripheral vascular disease): Cerebrovascular disease, including prior CVA, prior TIA, prior carotid surgery, carotid stenosis by history or radiographic studies, or carotid bruit. Lower extremity disease including claudication, amputation, prior lower extremity bypass, absent pedal pulses or lower-extremity ulcers.

Dialysis: Peritoneal or hemodialysis dependent renal failure.

MI less than or equal to 7 days: The development of 1) new Q wave on ECG, or 2) new ST-T changes with a significant rise (defined locally) in CPK with positive (defined locally) isoenzymes.

LVEF less than 40%: The patient's current left ventricular ejection fraction is less than 40%.

WBC greater than 12K (white blood cells greater than 12,000): Use the patient's last preoperative measurement of WBC taken before the procedure.

Urgent: Medical factors require patient to stay in hospital to have operation before discharge. The risk of immediate morbidity and death is believed to be low.

Emergency: Patient's cardiac disease dictates that surgery should be performed within hours to avoid unnecessary morbidity or death.

Table 2 continued

Height	Weight (lbs)	
(feet and inches)	Obesity BMI 31 - 36	Severe Obesity BMI ≥ 37
5'0"	158 - 186	≥ 187
5'1"	164 - 192	≥ 193
5'2"	169 - 199	≥ 200
5'3"	175 - 205	≥ 206
5'4"	180 - 212	≥ 213
5'5"	186 - 219	≥ 220
5'6"	191 - 225	≥ 226
5'7"	198 - 232	≥ 233
5'8"	203 - 239	≥ 240
5'9"	209 - 246	≥ 247
5'10"	215 - 254	≥ 255
5'11	222 - 261	≥ 262
6'0"	228 - 268	≥ 269
6'1"	235 - 276	≥ 277
6'2"	241 - 283	≥ 284
6'3"	248 - 291	≥ 292

Data set and definitions for dependent variables: The regression models that generated the scores for these prediction rules were based on 14,971 patients receiving isolated CABG surgery between 1999 and 2002. The dependent variables and observed event rates are as follows: inhospital mortality (2.5%); cerebrovascular accident, defined as a new focal neurologic event persisting at least 24 hours (1.6%); and mediastinitis during the index admission defined by positive deep culture and/or gram stain and/or radiographic findings indicating infection and requiring re-operation (1.0%).

Northern New England Cardiovascular Disease Study Group 4/03.

BMI indicates body mass index;
CVA, cerebrovascular accident;
LM, left main;
TIA, transient ischemic attack;
ECG, electrocardiogram.

B. Morbidity Associated With Bypass Surgery

1. Neurological Events

Neurological impairment after bypass surgery may be attributable to hypoxia, emboli, hemorrhage, and/or metabolic abnormalities. Postoperative neurological deficits have been divided into type 1 (associated with major focal neurological deficits, stupor, or coma) and type 2 (in which deterioration in intellectual function is evident). Adverse cerebral outcomes are observed in approximately 6% of patients after bypass surgery, divided equally between type 1 and type 2 deficits.

Predictors of type 1 deficits include proximal aortic atherosclerosis (defined by the surgeon at operation), prior neurological disease, use of an intra-aortic balloon pump (IABP), diabetes, hypertension, unstable angina, and increased age. Predictors of type 2 deficits include history of excess alcohol consumption, arrhythmias including atrial fibrillation, hypertension, prior bypass surgery, peripheral vascular disease, and congestive heart failure (CHF). Estimation of a patient's risk for postoperative stroke can be calculated from *Table 2*.

Off-pump coronary artery bypass (OPCAB) avoids both aortic cannulation and cardiopulmonary bypass (CPB). Accordingly, one would expect postoperative neurological deficits to be reduced in

patients undergoing OPCAB. Three randomized controlled trials have not firmly established a significant change in neurological outcomes between OPCAB patients and conventional CABG patients. Each trial demonstrates problems inherent with small patient cohorts, differing definitions, and patient selection. At this point, there is insufficient evidence of a difference in neurological outcomes for patients undergoing OPCAB compared with those undergoing conventional CABG.

2. Mediastinitis

Deep sternal wound infection occurs in 1% to 4% of patients after bypass surgery and carries a mortality rate of approximately 25%. Predictors of this complication include obesity, reoperation, use of both internal mammary arteries at surgery, duration and complexity of surgery, and diabetes. An individual patient's risk of postoperative mediastinitis can be estimated from *Table 2*.

3. Renal Dysfunction

Postoperative renal dysfunction occurs in as many as 8% of patients. Among patients who develop postoperative renal dysfunction (defined as a postoperative serum creatinine level greater than 2.0 mg/dL or an increase in baseline creatinine level of greater than 0.7 mg/dL), 18% require dialysis. Overall mortality among patients who develop postoperative renal dysfunction is 19% and approaches 67% among patients requiring dialysis. Predictors of renal dysfunction include advanced age, history of moderate or severe congestive heart failure, prior bypass surgery, type 1 diabetes, and prior renal disease.

Table 3 can be used to estimate the risk for an individual patient. Patients with advanced preoperative renal dysfunction who undergo CABG have an extraordinarily high risk for postoperative dialysis. Among patients with a preoperative creatinine level greater than 2.5 mg/dL, 40% to 50% require hemodialysis.

Table 3. Risk of Postoperative Renal Dysfunction (PRD) After Coronary Artery Bypass Graft Surgery

Number of Risk Factors	Combinations of Preoperative Risk Factors for PRD			
	CHF	REOP	DM	CREAT > 1.4
None	–	–	–	–
One	–	–	–	+
	–	–	+	–
	–	+	–	–
	+	–	–	–
Two	–	–	+	+
	–	+	–	+
	–	+	+	–
	+	–	–	+
	+	–	+	–
	+	+	–	–
Three	–	+	+	+
	+	–	+	+
	+	+	–	+
	+	+	+	–
Four	+	+	+	+

CHF: prior congestive heart failure
Reop: redo coronary bypass operation
DM: type 1 diabetes mellitus
Creat > 1.4: preoperative serum creatinine level greater than 1.4 mg/dL

Risk of PRD in Various Clinical Strata Depending on Risk Factors and Age		
Age < 70 y	**Age 70-79 y**	**Age ≥ 80 y**
1.9% (n=909)	7.0% (n=330)	11.8% (n=68)
5.0% (n=80)	18.4% (n=76)	12.5% (n=16)
5.9% (n =68)	4.8% (n=81)	*
6.2% (n=130)	14.3% (n=56)	25.0% (n=4)
7.6% (n=144)	12.3% (n=73)	29.4% (n=17)
22.2% (n=9)	0.0% (n=7)	*
20.0% (n=25)	30.8% (n=13)	*
37.6% (n=8)	33.3% (n=3)	*
47.4% (n=19)	7.7% (n=26)	44.4% (n=9)
25.9% (n=27)	18.2% (n=11)	*
31.6% (n=19)	7.1% (n=14)	*
100% (n=1)	100% (n=1)	*
8.3% (n=12)	25% (n=4)	*
*	33.3% (n=9)	*
33.3% (n=3)	*	*
50.0% (n=2)	*	*

n : observed number of patients within each clinical stratum

– : risk factor absent

+ : risk factor present

*** :** insufficient patient numbers, number is less than five.

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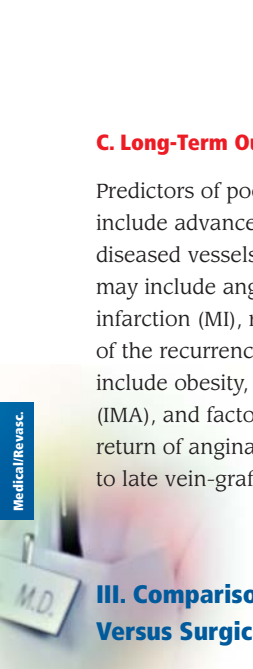
C. Long-Term Outcomes

Predictors of poor long-term survival after bypass surgery include advanced age, poor LVEF, diabetes, number of diseased vessels, and female gender. Additional predictors may include angina class, hypertension, prior myocardial infarction (MI), renal dysfunction, and clinical CHF. Predictors of the recurrence of angina, late MI, or any cardiac event also include obesity, lack of use of an internal mammary artery (IMA), and factors identified above. Of these events, the return of angina is the most common and is primarily related to late vein-graft atherosclerosis and occlusion.



III. Comparison of Medical Therapy Versus Surgical Revascularization

The comparison of medical therapy with coronary surgical revascularization is primarily based on randomized clinical trials and large registries. Although clinical trials have provided valuable insights, there are limitations to their interpretation in the current era. Most notably, the trials were completed years ago before modern-day advances in medical, surgical, and catheter-based treatments.

A. Overview: Randomized Trials

There were 3 major randomized trials and several smaller ones. A collaborative meta-analysis of 7 trials with a total enrollment of 2,649 patients has allowed comparison of outcomes at 5 and 10 years (*Table 4*). Among all patients, the extension in survival of CABG surgical patients compared with medically treated patients was 4.3 months at 10 years of follow-up. The benefit of CABG compared with medical therapy in various clinical subsets is presented below.

B. Left Main Coronary Artery Disease

The trials defined significant left main coronary artery stenosis as a greater than 50% reduction in lumen diameter. Median survival for surgically treated patients was 13.3 years versus 6.6 years in medically treated patients. Left main equivalent disease (greater than or equal to 70% stenosis in both the proximal left anterior descending [LAD] and proximal left circumflex arteries) resembles true left main coronary artery disease.

C. Three-Vessel Disease

If one defines 3-vessel disease as stenosis of 50% or more in all 3 major coronary territories, the overall extension of survival was 7 months in CABG patients compared with medically treated patients. Patients with class III or IV angina, those with more proximal and severe LAD stenosis, those with worse LV function, and/or those with more positive stress tests derived more benefit from surgery.

Table 4. Subgroup Results at 5 Years

Subgroup		Overall Numbers Deaths	Patients
Number of diseased vessels	One vessel	21	271
	Two vessels	92	859
	Three vessels	189	1341
	Left main artery	39	150
No LAD disease	One or 2 vessels	50	606
	Three vessels	46	410
	Left main artery	16	51
	Overall	112	1067
LAD disease present	One or 2 vessels	63	524
	Three vessels	143	929
	Left main artery	22	96
	Overall	228	1549
LV function	Normal	228	2095
	Abnormal	115	549
Exercise test status	Missing	102	664
	Normal	60	585
	Abnormal	183	1400
Severity of angina	Class I, II	178	1716
	Class III, IV	167	924

CI: indicates confidence interval
CABG: coronary artery bypass graft
LAD: left anterior descending coronary artery
LV: left ventricular.
*Includes only The Veterans Administration Coronary Artery Bypass Surgery Cooperative Study Group. *N Engl J Med*. 1984;311:1333-1339 and Varnauskas E. *N Engl J Med*. 1988;3199:332-337.

Mortality Rates, % Surgical	Mortality Rates, % Medical	Ratio (95% CI)	*P* for CABG Surgery vs Medical Therapy
5.4	9.9	0.54 (0.22-1.33)	0.18*
9.7	11.7	0.84 (0.54-1.32)	0.45*
10.7	17.6	0.58 (0.42-0.80)	< 0.001*
15.8	36.5	0.32 (0.15-0.70)	0.004*
8.3	8.3	1.05 (0.58-1.90)	0.88
7.7	14.5	0.47 (0.25-0.89)	0.02
18.5	45.8	0.27 (0.08-0.90)	0.03†
8.6	12.3	0.66 (0.44-1.00)	0.05
9.2	14.6	0.58 (0.34-1.01)	0.05
12.0	19.1	0.61 (0.42-0.88)	0.009
12.8	32.7	0.30 (0.11-0.84)	0.02‡
11.2	18.3	0.58 (0.43-0.77)	0.001
8.5	13.3	0.61 (0.46-0.81)	< 0.001
16.5	25.2	0.59 (0.39-0.91)	0.02§
13.1	17.4	0.69 (0.45-1.07)	0.10
9.0	11.6	0.78 (0.45-1.35)	0.38
9.4	16.8	0.52 (0.37-0.72)	< 0.001
8.3	12.5	0.63 (0.46-0.87)	0.005
13.8	22.4	0.57 (0.40-0.81)	0.001

† Excludes Varnauskas E. *N Engl J Med*. 1988;3199:332-337.

‡ Excludes Varnauskas E. *N Engl J Med*. 1988;3199:332-337; Kloster FE, et al. *N Engl J Med*. 1979;300:149-157; Mather VS, et al. *Cardiovasc Clin.* 1977;8:131-144; and Norris RM, et al. *Circulation*. 1981;63:785-792.

§ Excludes CASS Study. *Circulation*. 1983;68:951-960.

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D. Proximal LAD Disease

In patients with severe proximal LAD stenosis (greater than 50%), the relative risk reduction due to bypass surgery compared with medical therapy was 42% at 5 years and 22% at 10 years. This was greatest in patients with depressed LV function.

E. LV Function

In patients with mildly to moderately depressed LV function, the poorer the LV function, the greater was the potential advantage of CABG. Although the relative benefit was similar, the absolute benefit was greater because of the high-risk profile of these patients.

F. Symptoms and Quality of Life

Improvement in symptoms and quality of life after bypass surgery parallels the survival data. Bypass surgery may be indicated to alleviate symptoms of angina above and beyond medical therapy or to reduce the incidence of nonfatal complications such as MI, CHF, and hospitalization.

Registry studies have shown a reduction in late MI among the highest-risk patients, such as those with 3-vessel disease or those with severe angina. Antianginal medications were required less frequently after bypass surgery. At 5 years, 63% of bypass patients were symptom-free compared with 38% of medically assigned patients.

G. Loss of Benefit of Surgery

After 10 to 12 years of follow-up, there was a tendency for the bypass surgery and medical therapy curves to converge for both survival and nonfatal outcomes, owing to a number of factors. The increased event rate in the late follow-up period of surgically assigned patients was due to progression of native coronary and graft disease over time. In addition, medically assigned patients tended to cross over to surgery late, thus allowing the highest-risk medically assigned patients to gain from the benefit of surgery later in the course of follow-up. *Table 4* provides estimates of long-term outcomes among patients randomized in the trials. This can be used to estimate the general survival expectations in various anatomic categories.

IV. Comparison of Bypass Surgery With Percutaneous Revascularization

CABG versus PTCA

A number of randomized clinical trials comparing percutaneous transluminal coronary angioplasty (PTCA) and bypass surgery have been published. The trials excluded patients in whom survival had already been shown to be longer with bypass surgery versus medical therapy. None was sufficiently large to detect modest differences in survival between the two techniques.

Procedural complications were low for both procedures but tended to be higher with CABG (*Table 5*). For patients randomized to PTCA, CABG was needed in approximately 6% during the index hospitalization and approximately 20% by 1 year. The initial cost and length of stay were lower for PTCA than for CABG, and patients returned to work sooner and were able to exercise more at 1 month. The extent of revascularization achieved by bypass surgery was higher. Long-term survival was difficult to evaluate owing to the short period of follow-up and the small sample size of the trials. In the largest trial with the longest follow-up, Bypass Angioplasty Revascularization Investigation (BARI), bypass patients had a mean 7.8 year overall survival rate of 84.4% compared with 80.9% for PTCA (P=0.043), due to a marked survival benefit in study subjects with diabetes who were treated surgically (76.4% versus 55.7% with PTCA, P=0.0011). In long-term follow-up, the most striking difference was the 4- to 10-fold higher likelihood of reintervention after initial PTCA. Quality of life, physical activity, employment, and cost were similar at 3 to 5 years.

Registry data are similar to those of the trials. In New York State, after adjustment for various covariates, CABG was associated with longer survival in patients with severe proximal LAD stenosis or 3-vessel disease. Conversely, patients with 1-vessel disease not involving the proximal LAD had

improved survival with PTCA. Table 6 summarizes survival data from New York State's Cardiac Surgery Reporting System with respect to various cohorts of patients undergoing PTCA or bypass surgery. These data can be used to estimate 3-year survival expectations for patients with various anatomic features.

CABG versus stenting

Several trials have compared surgery with bare-metal stent implantation (*Table 5*). In the largest of these trials, the Arterial Revascularization Therapies Study (ARTS), 1,205 patients with multivessel disease were randomized to surgery or stenting. There was no difference in the combined rate of death, MI, and stroke at 1 year. The rate of repeat revascularization remained higher with stenting (16.8% versus 3.5% with surgery), however this rate was substantially lower than in balloon angioplasty alone trials and was associated with a net cost savings relative to surgery. Overall, compared with the earlier trials utilizing balloon angioplasty, stent usage and left internal mammary artery (IMA) revascularization rates increased in these trials. The results in terms of death, MI, and stroke are similar in the more recent trials, and the disparity in the need for repeat revascularization favoring surgery has narrowed. Drug-eluting stents, which are rapidly replacing bare-metal stents, will likely result in further narrowing of this difference.

Table 5. CABG Versus PTCA: Randomized Controlled Trials

	Trial††	Age, y (% Female)	CAD	N	Acute Outcome, % Death: CABG PCI	QW-MI: CABG PCI	Hosp CABG
PCI TRIALS	**BARI**	61 (26%)	MV	1829	1.3 1.1	4.6 2.1	N/A 2.1
	EAST	61 (26%)	MV	392	1.0 1.0	10.3 3.0†	N/A 10.1
	GABI	N/A (20%)	MV	359	2.5 1.1	8 2.3†	N/A 8.5
	Toulouse	67 (23%)	MV	152	1.3 1.3	6.6 3.9	N/A 3.9
	RITA	57 (19%)	SV+ MV*	1011	1.2 0.8	2.4 3.5	N/A 4.5
	ERACI	58 (13%)	MV	127	4.6 1.5	6.2 6.3	N/A 1.5
	MASS	56 (42%)	SV (LAD)	142	1.4 1.4	1.4 0	N/A 11
	Lausanne	56 (20%)	SV (LAD)	134	0 0	0 0	N/A 2.9
	CABRI	60 (22%)	MV	1054	1.3 1.3	N/A N/A	N/A N/A
STENT TRIALS	**SoS**	61 (21%)	MV	988	N/A	N/A	N/A
	ERACI II	62 (21%)	MV	450	N/A	N/A	N/A
	ARTS	61 (24%)	MV	1205	N/A	N/A	N/A
	AWESOME	67 (N/A)	MV	454	N/A	N/A	N/A
	SIMA	59 (21%)	SV	121	N/A	N/A	N/A
	LEIPZIG	62 (25%)	SV	220	N/A	N/A	N/A

CABG indicates coronary artery bypass graft; **PCI**, percutaneous coronary intervention; **CAD**, coronary artery disease; **QWMI**, Q-wave myocardial infarction; **Hosp CABG**, required CABG after PCI and before hospital discharge; **RR**, repeated revascularization; **F/U**, follow-up; **MV**, multivessel; **D**, death; **T**, thallium defect; **A**, angina; **SV**, single vessel; and **LAD**, left anterior descending coronary artery.

Late Outcome, %						
Death	QW-MI	Angina	RR % Total/PCI/CABG	Primary End Point	Primary End Point, %	F/U, y
15.6** 6.3	19.6 19.1**	N/A 21.3	8/7/1 N/A	D 54/34/31	15.6**	8§ 19.1**
17 21	19.6 16.6	12 20†	13/13/1 54/41/22	D+MI+T	27.3 28.8	8¶
6.5 2.6	9.4 4.5	26 29	6/5/1 44/27/21	A	26 29	1
10.5 13.2	1.3 5.3	5.3 21.1†	9/9/0 29/15/15	A	5.2 21.1†	5
3.6 3.1	5.2 6.7	21.5 31.3†	4/3/1 31/18/19	D+MI	8.6 9.8	2.5‡
4.7 9.5	7.8 7.8	3.2 4.8	6/3/3 37/14/22	D+MI+A+RR	23 53†	3
N/A N/A	N/A N/A	2 18	0/0/0 22/29/14	D+MI+RR	3 24†	3
1.5 0	1.5 2.9	5 6	3/3/0 25/12/13	D+MI+RR	7.6 36.8†	2‡
2.7 3.9	3.5 4.9	10.1 13.9†	9/6/1 36/21/18	D	2.7 3.9	1
2 5†	8 5	21 34†	6/4/1 21†/13/9	RR	6 21†	1
8 3†	6 3†	8 15†	5/0/0 17†/0/5	D+MI+CVA+RR	19 23	1.6
3 3	5 6	10 21†	4/3/1 21†/16/7	D+MI+CVA+RR	12 26†	1
N/A	N/A	N/A	N/A	D	27 30	3
4 2	4 5	5 9	0/0/0 24†/13/6	D+MI+RR	7 31†	2.4
2 0	5 3	21 38†	8/8/0 29/25/4	D+MI+RR	15 31†	0.5

* Included total occlusion.
† *P* is less than 0.05 comparing CABG and PCI cohorts.
‡ Planned 5-year follow-up (interim results).
§ Primary endpoint and mortality at 8 years, other endpoints at 5 years.
¶ Primary endpoint and mortality at 8 years, other endpoints at 3 years.
** Statistically significant.
†† References found in the full-text guidelines.

Table 6. Three-Year Survival by Treatment in Each Anatomic Subgroup

Coronary Anatomy Group		Patients, n	Survival		*P*
			Observed,%	Adjusted, %	
One vessel, no LAD	CABG	507	89.2	92.4	0.003
	PTCA	11,233	95.4	95.3	
One vessel, nonproximal LAD	CABG	153	95.8	96.0	0.857
	PTCA	4130	95.7	95.7	
One vessel, proximal LAD	CABG	1917	95.8	96.6	0.010
	PTCA	5868	95.5	95.2	
Two vessels, no LAD	CABG	1120	91.0	93.0	0.664
	PTCA	2729	93.4	92.6	
Two vessels, nonproximal LAD	CABG	850	91.3	92.3	0.438
	PTCA	2300	93.3	93.1	
Two vessels, proximal LAD	CABG	7242	93.5	93.8	< 0.001
	PTCA	2376	92.8	91.7	
Three vessels, nonproximal LAD	CABG	1984	90.1	90.3	0.002
	PTCA	660	86.7	86.0	
Three vessels, proximal LAD	CABG	15,873	90.1	90.3	< 0.001
	PTCA	634	88.2	86.1	

LAD indicates left anterior descending coronary artery; **CABG**, coronary artery bypass graft; **PTCA**, percutaneous transluminal coronary angioplasty. Comparative observed and adjusted 3-year survival of patients treated with PTCA or CABG in various anatomic subgroups.

V. Management Strategies: Reduction of Perioperative Mortality and Morbidity

A. Reducing the Risk of Type 1 Brain Injury After CABG

Postoperative neurological complications represent one of the most devastating consequences of CABG surgery. Type 1 injury, in which a significant, permanent neurological injury is sustained, occurs in approximately 3% of patients overall and is responsible for a 21% mortality rate.

1. Atherosclerotic Ascending Aorta

Perioperative atheroembolism from aortic plaque is thought to be responsible for approximately one third of strokes after CABG. Atherosclerosis of the ascending aorta is strongly related to increased age. Stroke risk is particularly increased in patients older than 75 years of age. Preoperative noninvasive testing to identify high-risk patients has variable accuracy. Computed tomography (CT) underestimates mild or moderate disease compared with echocardiography. Transesophageal echocardiography (TEE) of the ascending aorta was limited by the intervening trachea with earlier monoplane techniques; multiplane TEE technology now allows good visualization of the aorta. Intraoperative palpation underestimates the high risk aorta. Intraoperative assessment with epiaortic imaging is superior to TEE and direct palpation. The highest-risk aortic pattern is a protruding or mobile aortic arch plaque.

An aggressive approach to the management of patients with severely diseased ascending aortas identified by intraoperative epiaortic ultrasound imaging reduces the risk of postoperative stroke. For patients with aortic walls with less than or equal to 3-mm thickening, standard treatment is used. For aortas with greater than 3-mm thickening, the cannulation, clamp, or proximal anastomotic sites may be changed, or a no-clamp, fibrillatory arrest strategy may be used. For high-risk patients with multiple or circumferential involvement or those with extensive middle ascending aortic involvement, replacement of the ascending aorta under hypothermic circulatory arrest may be indicated. Alternatively, a combined approach with off-bypass, in situ internal mammary grafting to the LAD and percutaneous coronary intervention (PCI) to treat other vessel stenoses has conceptual merit.

2. Atrial Fibrillation (AF) and Stroke

Chronic AF is a hazard for perioperative stroke. Intraoperative surgical manipulation or spontaneous resumption of sinus rhythm during the early postoperative period may lead to embolism of a left atrial clot. One approach to reduce this risk is the performance of preoperative TEE. In the absence of a left atrial clot, the operation may proceed with acceptable risk. If a left atrial clot is identified, 3 to 4 weeks of anticoagulation therapy followed by restudy and then subsequent surgery is reasonable if the clinical situation allows this. Few clinical trial data are available to assist clinicians in this circumstance.

New-onset postoperative AF occurs in approximately 30% of post-CABG patients, particularly on the second and third postoperative days, and is associated with a 2- to 3-fold increased

risk of postoperative stroke. Risk factors for postoperative AF include advanced age, chronic obstructive pulmonary disease, proximal right coronary disease, prolonged operation, atrial ischemia, and withdrawal of beta-blockers.

The role of anticoagulants in patients who develop post-CABG AF is unclear. Aggressive anticoagulation and cardioversion may reduce the neurological complications associated with this arrhythmia. Early cardioversion within 24 hours of the onset of AF can probably be performed safely without anticoagulation. However, persistence of the arrhythmia beyond this time argues for the use of anticoagulants to reduce stroke risk in patients who remain in AF and in those for whom later cardioversion is planned.

3. Recent MI, LV Thrombus, and Stroke

Patients with a recent anterior MI and residual wall-motion abnormality are at increased risk for the development of an LV mural thrombus and its potential for embolization. Therefore, preoperative screening with echocardiography may be appropriate to identify the presence of a clot. If found, the technical approach and the timing of surgery may be affected. Three to 6 months of anticoagulation therapy is probably indicated for patients with new, persistent, and extensive anterior wall-motion abnormalities after CABG.

4. Recent Antecedent Cerebrovascular Event

A recent preoperative cerebrovascular accident represents a situation in which delaying surgery may reduce the perioperative neurological risk. Evidence of a hemorrhagic component based on CT scan identifies those patients at high risk for the

extension of neurological damage with heparinization CPB. A delay of 4 weeks or more after a cerebrovascular accident is prudent, if coronary anatomy and symptoms permit, before proceeding with CABG.

5. Carotid Disease and Neurological Risk Reduction

Hemodynamically significant carotid stenoses are associated with up to 30% of early postoperative strokes. The trend for coronary surgery to be performed in an increasingly elderly population and the increasing prevalence of carotid disease in this same group of patients underscore the importance of this issue. Perioperative stroke risk relates to severity of underlying stenosis:

Severity of Disease	Perioperative Stroke Risk
Carotid stenosis less than 50%	2%
Carotid stenosis 50-80%	10%
Carotid stenosis greater than 80%	11-19%
Bilateral severe stenosis (or occlusion)	20%

Carotid endarterectomy for patients with high-grade stenosis is generally done before or coincident with coronary bypass surgery and, with proper teamwork in high-volume centers, is associated with a low risk for both short- and long-term adverse neurological sequelae. Carotid endarterectomy performed in this fashion carries a low mortality rate (3.5%) and reduces early postoperative stroke risk to less than 4%, with a 10-year rate of freedom from stroke of 88% to 96%.

The decision about who should undergo preoperative carotid screening is controversial. Carotid screening is probably indicated in the following subsets:

- advanced age (greater than 65 years)
- PVD
- previous transient ischemic attack/stroke
- a history of smoking
- left main coronary disease
- carotid bruit on examination

Many centers screen all patients age 65 years and older. Patients with left main coronary disease are often screened, as are those with a previous transient ischemic attack or stroke. Preoperative central nervous system symptoms suggestive of vertebral basilar insufficiency should lead to an evaluation before elective CABG.

When surgery of both carotid and coronary disease is planned, the most common approach is to perform the operation in a staged manner, in which the patient first has carotid surgery followed by coronary bypass in 1 to 5 days. Alternatively, if the patient has compelling cardiac symptoms or coronary anatomy, the operations may be performed during a single period of anesthesia, with the carotid endarterectomy immediately preceding coronary bypass. Neither strategy has been established as being superior. Stroke risk is increased if a reversed-stage procedure is used, in which the coronary bypass operation precedes the carotid endarterectomy by 1 day or more.

B. Reducing the Risk of Type 2 Brain Injury

Type 2 neurological complications are seen in a percentage of patients and are associated with increases in post-CABG time in the intensive care unit, length of stay, hospital costs and the need for postdischarge transfer to rehabilitation or extended care facilities. Microembolization is thought to be a major contributor. The release of microemboli during extracorporeal circulation, involving small gaseous emboli, may be responsible. The use of a 40-micron arterial-line filter on the heart-lung machine circuit and routine use of membrane oxygenators rather than bubble oxygenators may reduce such neurological injury. Additional maneuvers to reduce type 2 neurological injury include maintenance of steady cerebral blood flow during CPB, avoidance of cerebral hyperthermia during and after CPB, meticulous control of perioperative hyperglycemia, and avoidance and limitation of post-operative cerebral edema. The return of shed mediastinal blood to the CPB circuit via the cardiotomy suction system may increase the microembolic load to the brain. Some centers avoid cardiotomy suction and simply discard shed blood. Alternatively, shed blood may be scavenged and red blood cells returned after centrifugation via cell-saving devices.

C. Reducing the Risk of Perioperative Myocardial Dysfunction

1. Myocardial Protection for Acutely Depressed Cardiac Function

Several studies have suggested that blood cardioplegia (compared with crystalloid cardioplegia) may offer a greater margin of safety during CABG performed on patients with acute coronary occlusion, failed angioplasty, urgent revascularization for unstable angina, or chronically impaired LV function.

2. Protection for Chronically Depressed LV Function

The use of a prophylactic intra-aortic balloon pump (IABP) as an adjunct to myocardial protection may reduce mortality in patients having CABG in the setting of severe LV dysfunction (e.g., LVEF less than 0.25). Placement of the IABP immediately before operation appears to be as effective as placement on the day preceding bypass surgery.

3. Biomarker Assessment of Risk After CABG

It has now been demonstrated that marked elevation of the cardiac biomarker creatine kinase (CK-MB) after surgery is associated with an adverse prognosis, with the worst outcome in those patients with levels greater than 5 times the upper limit of normal. The prognostic value of troponins after CABG is not as well established, but available studies have suggested that troponin T is more discriminatory than CK-MB in predicting early complications. For patients with elevated biomarkers after CABG, it is particularly important that attention be given to optimizing medical therapy, including the use of beta-blockers, angiotensin converting enzyme (ACE) inhibitors, antiplatelet agents and statins in eligible individuals.

4. Inferior Infarct With Right Ventricular Involvement

An acutely infarcted right ventricle is at great risk for severe postoperative dysfunction and predisposes the patient to a greater chance of post-operative mortality. The best defense against right ventricular dysfunction is its recognition during preoperative evaluation. When possible, CABG should be delayed for 4 weeks or more to allow the right ventricle to recover.

D. Attenuation of the Systemic Consequences of Cardiopulmonary Bypass

A variety of measures have been tried to reduce the systemic consequences of CPB, which elicits a diffuse inflammatory response that may cause transient or prolonged multisystem organ dysfunction. Administration of corticosteroids before CPB may reduce complement activation and release of pro-inflammatory cytokines. The administration of the serine protease inhibitor aprotinin may attenuate complement activation and cytokine release during extracorporeal circulation. Another method to reduce the inflammatory response is perioperative leukocyte depletion through hematologic filtration.

E. Reducing the Risk of Perioperative Infections

Several methods exist to reduce the risk of wound infections in patients undergoing CABG. These include the following:

- Interval reporting to individual surgeons regarding their respective wound-infection rates
- Adherence to sterile operative technique
- Skin preparation with topical antiseptics
- Clipping rather than shaving the skin
- Avoidance of hair removal
- Reduction of operating room traffic
- Laminar-flow ventilation
- Shorter operations
- Minimization of electrocautery

- Avoidance of bone wax
- Use of double-glove barrier techniques for the operating room team
- Routine use of a pleural pericardial flap
- Aggressive perioperative glucose control in patients with diabetes through the use of continuous intravenous insulin infusion (reduces perioperative hyperglycemia and its associated infection risk)
- Avoidance of homologous blood transfusions after CABG may reduce the risk of both viral and bacterial infections (this is due to an immunosuppressive effect of transfusion). Leukodepletion of transfused blood also reduces this effect. This can be accomplished by regional blood blanks at the time of donation or at the bedside by use of a transfusion filter.

Preoperative antibiotic administration reduces by 5-fold the risk of postoperative infection. Efficacy depends on adequate drug tissue levels before microbial exposure. Cephalosporins are the agents of choice. *Table 7* identifies appropriate choices, doses, and routes of therapy. A 1-day course of intravenous antimicrobials is as effective as 48 hours or more. Therapy should be administered within 30 minutes of incision and again in the operating room if the operation exceeds 3 hours. If deep sternal wound infection does occur, aggressive surgical debridement and early vascularized muscle flap coverage are the most effective methods for treatment, along with long-term systemic antibiotics.

Table 7. Prophylactic Antimicrobials for Coronary Artery Bypass Graft Surgery

Antibiotic	Equivalent-Efficacy IV Dosing Regimens, Dose and Interval	Cost per Dose
Cefuroxime	1.5 g preoperatively 1.5 g after CPB 1.5 g Q 12 x 48	$6.33/1.5 g
Cefamandole, cefazolin	1 g preoperatively 1 g at sternotomy 1 g after CPB 1 g Q 6 h x 48 (initial dose to be given 30-60 minutes before skin incision)	$6.27/1 g $0.90/1 g
Vancomycin	1 g Q 12/h/until lines/tubes out At least 2 doses (During 30-60-minute infusion timed to end before skin incision)	$5.77/1 g

CPB indicates cardiopulmonary bypass.

Comment

First-line agents; low toxicity; pharmacokinetics vary; shorter prophylaxis duration < 24 h may be equally efficacious for cefuroxime

Reserved for penicillin-allergic; justified in periods of methicillin-resistant *Staphylococcus* species outbreaks; vancomycin-resistant *Enterococcus* problem is on horizon; more likely to require vasopressor agent perioperatively

References

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Romanelli et al. *Crit CareMed* 1993;21:1124-1131.

F. Prevention of Postoperative Arrhythmias

Postoperative AF increases the length of stay after CABG up to 5 days, increases charges by as much as $10,055, and is associated with a 2- to 3-fold increase in postoperative stroke. There are several methods which reduce the risk of AF. First, withdrawal of preoperative beta-blockers in the postoperative period doubles the risk of AF after CABG. Thus, early reinitiation of beta-blockers is critical for avoidance of this complication. Prophylactic use of beta-blockers lowers the frequency of AF. For patients who have contraindications to beta-blockers, amiodarone is appropriate prophylactic therapy. Digoxin and nondihydropyridine calcium-channel blockers have no consistent benefit for preventing AF after CABG, although they are frequently used to control the rate of AF if it does occur. The routine preoperative or early postoperative administration of beta-blockers is considered standard therapy to reduce the risk of AF after CABG.

G. Strategies to Reduce Perioperative Bleeding and Transfusion Risk

1. Transfusion Risk

Despite the increasing safety of homologous blood transfusion, concerns surrounding viral transmission during transfusion remain. However, the risks are very low:

Risk of Viral Transmission During Transfusion

HIV	1/493,000
HTLV	1/641,000
HCV	1/103,000

HIV indicates human immunodeficiency virus; **HTLV**, human T-cell lymphotrophic virus; **HCV**, hepatitis C virus.

2. Perioperative Bleeding

Risk factors for blood transfusion after CABG include advanced age, low preoperative red blood cell volume, preoperative aspirin therapy, urgent operation, duration of CPB, recent fibrinolytic therapy, reoperation, and differences in heparin management. Institutional protocols that establish minimum thresholds for transfusion lead to a reduced number of units transfused and a reduction in the percentage of patients requiring blood. For stable patients, aspirin and other antiplatelet drugs may be discontinued 7 to 10 days before elective CABG. Clopidogrel should be discontinued 5 or more days before CABG when the clinical situation will permit it. Aprotinin, a serum protease inhibitor with antifibrinolytic activity, also decreases postoperative blood loss and transfusion requirements in high-risk patients. Routine use of aprotinin is limited by its high cost.

H. Antiplatelet Therapy for Saphenous Vein Graft Patency

Aspirin significantly reduces vein graft closure during the first postoperative year. The aspirin should be started within 24 hours after surgery, because its benefit on saphenous vein graft patency is lost when begun later. Dosing regimens from 100 to 325 mg per day appear to be efficacious. Ticlopidine offers no advantage over aspirin but is an alternative in truly aspirin-allergic patients. Life-threatening neutropenia is a rare but recognized side effect. Clopidogrel has fewer side effects than ticlopidine as an alternative in aspirin-allergic patients.

I. Pharmacological Management of Hyperlipidemia

Aggressive treatment of hypercholesterolemia reduces progression of atherosclerotic vein graft disease in patients after bypass surgery. Statin therapy reduces saphenous vein graft disease progression over the ensuing years after bypass. Patients with unknown low-density lipoprotein cholesterol (LDL-C) levels should have cholesterol levels determined after bypass and treated pharmacologically if the LDL-C level exceeds 100 mg/dL. In patients being treated for high LDL-C, a low-fat diet and cholesterol-lowering medications should be continued after bypass surgery to reduce subsequent graft attrition. Data regarding the benefit of cholesterol lowering after bypass surgery are most supported by studies that have used HMG CoA (3-hydroxy-3-methylglutaryl coenzyme A) reductase inhibitors, particularly targeting LDL-C levels to less than 100 mg/dL. New data supports an even more aggressive goal of LDL-C less than 70 mg/dL in very high-risk patients. In addition, because patients are more likely to continue on statin therapy begun in the hospital, it is recommended that statin therapy be continued or started as an inpatient after surgery.

J. Smoking Cessation

Smoking cessation is the single most important risk-modification goal after CABG in patients who smoke. Smoking cessation leads to less recurrent angina, improved function, fewer hospital admissions, maintenance of employment, and improved survival. Treatment individualized to the patient is crucial. Depression may be a complicating factor and should be approached with behavioral and drug therapy.

Nicotine replacement with a transdermal patch, nasal spray, gum, or inhaler is beneficial. A sustained-release form of the antidepressant bupropion reduces the nicotine craving and anxiety of smokers who quit. All smokers should receive educational counseling and be offered smoking cessation therapy, including pharmacological therapy if appropriate, after CABG (*Table 8*).

K. Cardiac Rehabilitation

Cardiac rehabilitation, including early ambulation during hospitalization, outpatient prescriptive exercise, family education, and dietary and sexual counseling, has been shown to improve outcomes after CABG and should be considered a part of routine post-CABG care.

Table 8. Proven Management Strategies to Reduce Perioperative and Late Morbidity and Mortality

	Timing	Class Indication	Intervention	Comment
Preoperative	Carotid screening	IIa	Carotid duplex ultrasound in defined population	Carotid endarterectomy if stenosis ≥ 80%
Perioperative	Antimicrobials	I	Prophylactic antimicrobials	See Table 7
	Antiarrhythmics	I	Beta-blockers to prevent postoperative atrial fibrillation	Propafenone or amiodarone are alternatives if contraindication to beta-blocker
Postoperative	Antiplatelet agents	I	Aspirin to prevent early vein graft attrition	Ticlopidine or clopidogrel are alternatives if contra-indications to aspirin
	Lipid-lowering therapy	I	Cholesterol-lowering agent plus low-fat diet if low-density lipoprotein cholesterol > 100 mg/dL	3-Hydroxy-3-methyglutaryl/ coenzyme A reductase inhibitors preferred if elevated low-density lipoprotein is major aberration
	Smoking cessation	I	Smoking cessation education, and offer counseling and pharmacotherapies	

L. Emotional Dysfunction and Psychosocial Considerations

Lack of social participation and low religious strength are independent predictors of death in elderly patients undergoing CABG. Although controversial, a hypothesis exists that the high prevalence of depression after bypass surgery may reflect a high prevalence preoperatively. Cardiac rehabilitation has a beneficial effect in patients who are moderately or severely depressed. Evaluation of social supports and attempts to identify and treat underlying depression should be part of routine post-CABG care.

M. Rapid Sustained Recovery After Operation

Rapid recovery and early discharge are standard goals after CABG. The shortest in-hospital postoperative stays are followed by the fewest rehospitalizations. Important components of "fast-track" care are careful patient selection, patient and family education, early extubation, prophylactic antiarrhythmic therapy, dietary considerations, early ambulation, early outpatient telephone follow-up, and careful coordination with other physicians and healthcare providers.

N. Communication Between Caregivers

Maintenance of appropriate and timely communication between treating physicians regarding care of the patient is crucial. When possible, the primary care physician should monitor the patient during the perioperative course. The referral physician must provide clear written reports of the findings and recommendations to the primary care physician, including discharge medications and dosages along with long-term goals.

VI. Special Patient Subsets

A. Patients With Chronic Obstructive Pulmonary Disease or Respiratory Insufficiency

Because CABG is associated with various degrees of postoperative respiratory insufficiency, it is important to identify patients at particular risk for pulmonary complications. The intent is to treat reversible problems that may contribute to respiratory insufficiency in high-risk patients, with the hope of avoiding prolonged periods of mechanical ventilation after CABG. High-risk patients often benefit from the use of preoperative antibiotics, bronchodilator therapy, a period of cessation from smoking, perioperative incentive spirometry, deep breathing exercises, and chest physiotherapy. If pulmonary venous congestion of pleural effusions are identified, diuresis often improves lung performance. Although preoperative spirometry to identify patients with a low (e.g., less than 1.0 L) 1-second forced expiratory volume has been used to disqualify candidates for CABG, clinical evaluation of lung function is likely as important, if not more so. Patients with advanced chronic obstructive pulmonary disease are at particular risk for postoperative arrhythmias that may be fatal.

B. Patients With End-Stage Renal Disease

Coronary artery disease is the most important cause of mortality in patients with end-stage renal disease. Many of such patients have diabetes and other coronary risk factors, including hypertension, myocardial dysfunction, abnormal lipids, anemia, and increased plasma homocysteine levels. Although

patients on chronic dialysis are at greater risk when undergoing coronary angioplasty or CABG, they are at even higher risk with conservative medical management. Thus, in the select group of high-risk patients with modest reductions in LV function, significant left main or 3-vessel disease, or unstable angina, coronary revascularization can lead to relief of coronary symptoms, improvement in overall functional status, and improved long-term survival.

C. Reoperative Patients

Operative survival and long-term benefit of reoperative CABG are inferior to first-time operations. Patients undergoing repeated CABG have higher rates of postoperative bleeding, perioperative MI, and neurological and pulmonary complications. Nevertheless, reasonable 5- and 10-year survival rates after reoperation for coronary disease can be achieved, and the operation is appropriate if the severity of symptoms and anticipated benefit justify the immediate risk.

D. CABG in Acute Coronary Syndromes

Coronary bypass surgery offers a survival advantage compared with medical therapy in patients with unstable angina and LV dysfunction, particularly in the presence of 3-vessel disease. However, the risk of bypass surgery in patients with unstable or postinfarction angina or early after non-ST-elevation MI (NSTEMI) and ST-elevation MI (STEMI) is increased severalfold compared with patients with stable angina. Although this risk is not necessarily higher than that with medical therapy, it has led to the argument for consideration of PCI or delay of CABG in such patients if medical stabilization can be easily accomplished.

VII. Institutional and Operator Competence

Studies suggest that mortality after CABG is higher when CABG is performed in institutions that annually perform fewer than a minimum number of cases. Similar conclusions have been drawn regarding individual surgeons' volumes. This observation strengthens the argument for careful outcome tracking and supports the monitoring of institutions or individuals who annually perform less than 100 cases. It is also true that there is a wide variation in risk-adjusted mortality rates in low-volume situations. Thus, some institutions and practitioners maintain excellent outcomes despite relatively low volumes.

Outcome reporting in the form of risk-adjusted mortality rates after bypass has been effective in reducing mortality rates nationwide. Public release of hospital- and physician-specific mortality rates has not been shown to drive this improvement and has failed to effectively guide consumers or alter physician referral patterns.

VIII. Indications

A. Indications for CABG in Asymptomatic or Mild Angina

Class I

1. CABG should be performed in patients with asymptomatic ischemia or mild angina who have significant left main coronary artery stenosis. (*Level of Evidence: A*)

2. CABG should be performed in patients with asymptomatic ischemia or mild angina who have left main equivalent: significant (greater than or equal to 70%) stenosis of the proximal LAD and proximal left circumflex artery. (*Level of Evidence: A*)

3. CABG is useful in patients with asymptomatic ischemia or mild angina who have 3-vessel disease. (Survival benefit is greater in patients with abnormal LV function; e.g., LVEF less than 0.50 and/or large areas of demonstrable myocardial ischemia.) (*Level of Evidence: C*)

Class IIa

1. CABG can be beneficial for patients with asymptomatic or mild angina who have proximal LAD stenosis with 1- or 2-vessel disease. (This recommendation becomes Class I if extensive ischemia is documented by a noninvasive study and/or LVEF is less than 0.50.) (*Level of Evidence: A*)

Class IIb 1. CABG may be considered for patients with asymptomatic or mild angina who have 1- or 2-vessel disease not involving the proximal LAD. (If a large area of viable myocardium and high-risk criteria are met on noninvasive testing, this recommendation becomes a Class I.) (*Level of Evidence: B*)

B. Indications for CABG in Stable Angina

Class I 1. CABG is recommended for patients with stable angina who have significant left main coronary artery stenosis. (*Level of Evidence: A*)

2. CABG is recommended for patients with stable angina who have left main equivalent: significant (greater than or equal to 70%) stenosis of the proximal LAD and proximal left circumflex artery. (*Level of Evidence: A*)

3. CABG is recommended for patients with stable angina who have 3-vessel disease. (Survival benefit is greater when LVEF is less than 0.50.) (*Level of Evidence: A*)

4. CABG is recommended in patients with stable angina who have 2-vessel disease with significant proximal LAD stenosis and either LVEF less than 0.50 or demonstrable ischemia on noninvasive testing. (*Level of Evidence: A*)

5. CABG is beneficial for patients with stable angina who have 1- or 2-vessel CAD without

significant proximal LAD stenosis but with a large area of viable myocardium and high-risk criteria on noninvasive testing. (*Level of Evidence: B*)

6. CABG is beneficial for patients with stable angina who have developed disabling angina despite maximal noninvasive therapy, when surgery can be performed with acceptable risk. If the angina is not typical, objective evidence of ischemia should be obtained. (*Level of Evidence: B*)

Class IIa

1. CABG is reasonable in patients with stable angina who have proximal LAD stenosis with 1-vessel disease. (This recommendation becomes Class I if extensive ischemia is documented by noninvasive study and/or LVEF is less than 0.50.) (*Level of Evidence: A*)

2. CABG may be useful for patients with stable angina who have 1- or 2-vessel CAD without significant proximal LAD stenosis but who have a moderate area of viable myocardium and demonstrable ischemia on noninvasive testing. (*Level of Evidence: B*)

Class III

1. CABG is not recommended for patients with stable angina who have 1- or 2-vessel disease not involving significant proximal LAD stenosis, patients who have mild symptoms that are unlikely due to myocardial ischemia, or patients who have not received an adequate trial of medical therapy and the following:

a. Have only a small area of viable myocardium (*Level of Evidence: B*) or

b. Have no demonstrable ischemia on noninvasive testing. (*Level of Evidence: B*)

2. CABG is not recommended for patients with stable angina who have borderline coronary stenoses (50% to 60% diameter in locations other than the left main coronary artery) and no demonstrable ischemia on noninvasive testing. (*Level of Evidence: B*)

3. CABG is not recommended for patients with stable angina who have insignificant coronary stenosis (less than 50% diameter reduction). *(Level of Evidence: B*)

C. Indications for CABG in Unstable Angina/Non-ST-Segment Elevation MI (NSTEMI)

Class I

1. CABG should be performed for patients with unstable angina/NSTEMI with significant left main coronary artery stenosis. *(Level of Evidence: A*)

2. CABG should be performed for patients with unstable angina/NSTEMI who have left main equivalent: significant (greater than or equal to 70%) stenosis of the proximal LAD and proximal left circumflex artery. (*Level of Evidence: A*)

3. CABG is recommended for unstable angina/NSTEMI in patients in whom revascularization is not optimal or possible and who have ongoing

ischemia not responsive to maximal nonsurgical therapy. (*Level of Evidence: B*)

Class IIa 1. CABG is probably indicated in patients with unstable angina/NSTEMI who have proximal LAD stenosis with 1- or 2-vessel disease. *(Level of Evidence: A*)

Class IIb 1. CABG may be considered for patients with unstable angina/NSTEMI who have 1- or 2-vessel disease not involving the proximal LAD when percutaneous revascularization is not optimal or possible. (If there is a large area of viable myocardium and high-risk criteria are met on noninvasive testing, this recommendation becomes Class I.) (*Level of Evidence: B*)

D. Indications for CABG in ST-Segment Elevation MI (STEMI)

Class I 1. Emergency or urgent CABG in patients with STEMI should be undertaken in the following circumstances:

a. Failed angioplasty with persistent pain or hemodynamic instability in patients with coronary anatomy suitable for surgery. (*Level of Evidence: B*)

b. Persistent or recurrent ischemia refractory to medical therapy in patients who have coronary anatomy suitable for surgery, who have a significant area of myocardium at risk, and who are not candidates for PCI (*Level of Evidence: B*)

c. At the time of surgical repair of postinfarction ventricular septal rupture or mitral valve insufficiency. (*Level of Evidence: B*)

d. Cardiogenic shock in patients less than 75 years old with ST-segment elevation or left bundle-branch block or posterior MI who develop shock within 36 hours of MI and are suitable for revascularization that can be performed within 18 hours of shock, unless further support is futile because of the patient's wishes or contraindications/unsuitability for further invasive care. (*Level of Evidence: A*)

e. Life-threatening ventricular arrhythmias in the presence of greater than or equal to 50% left main stenosis and/or triple-vessel disease. (*Level of Evidence: B*)

Class IIa

1. CABG may be performed as primary reperfusion in patients who have suitable anatomy and who are not candidates for or who have had failed fibrinolysis/PCI and who are in the early hours (6 to 12 hours) of evolving STEMI. (*Level of Evidence: B*)

2. In patients who have had an ST-segment elevation MI or non-ST-segment elevation MI, CABG mortality is elevated for the first 3 to 7 days after infarction, and the benefit of revascularization must be balanced against this increased risk. Beyond 7 days after infarction, the criteria for revascularization described in previous sections are applicable. (*Level of Evidence: B*)

Class III

1. Emergency CABG should not be performed in patients with persistent angina and a small area of myocardium at risk who are hemodynamically stable. (*Level of Evidence: C*)

2. Emergency CABG should not be performed in patients with successful epicardial reperfusion but unsuccessful microvascular reperfusion. (*Level of Evidence: C*)

E. Indications for CABG in Poor LV Function

Class I

1. CABG should be performed in patients with poor LV function who have significant left main coronary artery stenosis. (*Level of Evidence: B*)

2. CABG should be performed in patients with poor LV function who have left main equivalent: significant (greater than or equal to 70%) stenosis of the proximal LAD and proximal left circumflex artery. (*Level of Evidence: B*)

3. CABG should be performed in patients with poor LV function who have proximal LAD stenosis with 2- or 3-vessel disease. (*Level of Evidence: B*)

Class IIa

1. CABG may be performed in patients with poor LV function with significant viable noncontracting, revascularizable myocardium and without any of the above anatomic patterns. (*Level of Evidence: B*)

Class III 1. CABG should not be performed in patients with poor LV function without evidence of intermittent ischemia and without evidence of significant revascularizable viable myocardium. (*Level of Evidence: B*)

F. Indications for CABG in Life-Threatening Ventricular Arrhythmias

Class I 1. CABG should be performed in patients with life-threatening ventricular arrhythmias caused by left main coronary artery stenosis. (*Level of Evidence: B*)

2. CABG should be performed in patients with life-threatening ventricular arrhythmias caused by 3-vessel coronary disease. (*Level of Evidence: B*)

Class IIa 1. CABG is reasonable in bypassable 1- or 2-vessel disease causing life-threatening ventricular arrhythmias. (This becomes a Class I recommendation if the arrhythmia is resuscitated sudden cardiac death or sustained ventricular tachycardia.) (*Level of Evidence: B*)

2. CABG is reasonable in life-threatening ventricular arrhythmias caused by proximal LAD disease with 1- or 2-vessel disease. (This becomes a Class I recommendation if the arrhythmia is resuscitated sudden cardiac death or sustained ventricular tachycardia.) (*Level of Evidence: B*)

Class III	1. CABG is not recommended in ventricular tachycardia with scar and no evidence of ischemia. (*Level of Evidence: B*)

G. Indications for CABG After Failed PTCA

Class I	1. CABG should be performed after failed PTCA in the presence of ongoing ischemia or threatened occlusion with significant myocardium at risk. (*Level of Evidence: B*) 2. CABG should be performed after failed PTCA for hemodynamic compromise. (*Level of Evidence: B*)
Class IIa	1. CABG is reasonable after failed PTCA for a foreign body in crucial anatomic position. (*Level of Evidence: C*) 2. CABG can be beneficial after failed PTCA for hemodynamic compromise in patients with impairment of the coagulation system and without previous sternotomy. (*Level of Evidence: C*)
Class IIb	1. CABG can be considered after failed PTCA for hemodynamic compromise in patients with impairment of the coagulation system and with previous sternotomy. (*Level of Evidence: C*)
Class III	1. CABG is not recommended after failed PTCA in the absence of ischemia. (*Level of Evidence: C*)

2. CABG is not recommended after failed PTCA with inability to revascularize due to target anatomy or no-reflow state. (*Level of Evidence: C*)

H. Indications for CABG in Patients With Previous CABG

Class I

1. Coronary bypass should be performed in patients with prior CABG for disabling angina despite optimal nonsurgical therapy. (If the angina is not typical, then objective evidence of ischemia should be obtained.) (*Level of Evidence: B*)

2. Coronary bypass should be performed in patients with prior CABG without patent bypass grafts but with Class I indications for surgery for native-vessel coronary artery disease (significant left main coronary stenosis, left main equivalent, 3-vessel disease). (*Level of Evidence: B*)

Class IIa

1. Coronary bypass is reasonable in patients with prior CABG and bypassable distal vessel(s) with a large area of threatened myocardium by noninvasive studies. (*Level of Evidence: B*)

2. Coronary bypass is reasonable in patients with prior CABG if atherosclerotic vein grafts with stenoses greater than 50% supplying the LAD coronary artery or large areas of myocardium are present. (*Level of Evidence: B*)

Keys to Successful CABG

Preoperative Period: Risk vs Benefit

1. Establish the indication (Pages 47 through 56)

2. Assess perioperative risk (Table 2, page 7)

3. Assess expected long-term outcome (Tables 2, page 7; 3, page 14; and 4, page 18)

Perioperative Period: Steps to Reduce Risks

Potential Complication	Steps to Consider in Certain Cohorts
4. Perioperative AF and stroke	■ Image ascending aorta (pg 27) ■ Anticoagulation for – Chronic AF (pg 28) – LV thrombus (pg 29) ■ Carotid screening (pg 30)
5. Low-output syndrome	■ Blood cardioplegia for acute ischemia/ syndrome LV dysfunction (pg 32) ■ Prophylactic IABP (pg 33) ■ Delay if acute right ventricular MI (pg 33)

6. Postoperative infection	■ Meticulous intraoperative steps (pg 34) ■ Preoperative antibiotics (Table 7; pg 36)
7. Postoperative arrhythmias	■ Beta-blockers or alternate (pg 38)
8. Bleeding and transfusion risk	■ Consider discontinuing aspirin (pg 38) ■ Autodonation of blood

In-hospital and Predischarge Period

9. Graft patency	■ Start aspirin (pg 39) ■ Assess/treat LDL-C if ≥100 mg/dL (pg 40) ■ Smoking cessation counseling/R_x (pg 41)
10. Functional recovery	■ Refer for cardiac rehabilitation (pg 41) ■ Evaluate for social isolation/depression (pg 43) ■ Arrange follow-up visit (pg 43) ■ Communication with all chronic care givers (pg 43)