Preoperative Cardiovascular Evaluation for Noncardiac Surgery

The patient…

The operation

December 11, 2009

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UTHSCSA and STVAHCS

ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery)

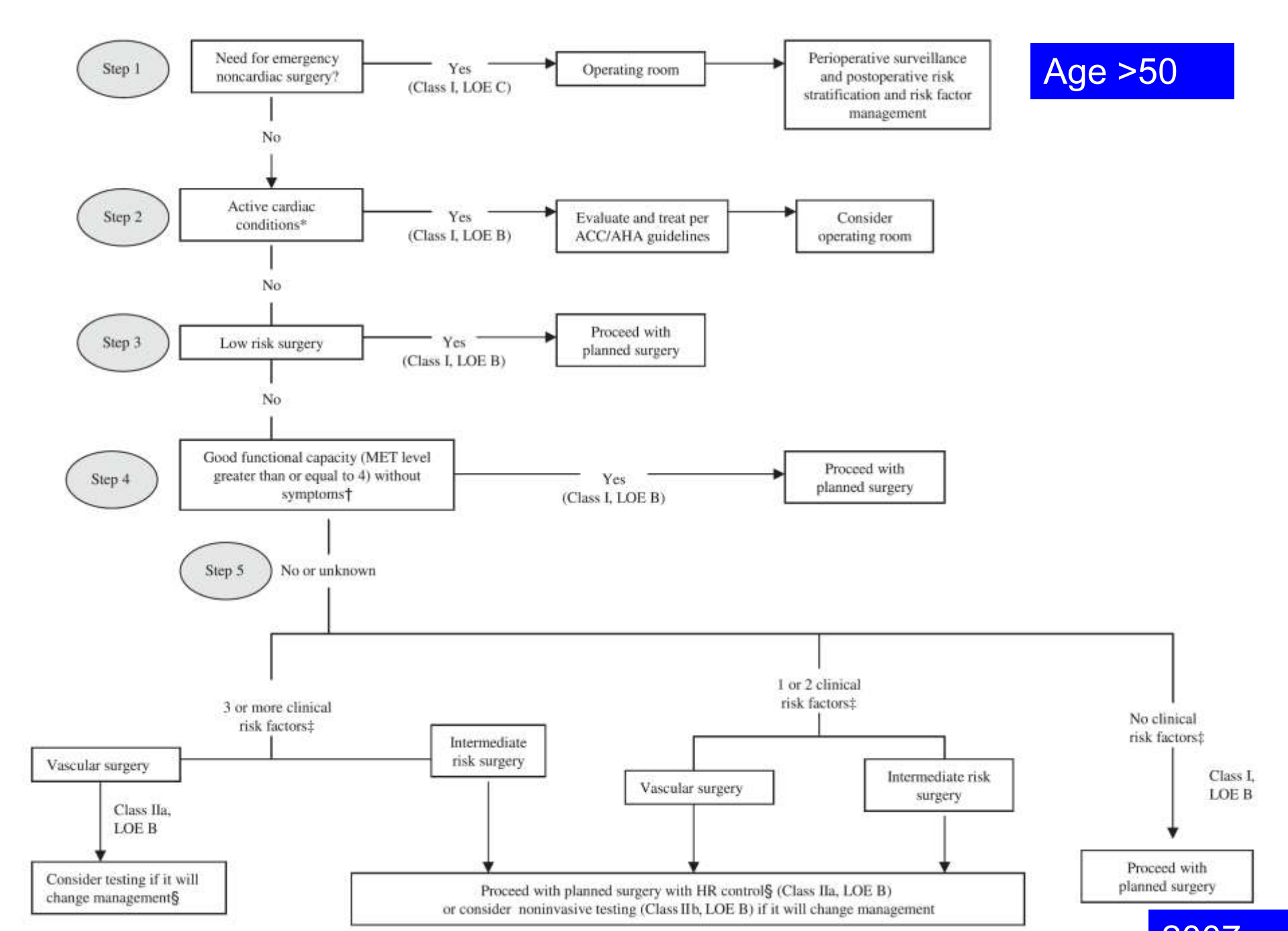
Developed in Collaboration With the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery

"The overriding theme of this document is that intervention is rarely necessary to simply lower the risk of surgery unless such intervention is indicated irrespective of the preoperative context."

ACC/AHA Guideline Perioperative CV Eval. 2007

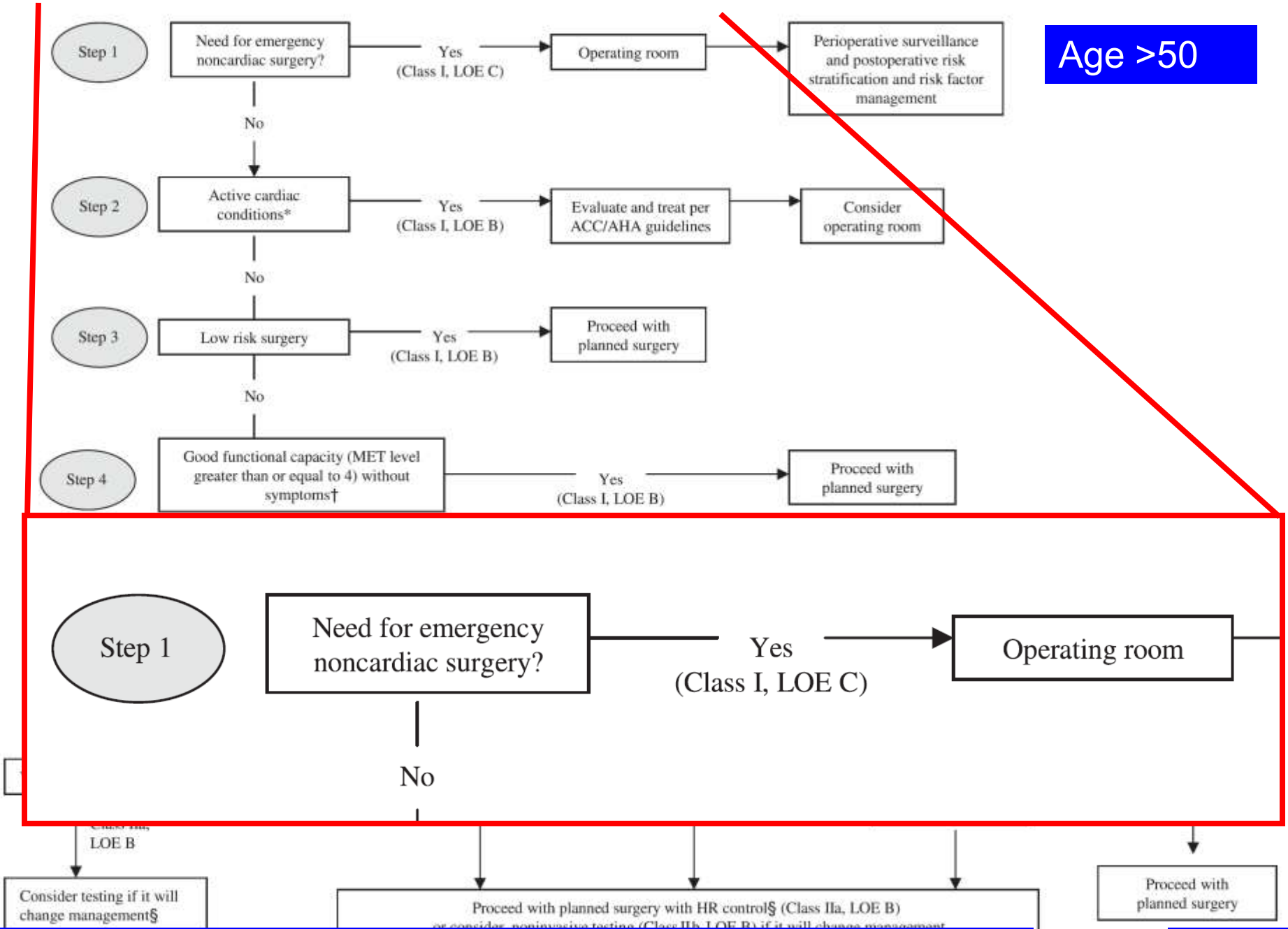
Major Aspects of Perioperative Care

- General assessment
- Disease-specific assessment
- Surgery-specific issues
- Supplemental preoperative assessment
- Perioperative therapy
- Anesthetic considerations
- Perioperative surveillance
- Postoperative and long-term management


Step 1
Need for emergency noncardiac surgery?
Yes
(Class I, LOE C)
Operating room
Perioperative surveillance and postoperative risk stratification and risk factor management
No
Step 2
Active cardiac conditions*
Yes
(Class I, LOE B)
Evaluate and treat per ACC/AHA guidelines
Consider operating room
No
Step 3
Low risk surgery
Yes
(Class I, LOE B)
Proceed with planned surgery
No
Step 4
Good functional capacity (MET level greater than or equal to 4) without symptoms†
Yes
(Class I, LOE B)
Proceed with planned surgery
Step 5
No or unknown
3 or more clinical risk factors‡
1 or 2 clinical risk factors‡
No clinical risk factors‡
Vascular surgery
Intermediate risk surgery
Vascular surgery
Intermediate risk surgery
Class IIa, LOE B
Class I, LOE B
Consider testing if it will change management§
Proceed with planned surgery with HR control§ (Class IIa, LOE B)
or consider noninvasive testing (Class IIb, LOE B) if it will change management
Proceed with planned surgery

Age >50

2007



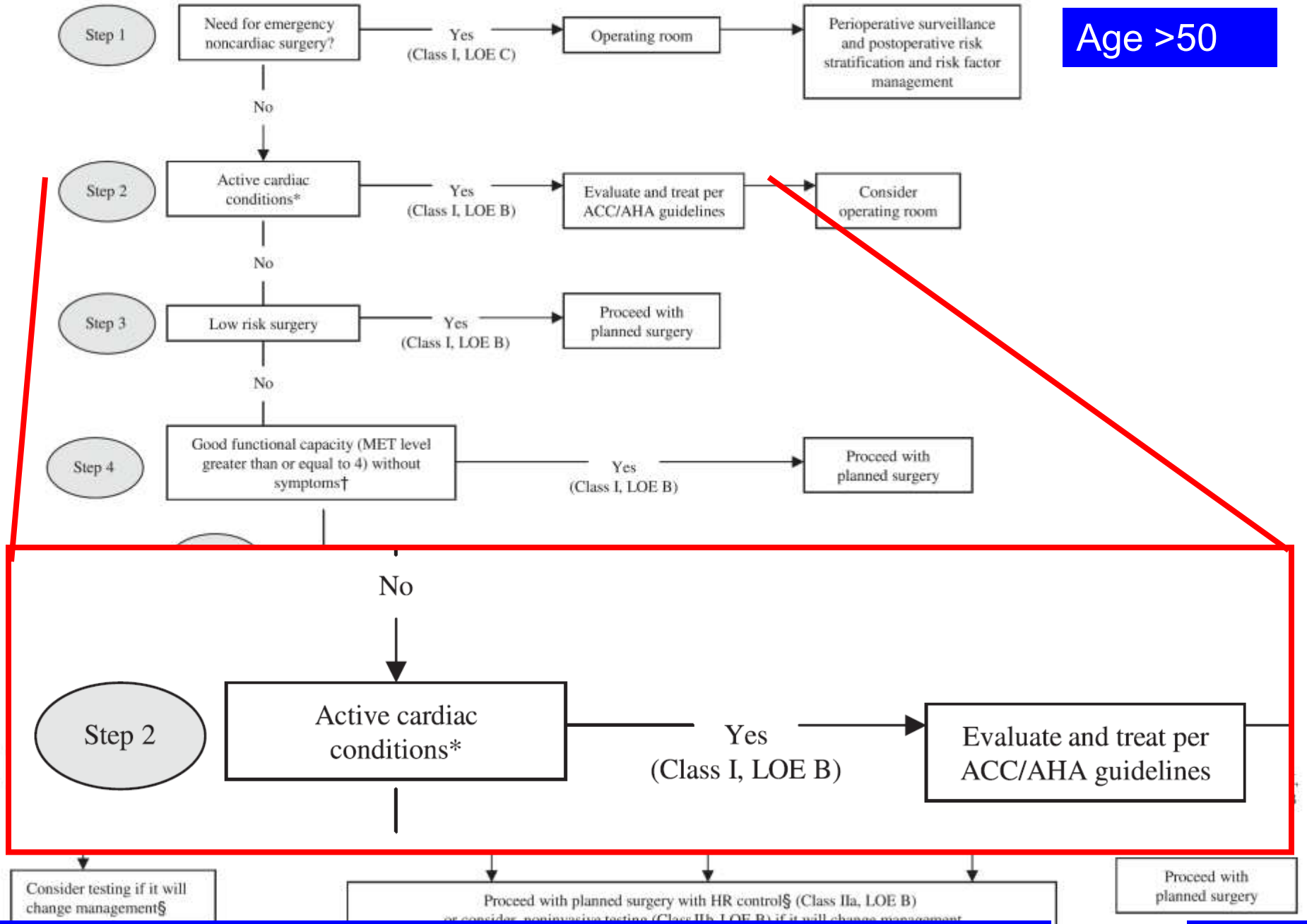
ACC/AHA Guideline Perioperative CV Eval. 2007, p. e169.

2007

Step 1 – Emergent Surgery?

- If the surgery is emergent or so urgent that it is unreasonable to worry about cardiac conditions, **operate**
- Emergent: Symptomatic aortic aneurysm, perforated viscus, major trauma
- Urgent: Arterial bypass for limb salvage, mesenteric revascularization to prevent intestinal gangrene
- Consultant may need to be involved in postop care and medical therapy and risk factor management

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e175.



Age >50

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e169.

2007

Step 2 – Active Cardiac Condition?

- Active ischemia
- Active heart failure
- Significant arrhythmias
- Severe valvular disease

- **Cancel or delay surgery** until cardiac issues are clarified and managed appropriately

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e165.

Step 2 – Active Cardiac Condition?

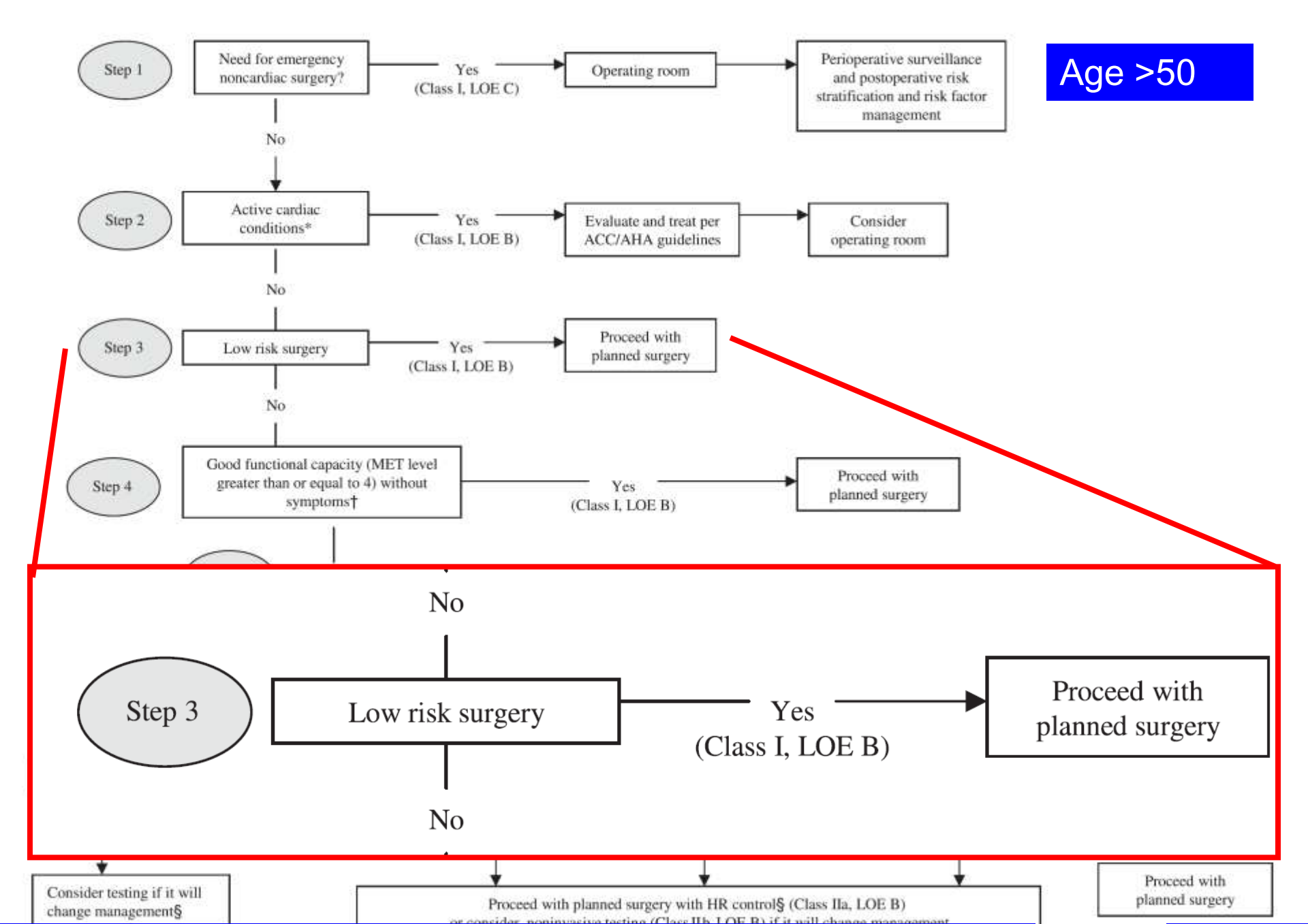
- Severe (CCS 3-4) or unstable angina or acute (<7d) or recent (<1mo) MI
- Decompensated heart failure (NYHA 4 or acute worsening)

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e165.

Step 2 – Active Cardiac Condition?

- Significant arrhythmias:
  - Mobitz II or high-grade or complete AV block
  - Symptomatic ventricular arrhythmias or symptomatic bradycardia
  - Supraventricular tachyarrhythmias (>100)
  - Newly recognized VTach
- Severe valvular disease (severe AS with mean gradient >40 or AVA<1.0 or sx, symptomatic MS)

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e165.



Age >50

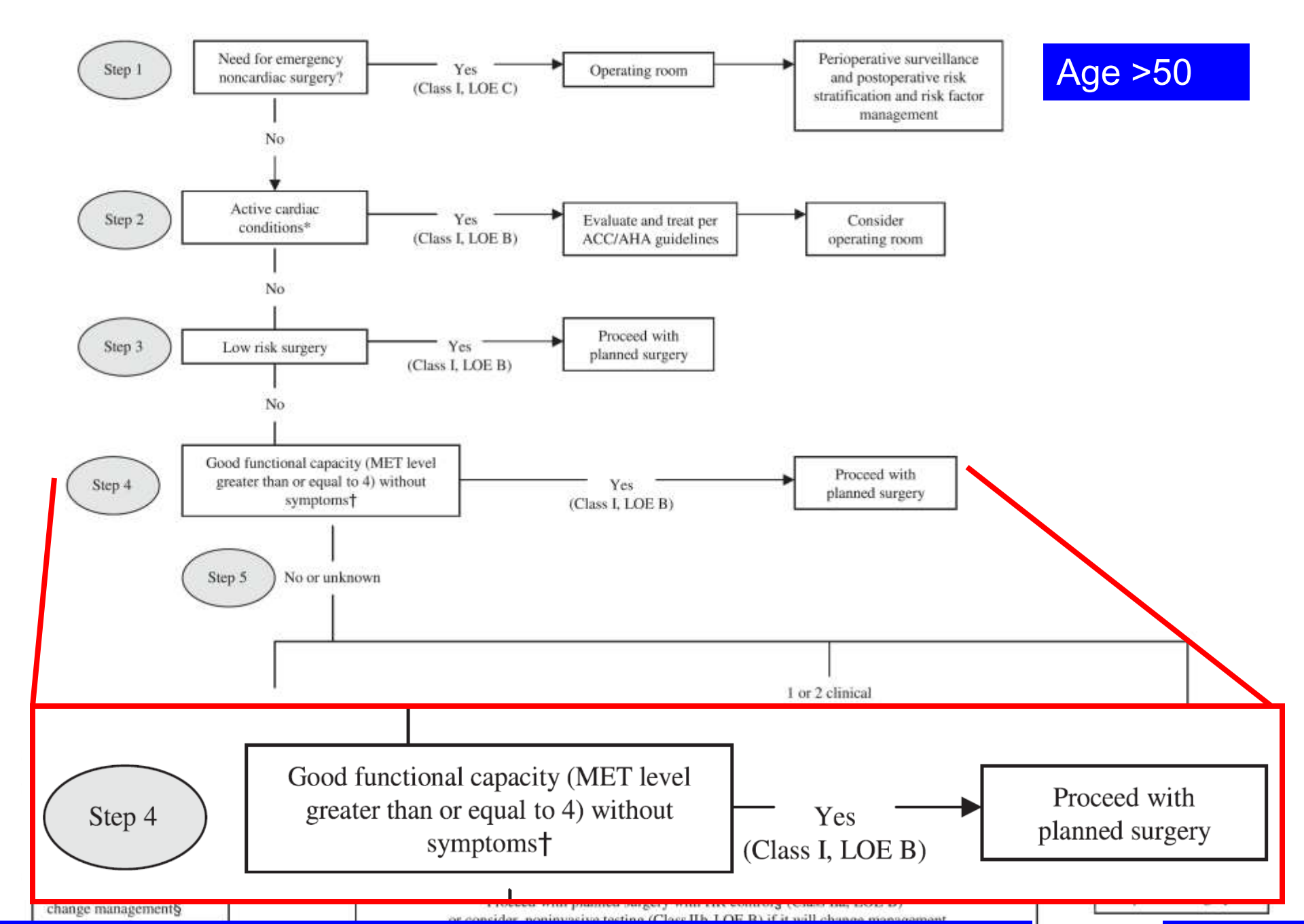
ACC/AHA Guideline Perioperative CV Eval. 2007, p. e169.

2007

Step 3 – Low Risk Surgery?

- Combined morbidity and mortality rate <1% even in high risk patients
- **Operate**
- Examples:
  - Endoscopic procedures
  - Superficial procedures
  - Cataract surgery
  - Breast surgery
  - Outpatient surgical procedures

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e165.



Age >50

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e169.

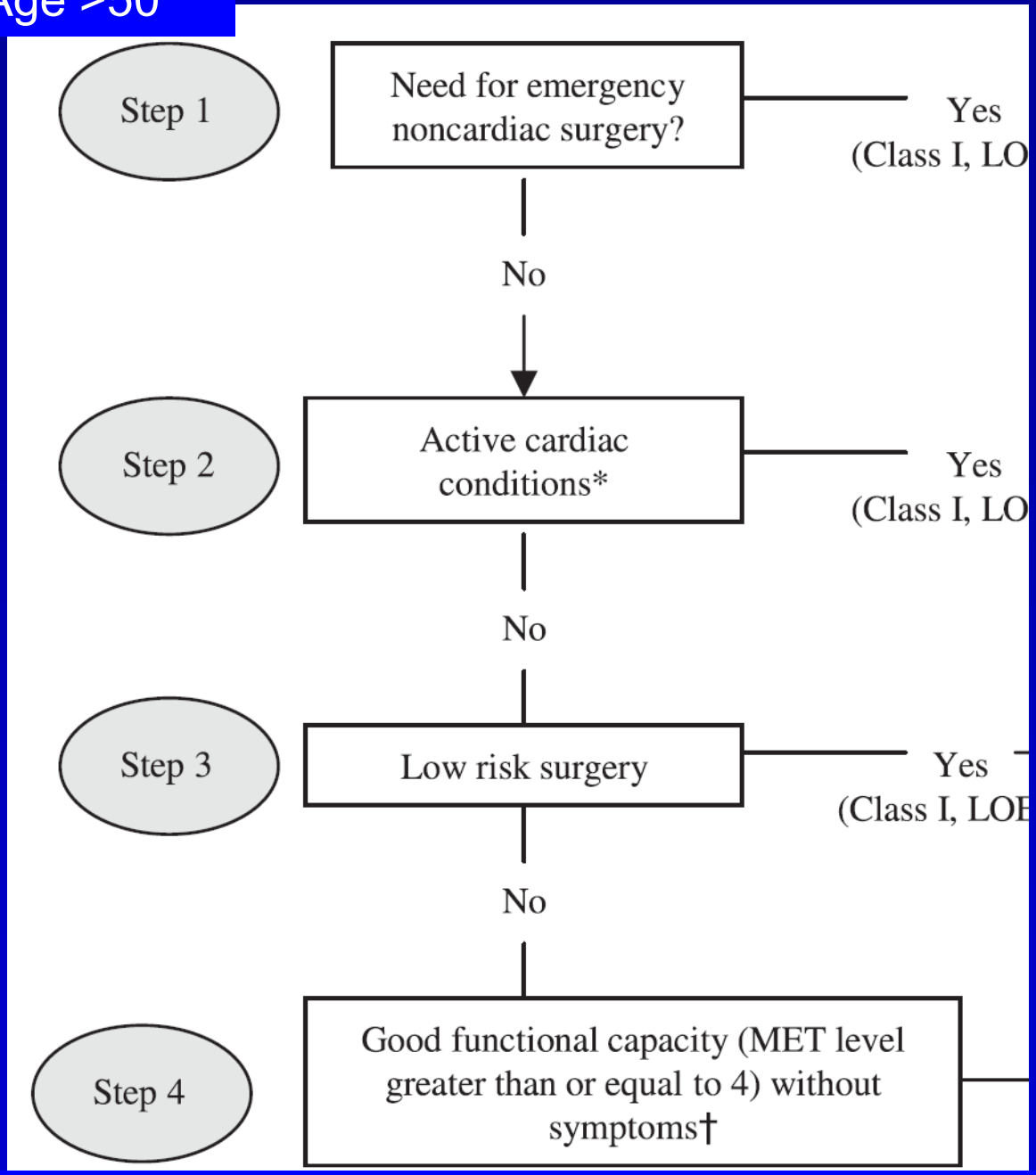
2007

Step 4 – Good functional Capacity?

- Active or highly functional asymptomatic patients, capacity of >4 METs
- **Operate**
- Examples:
  - Walk up a flight of stairs or up a hill
  - Walk 4 mph on level ground
  - Run a short distance
  - Scrubbing floors or moving heavy furniture
  - Golf, bowling, dancing, doubles tennis

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e166.

Age >50



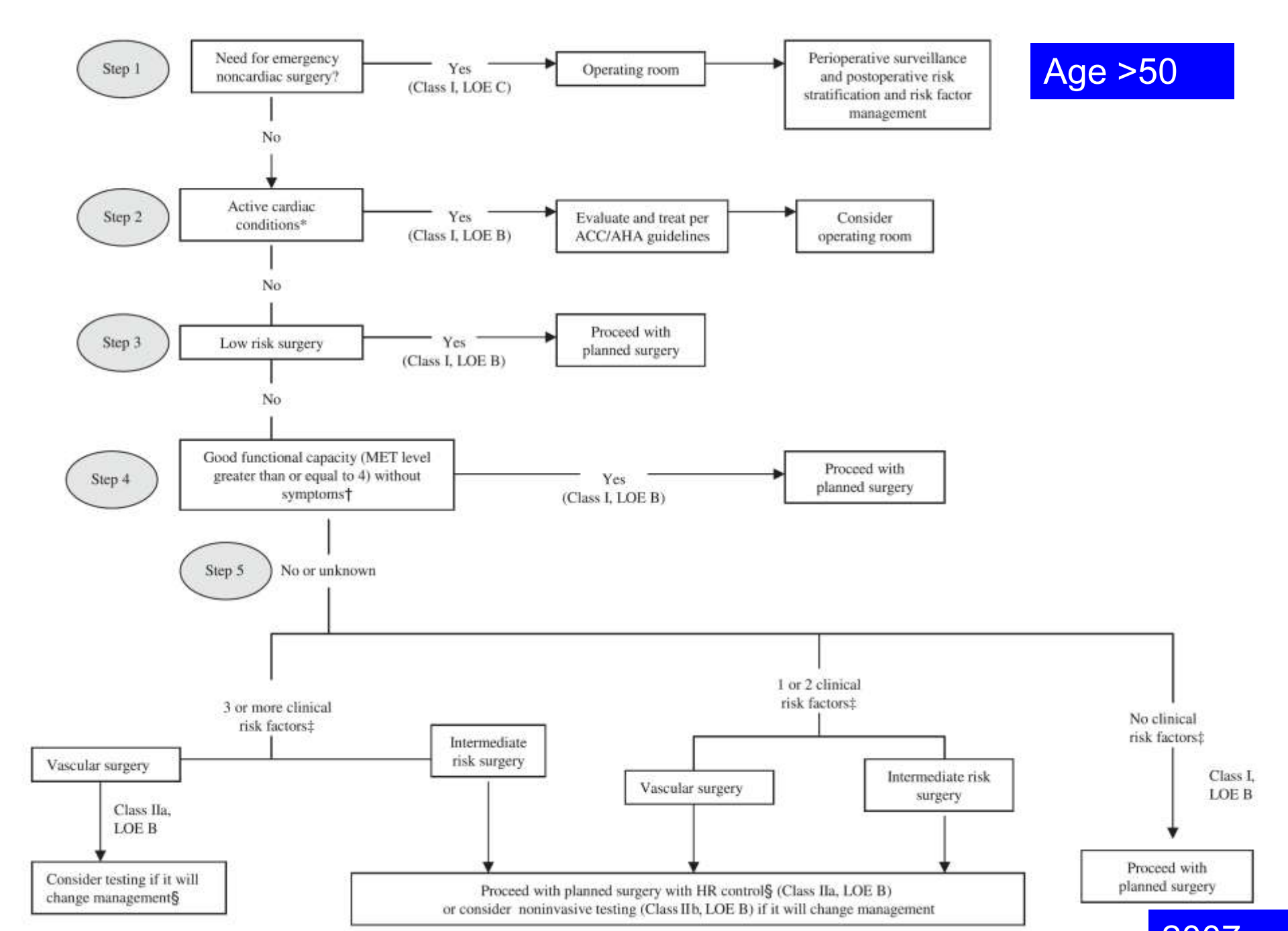
Review

- Operate
- No, consult
- Operate
- Operate

No Stress Testing mentioned

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e169.

2007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Age >50

2007

Step 5 – Everybody Else

- Elective or mildly urgent not low risk surgery with poor or unknown functional capacity
- **Count risk factors and assess surgical risk**

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e169.

Step 5: Defining the Risk Factors

1. Ischemic Heart Dz: Hx MI, Hx +ETT, current angina, nitrate use, ECG-MI Q wave (not mere prior CABG or prior PCI or ST-T abnormality) – *usually wait 4-6 weeks after MI to perform elective surgery
2. Heart Failure: Hx of HF; pulm edema or PND; rales or S3; CXR redistribution
3. Cerebrovascular dz: Hx of TIA or stroke
4. DM: insulin therapy
5. CKD: creatinine >2.0

Lee et al. Circulation. 1999;100:1043. 4315 pts >50 yo elective surg

Step 5

Risk Factors	Surgery Type	Stress Test	Action
0	All	-	OR
1-2	All	IIb*	OR – HR control
>2	Intermediate	IIb*	OR – HR control
>2	Vascular	IIa*	

* = “if it will change management”

ACC/AHA Guideline Perioperative CV Eval. 2007, p. e169.

Case 1:

- 76 y.o. with prior CABG, diabetes, CHF, receiving medical therapy, with a recent high risk thallium scan (preop for elective peripheral vascular surgery), presents with fever and wet gangrene of the left foot, sed rate 140, is now preop for amputation today. You are consulted.
- Your recommendations:

Case 1:

- 76 y.o. with prior CABG, diabetes, CHF, receiving medical therapy, with a recent high risk thallium scan (preop for elective peripheral vascular surgery), presents with fever and wet gangrene of the left foot, sed rate 140, is now preop for amputation today. You are consulted.
- Your recommendations:

Limited to optimization of medication and surveillance.
This is a Step 1 Decision – Emergency surgery.
Easy decision, bad situation for the patient.

Case 2:

- 65 y.o. man with CABG in 2006, diabetes, htn, no prior stroke or HF or CKD receiving medical therapy, with good response to CABG (resolution of exertional chest tightness and dyspnea), presents for evaluation for elective abdominal aortic aneurysm repair (6 cm dia).
- Your recommendations:

Case 2:

- 65 y.o. man with CABG in 2006, diabetes, htn, no prior stroke or HF or CKD receiving medical therapy, with good response to CABG (resolution of exertional chest tightness and dyspnea), presents for evaluation for elective abdominal aortic aneurysm repair (6 cm dia).
- Your recommendations:

Proceed to surgery.
This is a Step 5 Decision – Revascularization and asymptomatic status with 1 risk factor needs no further evaluation. Easy decision, generally a good situation for the patient.

Case 3:

- 72 y.o. woman with CABG in 1997, receiving medical therapy. She had recurrent chest pain and was admitted January 2008 for R/O MI with P Thall showing small MI and no ischemia, and has done well since then. Now she presents for elective surgery for colonic malignancy.
- Your recommendations:

Case 3:

- 72 y.o. woman with CABG in 1997, receiving medical therapy. She had recurrent chest pain and was admitted January 2008 for R/O MI with P Thall showing small MI and no ischemia, and has done well since then. Now she presents for elective surgery for colonic malignancy.
- Your recommendations:

Proceed to surgery.
This is a Step 5 Decision – Coronary evaluation within 2 years needs no further evaluation if favorable result and no recurrent Sx or Sn.

Case 4:

- 56 y.o. man with planned repair of hiatal hernia presents for clearance. During the history he reports that he has had decreased exercise tolerance for 3 weeks and with chest tightness with walking 25 feet during the last 3 days. Night before last he had pain at rest lasting 10 minutes. Your recommendations:

Case 4:

- 56 y.o. man with planned repair of hiatal hernia presents for clearance. During the history he reports that he has had decreased exercise tolerance for 3 weeks and with chest tightness with walking 25 feet during the last 3 days. Night before last he had pain at rest lasting 10 minutes. Your recommendations:

Delay or cancel this purely elective surgery.
This is a Step 2 Decision – this patient has an active cardiac condition, intermediate risk unstable angina, needs cardiac evaluation.

Case 5:

- 66 y.o. man with anterior wall MI in 1997 and LVEF at cath of 35% at that time, doing well on medication with LDL of 96. He walks 4 miles/day without symptoms, and is pre-op for elective AAA repair (5.6 cm infrarenal).
- Your recommendations:

Case 5:

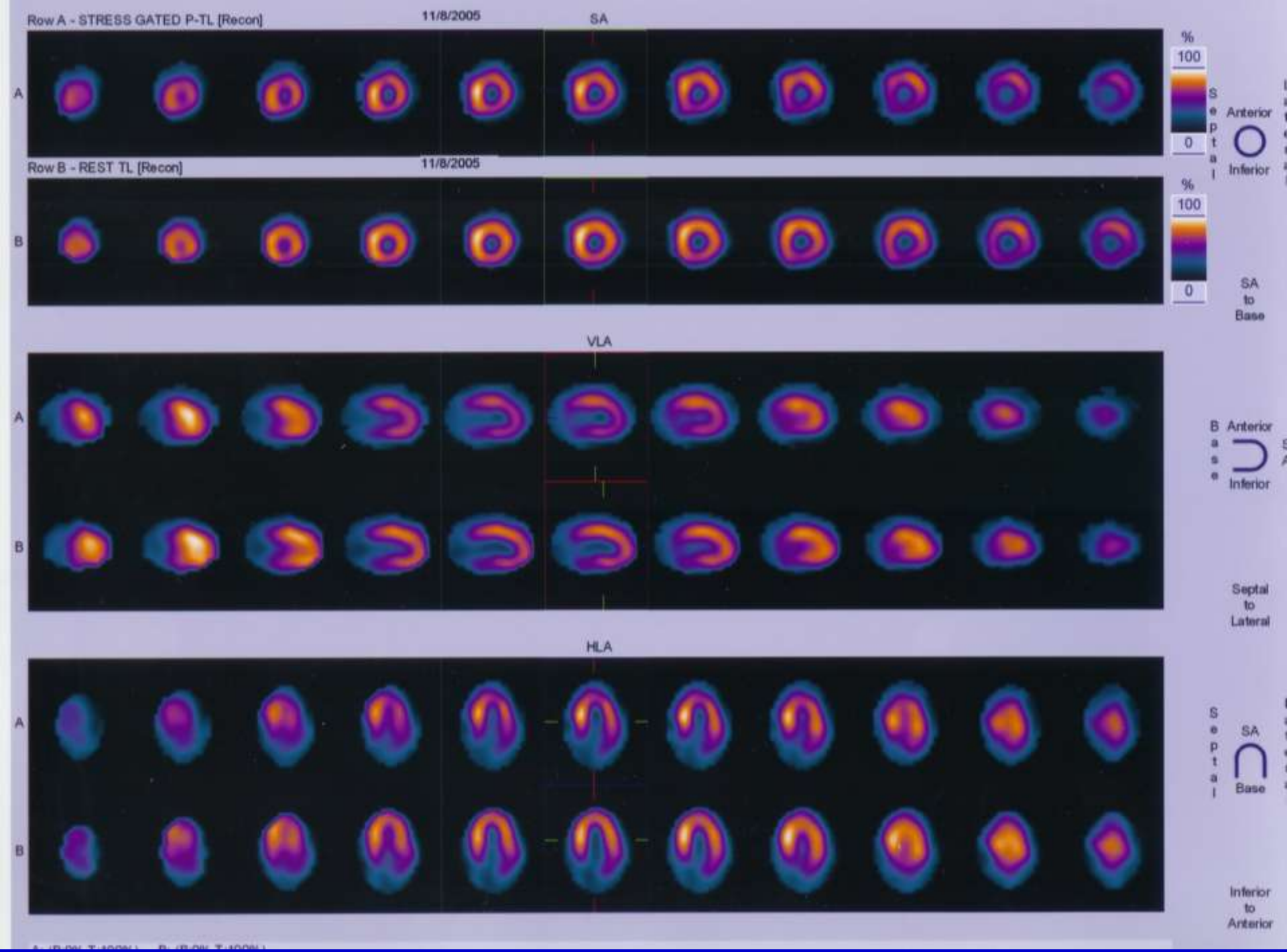
- 66 y.o. man with anterior wall MI in 1997 and LVEF at cath of 35% at that time, doing well on medication with LDL of 96. He walks 4 miles/day without symptoms, and is pre-op for elective AAA repair (5.6 cm infrarenal).
- Your recommendations:

Proceed to surgery.
This is a Step 4 Decision – this patient has a intermediate clinical predictor, prior MI, with good functional capacity so even with a high risk procedure he should do well.

Case 5:

- 66 y.o. man with anterior wall MI in 1997 and LVEF at cath of 35% at that time, doing well on medication with LDL of 96. He walks 4 miles/day without symptoms, and is pre-op for elective AAA repair (5.6 cm infrarenal).
- Your recommendations:

But he already got a thallium.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Case 5:

- 66 y.o. man with anterior wall MI in 1997 and LVEF at cath of 35% at that time, doing well on medication with LDL of 96. He walks 4 miles/day without symptoms, and is pre-op for elective AAA repair (5.6 cm infrarenal).
- Your recommendations:

Stress test was low risk
Scan not high risk
Therefore: Surgery

Tips on Assessing Results of Noninvasive Ischemia Testing

- Exercise – Protocol; duration (METs); symptoms; ECG ST changes
- Inability to exercise is a risk
- Imaging –
  - LV function (grain of salt)
  - LV size
  - Defects: number, size, reversibility (fixed defects may actually be ischemia)

Case 6:

- 79 y.o. man with no prior cardiac history or diabetes or HF or stroke or CKD. He is sedentary due to severe knee DJD, no cardiac symptoms, and is pre-op for elective right knee replacement. ECG reveals frequent PVC's and LBBB.
- Your recommendations:

Case 6:

- 79 y.o. man with no prior cardiac history or diabetes or HF or stroke or CKD. He is sedentary due to severe knee DJD, no cardiac symptoms, and is pre-op for elective right knee replacement. ECG reveals frequent PVC's and LBBB.
- Your recommendations:

Recommend proceed with surgery.
This is a Step 5 Decision – this patient has no risk factors, with poor functional capacity an an intermediate risk procedure, so needs no further cardiac evaluation.

Case 7:

- 79 y.o. man with no prior cardiac history or diabetes or HF or stroke or CKD. He is sedentary due to severe knee DJD, no cardiac symptoms, and is pre-op for elective outpatient surgical procedure. ECG reveals frequent PVC's and LBBB.
- Your recommendations:

Proceed to surgery.
This is a step 3 situation, low risk surgery.

CLASS I

1. Preoperative resting 12-lead ECG is recommended for patients with at least 1 clinical risk factor* who are undergoing vascular surgical procedures. (*Level of Evidence: B*)
2. Preoperative resting 12-lead ECG is recommended for patients with known CHD, peripheral arterial disease, or cerebrovascular disease who are undergoing intermediate-risk surgical procedures. (*Level of Evidence: C*)

CLASS IIa

1. Preoperative resting 12-lead ECG is reasonable in persons with no clinical risk factors who are undergoing vascular surgical procedures. (*Level of Evidence: B*)

CLASS IIb

1. Preoperative resting 12-lead ECG may be reasonable in patients with at least 1 clinical risk factor who are undergoing intermediate-risk operative procedures. (*Level of Evidence: B*)

CLASS III

1. Preoperative and postoperative resting 12-lead ECGs are not indicated in asymptomatic persons undergoing low-risk surgical procedures. (*Level of Evidence: B*)

Hx IHD

Hx HF

Hx CVD

DM

CKD

*Clinical risk factors include history of ischemic heart disease, history of compensated or prior HF, history of cerebrovascular disease, diabetes mellitus, and renal insufficiency.

Guideline Perioperative CV Eval. 2007

Results of Noninvasive Testing

- Low risk – proceed to surgery
- Intermediate risk - ????
- High risk – consider revascularization before surgery

CARP Trial ("Coronary Artery Revascularization Prophylaxis")

- 5859 pts pre-op maj vasc surg screened
  - Exclusion: urgent operation (1025), severe comorbidity (731), prior revascular iz without recurrent ischemia (626), LMCA >50% (54), EF<20%, (11) severe AS (8); 680 other exclusions
  - Cath if cardiologist opined increased cardiac risk for perioperative cardiac complication (1654 insufficient risk)
  - Randomizable if >70% stenosis of revascularizable vessel (363 nonobstructive, nonamenable 215, refusal 29)
- 510 pts (98% men, 33% AAA, 67% severe sx legs)
- Randomized to med (252) or revasc (59% PCI, 41% CABG)

McFalls EO et al. N Engl J Med. 2004;351:2795-804.

CARP Trial ("Coronary Artery Revascularization Prophylaxis")

- Delay to vascular surgery:
  - Med: 18 da
  - Revasc: 54 da
- Mortality after 2.7 yr f/u
  - Med: 23%
  - Revasc: 22%
- Perioperative MI (elevated troponin, <30 da, blinded outcomes committee validation)
  - Med: 14%
  - Revasc: 12%

McFalls EO et al. N Engl J Med. 2004;351:2795-804.

Table 1. Baseline Clinical Variables According to the Assigned Treatment before the Elective Major Vascular Surgery.*

Variable	Revascularization (N=258)	No Revascularization (N=252)	P Value
Age — yr	65.6±11.1	67.2±10.4	0.10
Angina — no. (%)	103 (39.9)	95 (37.7)	0.61
Previous myocardial infarction — no. (%)	111 (43.0)	103 (40.9)	0.62
Previous congestive heart failure — no. (%)	31 (12.0)	19 (7.5)	0.09
Previous stroke or TIA — no. (%)	54 (20.9)	47 (18.7)	0.50
Diabetes — no. (%)			
Treated with oral agents	49 (19.0)	52 (20.6)	0.84
Treated with insulin	48 (18.6)	49 (19.4)	0.84
Current smoker — no. (%)	128 (49.6)	114 (45.2)	0.41
Albumin — g/dl	3.7±0.6	3.7±0.5	0.99
Hemoglobin — g/dl	14.0±2.4	13.8±1.9	0.26
Total cholesterol — mg/dl	175±45	182±51	0.13
LDL cholesterol — mg/dl	105±37	107±42	0.60
HDL cholesterol — mg/dl	37±10	37±11	0.95
Glycosylated hemoglobin — %	6.6±1.7	6.8±1.9	0.41
C-reactive protein — mg/dl			0.12
Median	0.4	0.3	
Interquartile range	0.05–1.4	0.04–1.3	
Homocysteine — mg/dl			0.63
Median	10.3	9.8	
Interquartile range	0.8–13.6	0.3–12.8	
Left ventricular ejection fraction — %	54±12	55±12	0.36
Three-vessel coronary artery disease — no. (%)	91 (35.3)	79 (31.3)	0.69
Previous CABG — no. (%)	38 (14.7)	39 (15.5)	0.83
Indication for surgery†			0.61
Abdominal aneurysm — no. (%)	88 (34.1)	81 (32.1)	—
Claudication — no. (%)	100 (38.8)	89 (35.3)	—
Pain at rest — no. (%)	30 (11.6)	35 (13.9)	—
Tissue breakdown — no. (%)	40 (15.5)	47 (18.7)	—

* Plus–minus values are means ±SD. TIA denotes transient ischemic attack, LDL low-density lipoprotein, and HDL high-density lipoprotein. To convert the values for hemoglobin to millimoles per liter, multiply by 0.6206. To convert the values for cholesterol to millimoles per liter, multiply by 0.02586.

† A single P value is provided for the entire group (two-by-four chi-square test with three degrees of freedom). A dash denotes not applicable.

McFalls EO et al. N Engl J Med. 2004;351:2795-804.

Table 2. Procedural Characteristics and Postprocedural Complications of CABG and Percutaneous Coronary Intervention (PCI) in 240 Patients Assigned to Undergo Coronary-Artery Revascularization before Elective Major Vascular Surgery.*

Characteristic	CABG (N=99)	PCI (N=141)
Days since randomization		
Median	18	1
Interquartile range	7–34	0–7
Urgent or emergency cardiac status — no. (%)	2 (2.0)	1 (0.7)
No. of vessels revascularized	3.0±0.8	1.3±0.8
Completeness of revascularization — %†	98.0	61.9
Death — no. (%)‡	2 (2.0)	2 (1.4)
Myocardial infarction — no. (%)	7 (7.1)	7 (5.0)
Stroke, loss of leg, or renal dialysis — no.	0	0
Reoperation — no. (%)	6 (6.1)	NA
Urgent CABG — no. (%)	NA	1 (0.7)
Days in hospital after procedure		
Median	7	1
Interquartile range	5–12	1–2

* Plus–minus values are means ±SD. NA denotes not applicable.
† Completeness of revascularization indicates the percentage of major epicardial vessels with stenosis of more than 70 percent that were revascularized.
‡ One of the deaths in the CABG group and the two in the PCI group occurred within two weeks of the revascularization and after the vascular operation. They are listed as complications of both the revascularization and the vascular procedures, because they occurred within the same hospitalization period. Myocardial infarction associated with CABG or PCI was defined by cardiac-enzyme elevations and ischemic changes on the electrocardiogram.

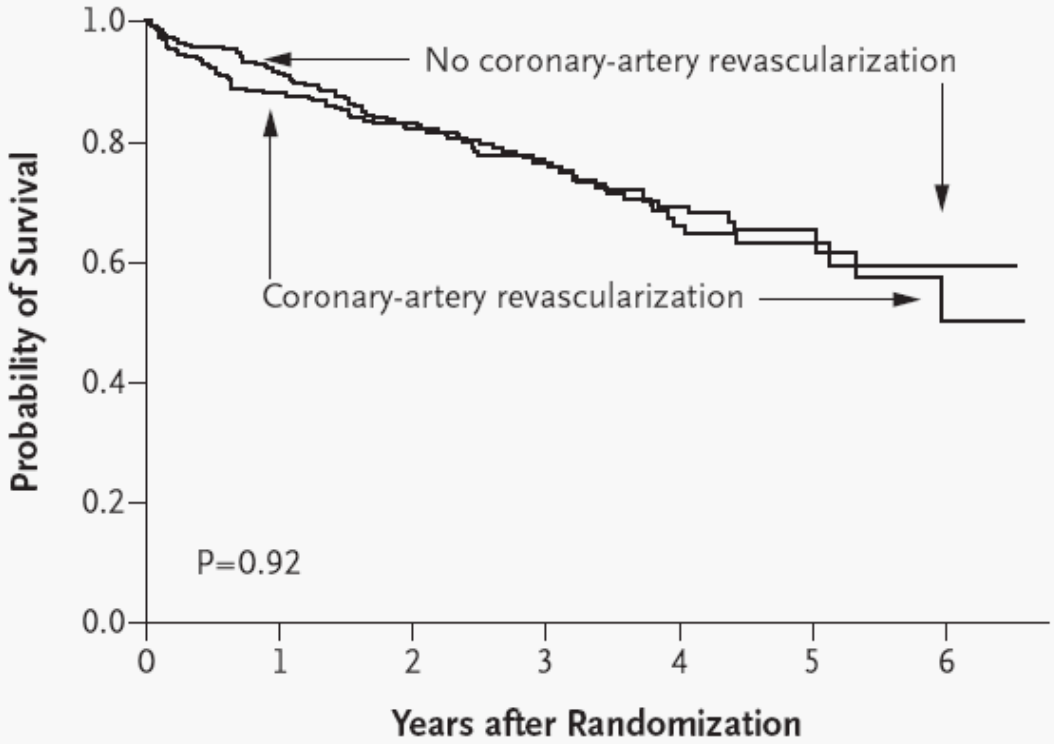
McFalls EO et al. N Engl J Med. 2004;351:2795-804.

Table 3. **Clinical Features and Outcomes of Vascular Surgery According to the Assigned Treatment before the Elective Major Vascular Surgery.**

Characteristic	Revascularization (N=225)	No Revascularization (N=237)	P Value
Surgical management			
Abdominal surgery — no. (%)*	89 (39.9)	99 (42.1)	0.89
Urgent or emergency status — no. (%)	13 (5.8)	14 (5.9)	0.90
General anesthesia — no. (%)	180 (80.0)	199 (84.0)	0.50
Altered surgical procedure — no. (%)†	33 (14.7)	27 (11.4)	0.30
Days after randomization			<0.001
Median	54	18	
Interquartile range	28–80	7–42	
Perioperative medications — no. (%)			
Beta-adrenergic blockers	188 (83.6)	204 (86.1)	0.45
Aspirin‡	168 (76.7)	165 (70.2)	0.12
Statins§	121 (53.8)	122 (54.0)	0.93
Heparin*	209 (93.7)	219 (93.2)	0.82
Intravenous nitroglycerin	63 (28.0)	87 (36.7)	0.05
Postoperative events (within 30 days)			
Death — no. (%)	7 (3.1)	8 (3.4)	0.87
Myocardial infarction¶			
Enzymes — no. (%)	26 (11.6)	34 (14.3)	0.37
Enzymes and ECG — no. (%)	19 (8.4)	20 (8.4)	0.99
Stroke — no. (%)	1 (0.4)	2 (0.8)	0.59
Loss of leg — no. (%)	1 (0.4)	5 (2.1)	0.11
Renal dialysis — no. (%)	1 (0.4)	1 (0.4)	0.97
Reoperation — no. (%)	17 (7.6)	18 (7.6)	0.99
Total days in the intensive care unit			0.25
Median	2.0	2.0	
Interquartile range	1–3	1–4	
Total days in the hospital			0.29
Median	6.5	7.0	
Interquartile range	4–10	5–12	

* No information was available for two patients in each group.
† An altered surgical procedure refers to a surgical procedure (abdominal or infrainguinal) that differed from the projected surgical procedure that was planned before randomization.
‡ No information was available for six patients in the revascularization group and two in the no-revascularization group.
§ No information was available for 11 patients in the no-revascularization group.
¶ Myocardial infarction was defined by any elevation in cardiac enzymes after surgery, as well as by any elevation in cardiac enzymes with ischemic changes on the electrocardiogram (ECG).

McFalls EO et al. N Engl J Med. 2004;351:2795-804.



No. at Risk						
Revascularization	226	175	113	65	18	7
No revascularization	229	172	108	55	17	12

Figure 1. Long-Term Survival among Patients Assigned to Undergo Coronary-Artery Revascularization or No Coronary-Artery Revascularization before Elective Major Vascular Surgery.

Kaplan–Meier estimates were used to generate survival curves, from the time of randomization, for all study patients.

McFalls EO et al. N Engl J Med. 2004;351:2795-804.

Table 4. Influence of Coronary-Artery Revascularization on Long-Term Survival among High-Risk Subgroups of Patients Scheduled for Vascular Surgery.*

High-Risk Variable	Patients (N=510)	Hazard Ratio (95% CI)	P Value
	no. (%)		
Angina	198 (38.8)	1.45 (0.79–2.64)	0.23
Positive stress imaging test†	226 (44.3)	1.26 (0.77–2.06)	0.35
Fulfillment of criteria of Eagle and colleagues[4]‡	142 (27.8)	0.90 (0.51–1.62)	0.73
With large stress-induced defect	37 (7.3)	3.96 (0.82–19.11)	0.09
Category of revised Cardiac Risk Index[13]§	248 (48.6)	1.20 (0.76–1.89)	0.44
With large stress-induced defect	50 (9.8)	1.65 (0.64–4.25)	0.30
Prior CABG	77 (15.1)	1.81 (0.81–4.05)	0.15
Three-vessel disease and left ventricular dysfunction	74 (14.5)	1.29 (0.62–2.65)	0.50
Pain at rest and tissue breakdown	152 (29.8)	0.76 (0.43–1.34)	0.34

* CI denotes confidence interval.
† The stress imaging test refers to a moderate or large reversible defect.
‡ The criteria include at least three of the following clinical risk factors: an age greater than 70 years, previous myocardial infarction, Q waves on an electrocardiogram, previous congestive heart failure, previous ventricular tachycardia, angina, or diabetes mellitus.
§ The index includes at least two of the following clinical risk factors: prior stroke or transient ischemic attack, congestive heart failure, coronary artery disease (excluding previous coronary-artery revascularization), a serum creatinine concentration greater than 2.0 mg per deciliter (177 μmol per liter), insulin-dependent diabetes mellitus, or a suprainguinal operation.

McFalls EO et al. N Engl J Med. 2004;351:2795-804.

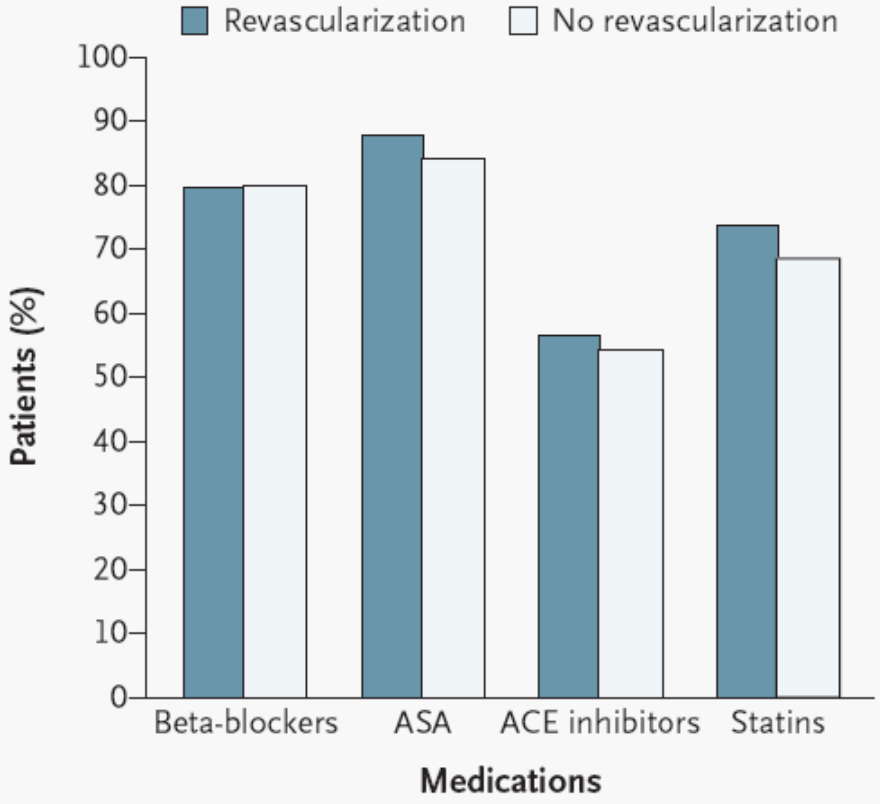


Figure 2. Long-Term Use of Medical Therapy in the Revascularization and No-Revascularization Groups at 24 Months after Randomization.

The cardiac medications used were beta-blockers, anti-platelet agents (ASA) such as aspirin or inhibitors of adenosine diphosphate, angiotensin-converting–enzyme (ACE) inhibitors, and statins.

McFalls EO et al. N Engl J Med. 2004;351:2795-804.

General Assessment

- Tasks of Consultant
- Show-stopper diagnoses
- History – Focus on assessing functional capacity
- Physical Examination
- Comorbidities affecting risk
- Stepwise approach in management

Consultant Tasks

- Review the available patient data
- Obtain a history
- Perform a physical examination –
  - Comprehensive cardiovascular exam
  - Pertinent aspects of patient's problem and proposed procedure
- Provide a comprehensive evaluation of risk
- Determine the cardiovascular stability of the patient
- Optimize the medical condition in context of surgical procedure

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Table 2. Active Cardiac Conditions for Which the Patient Should Undergo Evaluation and Treatment Before Noncardiac Surgery (Class I, Level of Evidence: B)

Condition	Examples
1. Unstable coronary syndromes	Unstable or severe angina* (CCS class III or IV)† Recent MI‡
2. Decompensated HF (NYHA functional class IV; worsening or new-onset HF)	New or poorly controlled ischemia-mediated HF

*According to Campeau (10).

†May include "stable" angina in patients who are unusually sedentary.

‡The American College of Cardiology National Database Library defines recent MI as more than 7 days but less than or equal to 1 month (within 30 days).

With important ischemic risk by symptoms or noninvasive study

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Table 2. Active Cardiac Conditions for Which the Patient Should Undergo Evaluation and Treatment Before Noncardiac Surgery (Class I, Level of Evidence: B)

Condition	Examples
Significant arrhythmias	High-grade atrioventricular block
	Mobitz II atrioventricular block
	Third-degree atrioventricular heart block
	Symptomatic ventricular arrhythmias
	Supraventricular arrhythmias (including atrial fibrillation) with uncontrolled ventricular rate (HR greater than 100 bpm at rest)
	Symptomatic bradycardia
	Newly recognized ventricular tachycardia

3.

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Table 2. Active Cardiac Conditions for Which the Patient Should Undergo Evaluation and Treatment Before Noncardiac Surgery (Class I, Level of Evidence: B)

Condition	Examples
4. Severe valvular disease	Severe aortic stenosis (mean pressure gradient greater than 40 mm Hg, aortic valve area less than 1.0 cm^2, or symptomatic) Symptomatic mitral stenosis (progressive dyspnea on exertion, exertional presyncope, or HF)

Table 3. Estimated Energy Requirements for Various Activities

	Can you . . .		Can you . . .
1 MET	Take care of yourself?	4 METs	Climb a flight of stairs or walk up a hill?
	Eat, dress, or use the toilet?		Walk on level ground at 4 mph (6.4 kph)?
	Walk indoors around the house?		Run a short distance?
	Walk a block or 2 on level ground at 2 to 3 mph (3.2 to 4.8 kph)?		Do heavy work around the house like scrubbing floors or lifting or moving heavy furniture?
4 METs	Do light work around the house like dusting or washing dishes?		Participate in moderate recreational activities like golf, bowling, dancing, doubles tennis, or throwing a baseball or football?
		Greater than 10 METs	Participate in strenuous sports like swimming, singles tennis, football, basketball, or skiing?

Excellent	>10
Good	7-10
Fair (moderate)	4-7
Poor	<4

kph indicates kilometers per hour; MET, metabolic equivalent; and mph, miles per hour.

*Modified from Hlatky et al (11), copyright 1989, with permission from Elsevier, and adapted from Fletc

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TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs

*These activities can often be done at variable intensities, assuming that the intensity is not excessive and that the courses are flat (no hills) unless so specified. Categories are based on experience or tolerance; if an activity is perceived to be more than indicated, it should be judged accordingly.

MET indicates metabolic equivalent or a unit of sitting, resting oxygen uptake.

AHA Sci Statement, Exercise Standards … Circulation. 2001;104:1694.

TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs
Leisure	
Mild	
Billiards	2.4
Canoeing (leisurely)	2.5
Dancing (ballroom)	2.9
Golf (with cart)	2.5
Horseback riding (walking)	2.3

Mild Leisure Activity - 1

AHA Sci Statement, Exercise Standards … Circulation. 2001;104:1694.

TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs
Leisure	
Mild	
Playing a musical instrument	
Accordion	1.8
Cello	2.3
Flute	2.0
Piano	2.3
Violin	2.5
Volleyball (noncompetitive)	2.9
Walking (2 mph)	2.5

Mild Leisure Activity - 2

Circulation. 2001;104:1694.

TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs
Leisure	
Moderate	
Calisthenics (no weight)	4.0
Cycling (leisurely)	3.5
Golf (without cart)	4.4
Swimming (slow)	4.5
Walking (3 mph)	3.3
Walking (4 mph)	4.5

Moderate Leisure Activity

Circulation. 2001;104:1694.

TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs
Leisure	
Vigorous	
Chopping wood	4.9
Climbing hills (no load)	6.9
Climbing hills (5 kg load)	7.4
Cycling (moderately)	5.7
Dancing	
Aerobic or ballet	6.0
Ballroom (fast) or square	5.5
Jogging (10 min mile)	10.2
Rope skipping	12.0

Vigorous Leisure Activity - 1

Circulation. 2001;104:1694.

TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs
Leisure	
Vigorous	
Skating	
Ice	5.5
Roller	6.5
Skiing (water or downhill)	6.8
Squash	12.1
Surfing	6.0
Swimming	7.0
Tennis (doubles)	5.0
Walking (5 mph)	8.0

Vigorous Leisure Activity - 2

Circulation. 2001;104:1694.

TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs
Activities of daily living	
Gardening (no lifting)	4.4
Household tasks, moderate effort	3.5
Lifting items continuously	4.0
Loading/unloading car	3.0
Lying quietly	1.0
Mopping	3.5
Mowing lawn (power mower)	4.5

ADL - 1

Circulation. 2001;104:1694.

TABLE 8. Energy Requirements of Selected Daily Activities*

Activities	METs
Activities of daily living	
Raking lawn	4.0
Riding in a vehicle	1.0
Sitting; light activity	1.5
Taking out trash	3.0
Vacuuming	3.5
Walking the dog	3.0
Walking from house to car or bus	2.5
Watering plants	2.5

ADL - 2

Circulation. 2001;104:1694.

Additional Activities

Mild	Baking	2.0
	Bookbinding	2.2
	Conducting an orchestra	2.2
	Play a trumpet	1.8
	Play a Violin	2.5-2.6
	Play a Woodwind	1.8
	Writing	1.7
Moderate	Croquet	3.0
	Play drums	3.8
	Sailing	3.0
Vigorous	Badminton	5.5
	Field hockey	7.7
	Karate or Judo	6.5

Fletcher GF et al. Circulation. 1995;91:580.

Core Components of the Physical Examination

- General appearance
- BP both arms
- Carotid, JVP, lung auscultation
- Precordial palpation and auscultation
- Abdominal palpation
- Extremities: edema and vascular integrity

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Comorbidities Affecting Prognosis and Management

- Pulmonary obstructive or restrictive disease (selective PFT or ABG)
- DM, particularly requiring insulin risk for heart failure
- Renal impairment often is associated with CV disease (Cr>2.0)
- Hematologic: anemia (hct <28%), polycythemia, thrombocytosis increase TE risk

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Step 5: Prevalence and Complications for Specific Risk Factors

TABLE 4. Rates of Major Cardiac Complications and Multivariate ORs* Among Patients With Individual Risk Factors in Derivation and Validation Sets

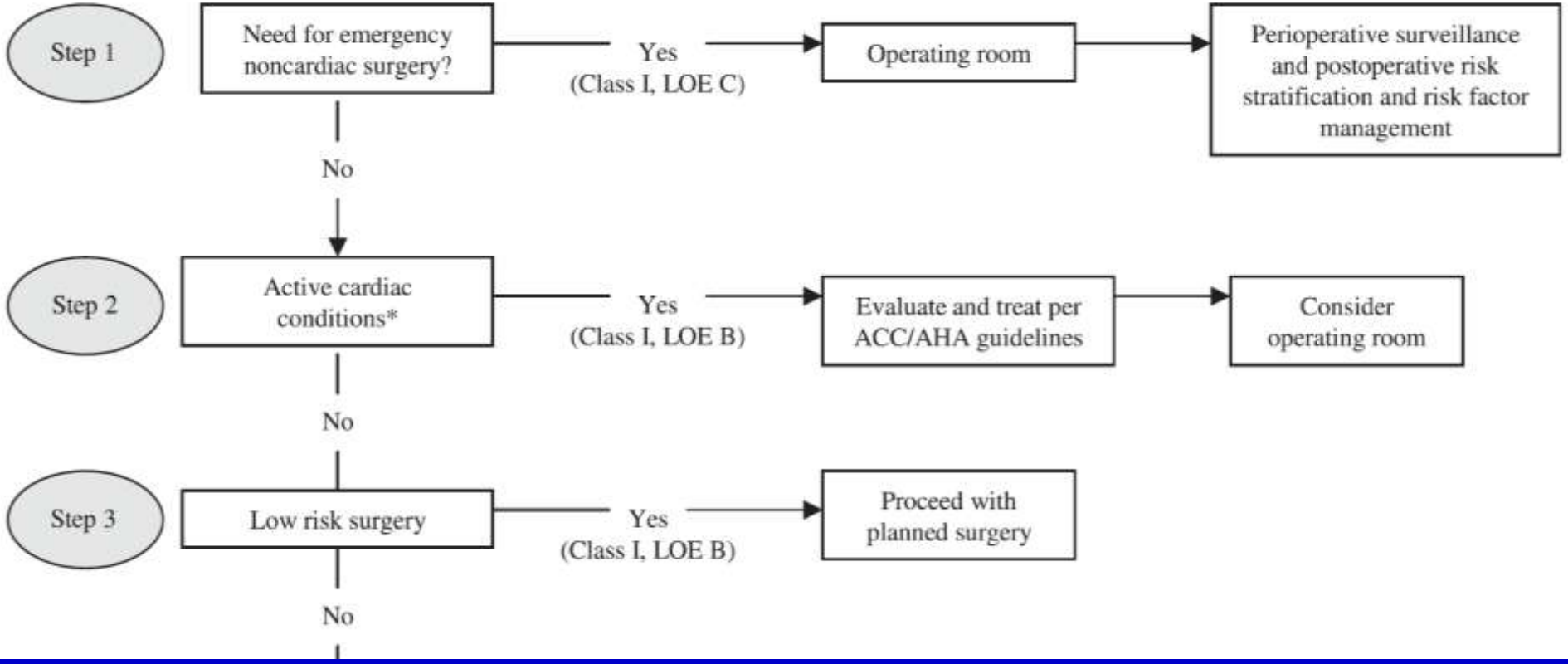
	Derivation Set (n=2893)		Validation Set (n=1422)	
	Crude Data	Adjusted OR (95% CI)	Crude Data	Adjusted OR (95% CI)
Revised Cardiac Risk Index				
1. High-risk type of surgery	27/894 (3%)	2.8 (1.6, 4.9)	18/490 (4%)	2.6 (1.3, 5.3)
2. Ischemic heart disease	34/951 (4%)	2.4 (1.3, 4.2)	26/478 (5%)	3.8 (1.7, 8.2)
3. History of congestive heart failure	23/434 (5%)	1.9 (1.1, 3.5)	19/255 (7%)	4.3 (2.1, 8.8)
4. History of cerebrovascular disease	17/291 (6%)	3.2 (1.8, 6.0)	10/140 (7%)	3.0 (1.3, 6.8)
5. Insulin therapy for diabetes	7/112 (6%)	3.0 (1.3, 7.1)	3/59 (5%)	1.0 (0.3, 3.8)
6. Preoperative serum creatinine >2.0 mg/dL	9/103 (9%)	3.0 (1.4, 6.8)	3/55 (5%)	0.9 (0.2, 3.3)

*Based on logistic regression models including these 6 variables.

*Clinical risk factors include history of ischemic heart disease, history of compensated or prior HF, history of cerebrovascular disease, diabetes mellitus, and renal insufficiency.

Lee et al. Circulation. 1999;100:1043. *ACC/AHA Periop Guideline 2007.

Evaluation and Care Algorithm - 1



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Evaluation and Care Algorithm - 2

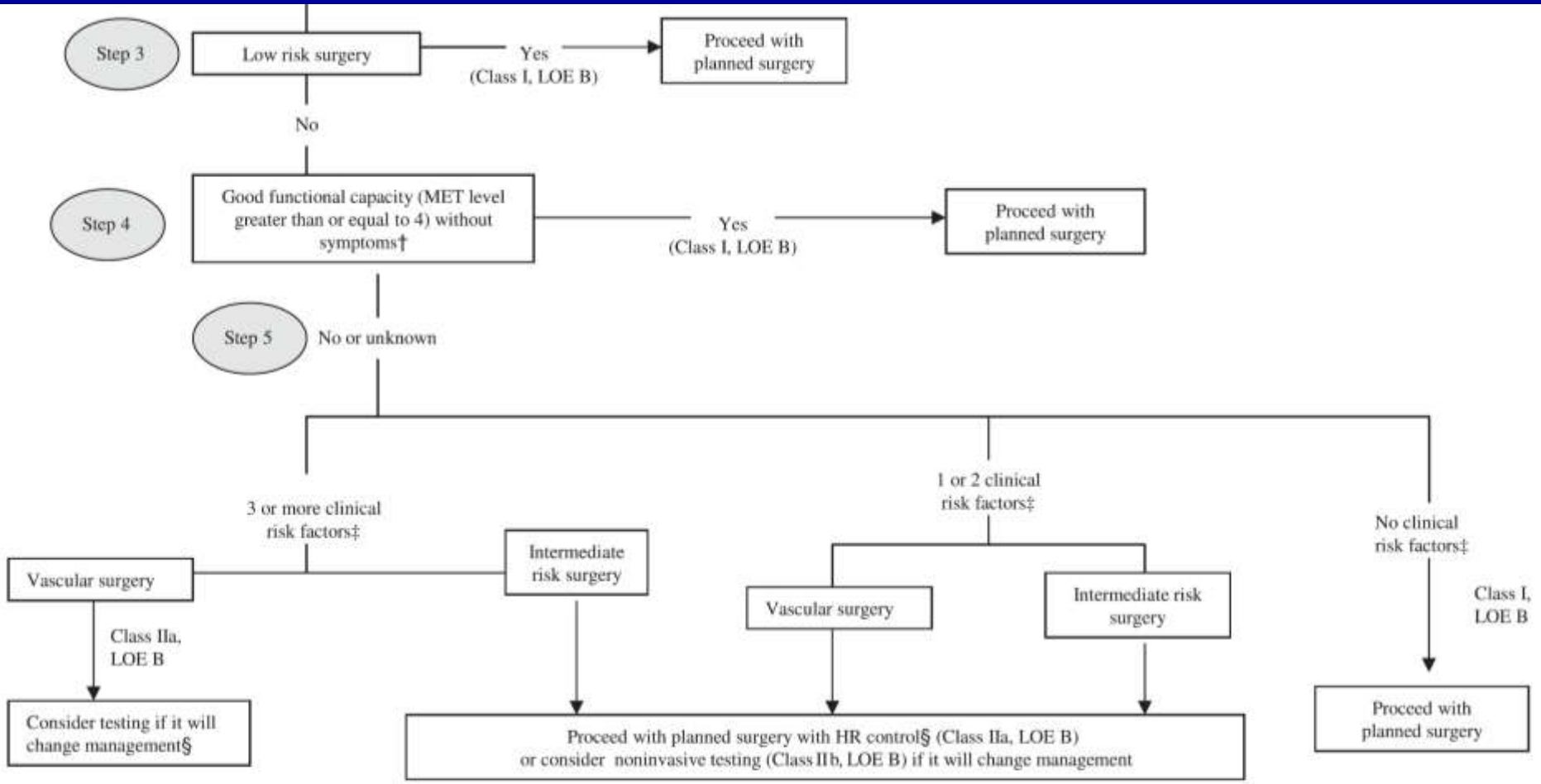
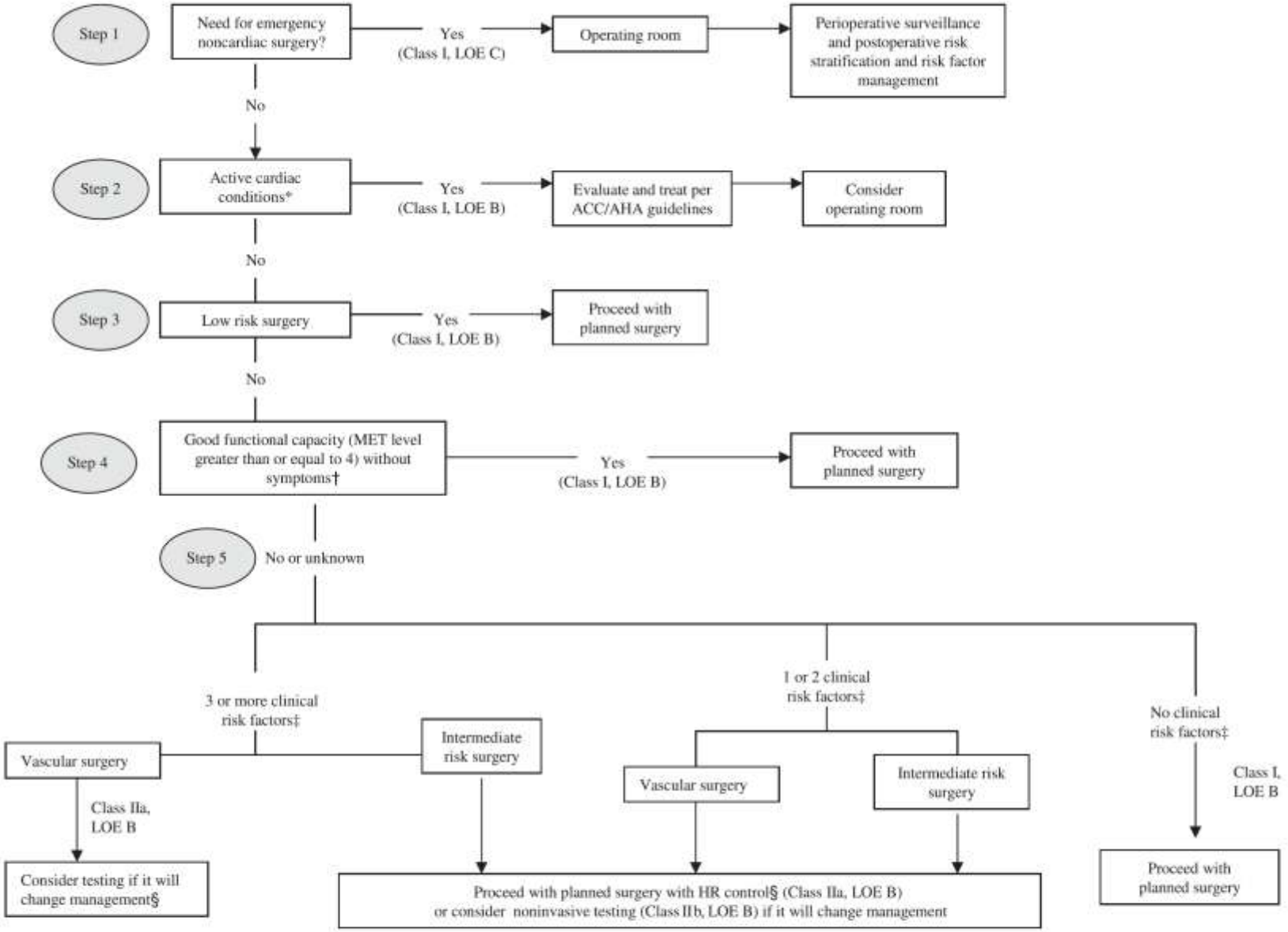


Figure 1. Cardiac evaluation and care algorithm for noncardiac surgery based on active clinical conditions, known cardiovascular disease, or cardiac risk factors for patients 50 years of age or greater. *See Table 2 for active clinical conditions. †See Table 3 for estimated MET level equivalent. ‡Clinical risk factors include ischemic heart disease, compensated or prior HF, diabetes mellitus, renal insufficiency, and cerebrovascular disease. §Consider perioperative beta blockade (see Table 11) for populations in which this has been shown to reduce cardiac morbidity/mortality. ACC/AHA indicates American College of Cardiology/American Heart Association; HR, heart rate; LOE, level of evidence; and MET, metabolic equivalent.



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Disease-Specific Approaches

- Coronary artery disease
- Hypertension
- Heart Failure
- Cardiomyopathy
- Valvular heart disease
- Arrhythmias and conduction defects
- Pacer/ICD
- Pulmonary vascular and congenital heart disease

Coronary Artery Disease

- Key questions:
  - What is the amount of myocardium in jeopardy?
  - What is the ischemic threshold?
  - What is the ventricular function?
  - Is the current medical regimen optimal?
- Is revascularization indicated (would it be beneficial) independent of impending surgical procedure? – if so, stress test is likely to be helpful
- Advanced age is a significant risk
- Female gender delays CAD by about 10 yr unless DM, but DM erases the benefit of femaleness

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Table 5. Prognostic Gradient of Ischemic Responses During an ECG-Monitored Exercise Test in Patients With Suspected or Proven CAD

Risk Level	Ischemic Response Gradient

*Workload and heart rate estimates for risk severity require adjustment for patient age. Maximum target heart rates for 40- and 80-year-old subjects taking no cardioactive medication are 180 and 140 bpm, respectively (61–68).

†Based on Weiner et al (61), Morris et al (62), Chaitman (63), Gianrossi et al (64), Detrano et al (65), Mark et al (66), Mark et al (67), and Gibbons et al (68).

Table 5. Prognostic Gradient of Ischemic Responses During an ECG-Monitored Exercise Test in Patients With Suspected or Proven CAD

Risk Level	Ischemic Response Gradient
High	Ischemia induced by low-level exercise* (less than 4 METs or heart rate less than 100 bpm or less than 70% of age-predicted heart rate) manifested by 1 or more of the following: Horizontal or downsloping ST depression greater than 0.1 mV ST-segment elevation greater than 0.1 mV in noninfarct lead Five or more abnormal leads Persistent ischemic response greater than 3 minutes after exertion Typical angina Exercise-induced decrease in systolic blood pressure by 10 mm Hg

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Table 5. Prognostic Gradient of Ischemic Responses During an ECG-Monitored Exercise Test in Patients With Suspected or Proven CAD

Risk Level	Ischemic Response Gradient
Intermediate	Ischemia induced by moderate-level exercise† (4 to 6 METs or heart rate 100 to 130 bpm [70% to 85% of age-predicted heart rate]) manifested by 1 or more of the following: Horizontal or downsloping ST depression greater than 0.1 mV Persistent ischemic response greater than 1 to 3 minutes after exertion Three to 4 abnormal leads

Table 5. Prognostic Gradient of Ischemic Responses During an ECG-Monitored Exercise Test in Patients With Suspected or Proven CAD

Risk Level	Ischemic Response Gradient
Low	No ischemia or ischemia induced at high-level exercise† (greater than 7 METs or heart rate greater than 130 bpm [greater than 85% of age-predicted heart rate]) manifested by: Horizontal or downsloping ST depression greater than 0.1 mV One or 2 abnormal leads

Table 5. Prognostic Gradient of Ischemic Responses During an ECG-Monitored Exercise Test in Patients With Suspected or Proven CAD

Risk Level	Ischemic Response Gradient
Inadequate test	Inability to reach adequate target workload or heart rate response for age without an ischemic response. For patients undergoing noncardiac surgery, the inability to exercise to at least the intermediate-risk level without ischemia should be considered an inadequate test.

bpm indicates beats per min; CAD, coronary artery disease; and MET, metabolic equivalent.

Hypertension - 1

- BP <180/110 is not an independent risk factor for perioperative complication
- But the preoperative evaluation provides an opportunity to initiate treatment or to improve control of hypertension
- Htn is a CAD risk factor
- Preoperative control of BP decreases intraoperative BP fluctuations that may cause ischemia
- Consider secondary causes: pheochromocytoma, hyperaldosteronism, renal artery stenosis

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Hypertension - 2

- Continue preoperative antihypertensives through surgery (parenteral if necessary), especially clonidine and beta-blockers, but maybe hold ACE-I or ARB which have been associated with intraoperative hypotension, restart when euvolemic
- BP>180/110 should control preoperatively, usually possible within hours with parenteral agents

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Heart Failure

- Carefully evaluate patients with no prior history of HF by H&P, maybe new diagnosis
- Optimize medical status if possible preoperatively
- Clarify etiology in known heart failure

Cardiomyopathy

- In patients with prior diagnosis of HF or with signs of HF, preoperative assessment, frequently echocardiography, to clarify degree of LV systolic and diastolic function may be recommended
- HCM:
  - Maintain euvolemia, beta-blockade
  - Hypotension – generally use volume loading and vasopressors emphasizing α-agonists rather than inotropes
  - LVOT gradient is not predictive of risk of perioperative HF

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Valvular Heart Disease - 1

- Murmur evaluation by examination – echo only if indications
- Severe aortic stenosis poses the greatest perioperative risk
  - If symptomatic, generally require AVR before noncardiac surgery
  - If no assessment in >1y, reassess severity
  - If refuse AVR or not a candidate, noncardiac surgical mortality is about 10%
  - If hemodynamically unstable, balloon aortic valvuloplasty is an option to temporize or bridge through surgery

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Valvular Heart Disease - 2

- Mitral stenosis is rarer but important – focus on control of heart rate – tachycardia gives high MV gradient and pulmonary congestion
- Preoperative correction of MS is indicated only with same indications as non-pre-operative setting; if severe and if anticipated procedure is high-risk, might benefit from preoperative MV repair/replacement
- AR – avoid bradycardia, volume control, afterload reduction
- MR – afterload reduction, volume control

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Prosthetic Heart Valves

- Mechanical– endocarditis prophylaxis
- Anticoagulation management
  - No heparin bridge for dental work, superficial biopsies: briefly reduce INR to low therapeutic or subtherapeutic range, then resume normal dose immediately post procedure
  - Heparin bridge for others if Bjork-Shiley or mitral or recent (<1y) thrombus or multiple risk factors (3 or more of: AFib, prior embolus, hypercoagulability, mechanical prosthesis, EF<30%)
  - Clinical judgment for intermediate risk

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Arrhythmias

- Presence of preoperative arrhythmia is an alert to consider possible underlying heart or metabolic disease
- AFib and PVCs – no particular recommendations
- “Physicians should have a low threshold to institute prophylactic beta-blocker therapy in patients at increased risk of developing a perioperative or postoperative supraventricular or ventricular tachyarrhythmia.”

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Conduction Abnormalities

- Complete AV block can increase perioperative risk and may necessitate initiation of temporary or permanent pacemaker
- IVCD or BBB very rarely deteriorate perioperatively to AV block
- Pacemaker and ICD presence in patients has implications for intraoperative management

Pulmonary Hypertension and Congenital Heart Disease

- No good data on which to base guideline
- Patients with prior repair for CHD may have increased pulmonary vasoreactivity to hypoxia
- Pulmonary hypertension probably poses increased perioperative risk – as in Eisenmenger's syndrome in peripartum period
- In cyanosis avoid drop in systemic vascular resistance which could deepen cyanosis and exacerbate acidosis

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Surgical Considerations

- Surgical procedural risk
- Situational risks
  - True surgical emergencies: symptomatic AAA, perforated viscus, trauma
  - Urgent situations: arterial bypass for limb salvage, mesenteric revascularization to prevent intestinal gangrene
  - Malignant neoplasms

Table 4. Cardiac Risk* Stratification for Noncardiac Surgical Procedures

Risk Stratification	Procedure Examples
Vascular (reported cardiac risk often more than 5%)	Aortic and other major vascular surgery Peripheral vascular surgery
Intermediate (reported cardiac risk generally 1% to 5%)	Intraperitoneal and intrathoracic surgery Carotid endarterectomy Head and neck surgery Orthopedic surgery Prostate surgery
Low† (reported cardiac risk generally less than 1%)	Endoscopic procedures Superficial procedure Cataract surgery Breast surgery Ambulatory surgery

*Combined incidence of cardiac death and nonfatal myocardial infarction.

†These procedures do not generally require further preoperative cardiac testing.

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Supplemental Tests

- Assess LV function – dyspnea unknown cause, or known HF with clin change (IIa); not routine
- Stress test – 3 or more risk factors AND high-risk vascular procedure AND poor functional capacity, IF it will change management (IIa)

When to Perform a Stress Test

Stress Test?	Clinical Risk Factors	Functional Capacity	Surgical Risk
IIa	3 or more	Poor	Vascular
IIb	1-2	Poor	Intermediate
IIb	1-2	Good	Vascular
III	0		Intermediate
III			Low

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Preoperative Revascularization

PCI or CABG?	Symptoms	Coronary Anatomy	LV Function
I	Stable angina	LMCA or 3V	Esp EF<50
		2VD +prox LAD	EF<50 or ischemia evid
	High risk UA or NSTEMI		
	STEMI		
IIb	Ischemic stress test (high or low risk)		

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Choice of Preoperative PCI Based on Need for Surgery

PCI Type	Time To wait for Surgery
Balloon angioplasty	14-29 da (>4 wk)
Bare metal stent	30-365 da (>4-6 wk*)
Drug-eluting stent	>365 da (12 mo*)

*If thienopyridine must be discontinued perioperatively

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Timing of Elective or Non-Urgent Surgery Post PCI

PCI Type	Time since PCI	
	Delay Surgery	Proceed with Surgery with ASA*
Balloon angioplasty	<14 da	>14 da
Bare metal stent	<30-45 da	>30-45 da
Drug-eluting stent	<365 da	>365 da

*Warfarin, antithrombotics, and GP IIb/IIIa inhibitors have not been shown to decrease the risk of stent thrombosis

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Perioperative Antiplatelet Agents and Non-Cardiac Surgery

- Aspirin plus clopidogrel adds 0.4-1.0% risk of major bleeding compared to aspirin alone
- Continuing low dose aspirin during surgery produces 1.5 fold increase in frequency of bleeding but not severity of bleeding or mortality (except maybe intracranial or prostatectomy)

When to Use Perioperative BB

	Vascular Surgery	Intermediate Risk Surgery	Low Risk Surgery
No risk factors	IIb, B	no	no
Risk factors	IIa, B	IIb, C	no
CHD or High risk	+NIWU – I Ow – IIa	IIa, B	no
Current BB	I, B	I, C	I, C

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When to Use Perioperative Statin

- Patient already on statin: continue statins through surgery
- Vascular surgery with or without risk factors, starting statin is reasonable (IIa)
- Intermediate risk surgery with risk factors, starting statin is an option (IIb)

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Other Perioperative Drugs

- Alpha-2 agonists (clonidine and mivazerol) may be beneficial in reducing ischemia – could use in hypertensives (IIb) with CAD or risk factors
- Calcium antagonists (diltiazem in particular) may be beneficial in reducing ischemia – no recommendation

Atrial Fibrillation

- Preoperative atrial fibrillation on coumadin – use antithrombotic bridge if risk of thrombus warrants
- Postoperative symptomatic or hemodynamically compromising AF = cardioversion
- Postoperative rate control
  - Beta blockers best to slow rate and better for reversion to NSR
  - Ca blockers second best
  - Digitalis preparations third best

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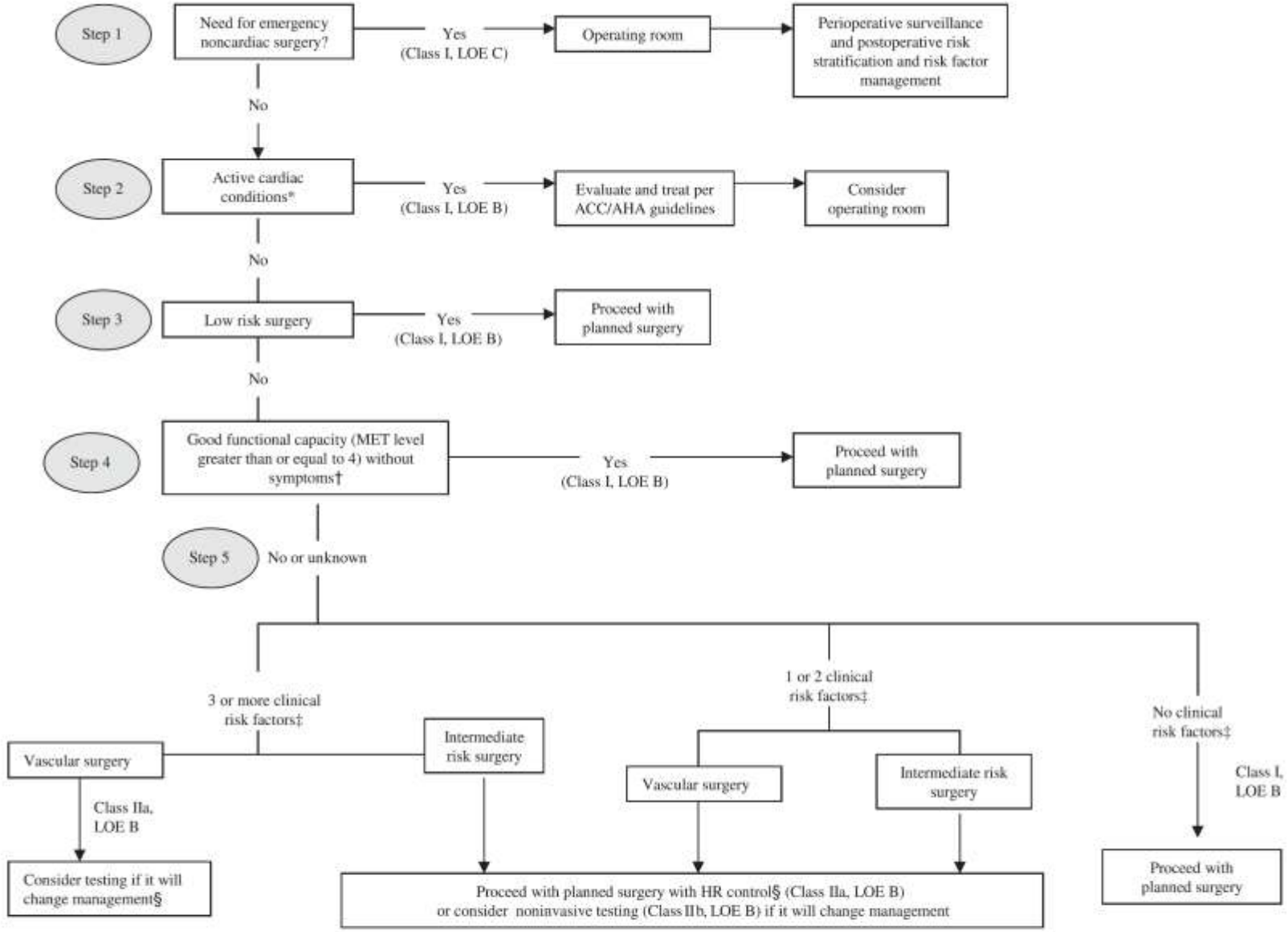
Table 14. Levels of Thromboembolism Risk in Surgical Patients Without Prophylaxis

	Deep Vein Thrombosis, %		Pulmonary Embolism, %		
Level of Risk	Calf	Proximal	Clinical Events	Fatal Events	Successful Prevention Strategies
Low	2	0.4	0.2	Less than 0.01	No specific prophylaxis; early and "aggressive" mobilization
Minor surgery in patients less than 40 years old with no additional risk factors					
Moderate	10 to 20	2 to 4	1 to 2	0.1 to 0.4	LDUH (every 12 hours), LMWH (less than or equal to 3400 U daily), GCS, or IPC
Minor surgery in patients with additional risk factors					
Surgery in patients aged 40 to 60 years with no additional risk factors					
High	20 to 40	4 to 8	2 to 4	0.4 to 1.0	LDUH (every 8 hours), LMWH (more than 3400 U daily), or IPC
Surgery in patients more than 60 years old or aged 40 to 60 years with additional risk factors (prior VTE, cancer, molecular hypercoagulability)					
Highest	40 to 80	10 to 20	4 to 10	0.2 to 5.0	LMWH (more than 3400 U daily), fondaparinux, oral VKAs (INR 2 to 3), or IPC/GCS plus LDUH/LMWH
Surgery in patients with multiple risk factors (age greater than 40 years, cancer, prior VTE)					
Hip or knee arthroplasty, HFS					
Major trauma; SCI					

GCS indicates graduated compression stocking; HFS, hip fracture surgery; INR, international normalized ratio; IPC, intermittent pneumatic compression; LDUH, low-dose unfractionated heparin; LMWH, low-molecular-weight heparin; SCI, spinal cord injury; U, unit; VKA, vitamin K antagonist; and VTE, venous thromboembolism.

Adapted with permission from Geerts et al (114).



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*Combined incidence of cardiac death and nonfatal myocardial infarction.

†These procedures do not generally require further preoperative cardiac testing.

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Table 4. Prognostic Gradient of Ischemic Responses During an ECG-Monitored Exercise Test*

Patients with suspected or proven CAD

High risk

Ischemia induced by low-level exercise† (less than 4 METs or heart rate less than 100 bpm or less than 70% age predicted) manifested by one or more of the following:

- Horizontal or downsloping ST depression greater than 0.1 mV
- ST-segment elevation greater than 0.1 mV in noninfarct lead
- Five or more abnormal leads
- Persistent ischemic response greater than 3 min after exertion
- Typical angina

Intermediate risk

Ischemia induced by moderate-level exercise* (4 to 6 METs or heart rate 100 to 130 bpm [70 to 85% age predicted) manifested by one or more of the following:

- Horizontal or downsloping ST depression greater than 0.1 mV
- Typical angina
- Persistent ischemic response greater than 1 to 3 min after exertion
- Three to four abnormal leads

Low risk

No ischemia or ischemia induced at high-level exercise* (greater than 7 METs or heart rate greater than 130 bpm [greater than 85% age predicted]) manifested by:

- Horizontal or downsloping ST depression greater than 0.1 mV
- Typical angina
- One or two abnormal leads

Inadequate test

Inability to reach adequate target workload or heart rate response for age without an ischemic response. For patients undergoing noncardiac surgery, the inability to exercise to at least the intermediate-risk level without ischemia should be considered an inadequate test.

ECG indicates electrocardiographically; MET, metabolic equivalent; bpm, beats per minute.

*Based on references 32 and 37-43.

†Workload and heart rate estimates for risk severity require adjustment for patient age. Maximum target heart rates for 40- and 80-year-old subjects on no cardioactive medication are 180 and 140 bpm, respectively (32,37-43).

ACC/AHA Guideline Perioperative CV Eval. 2002, basically unchanged in 2007

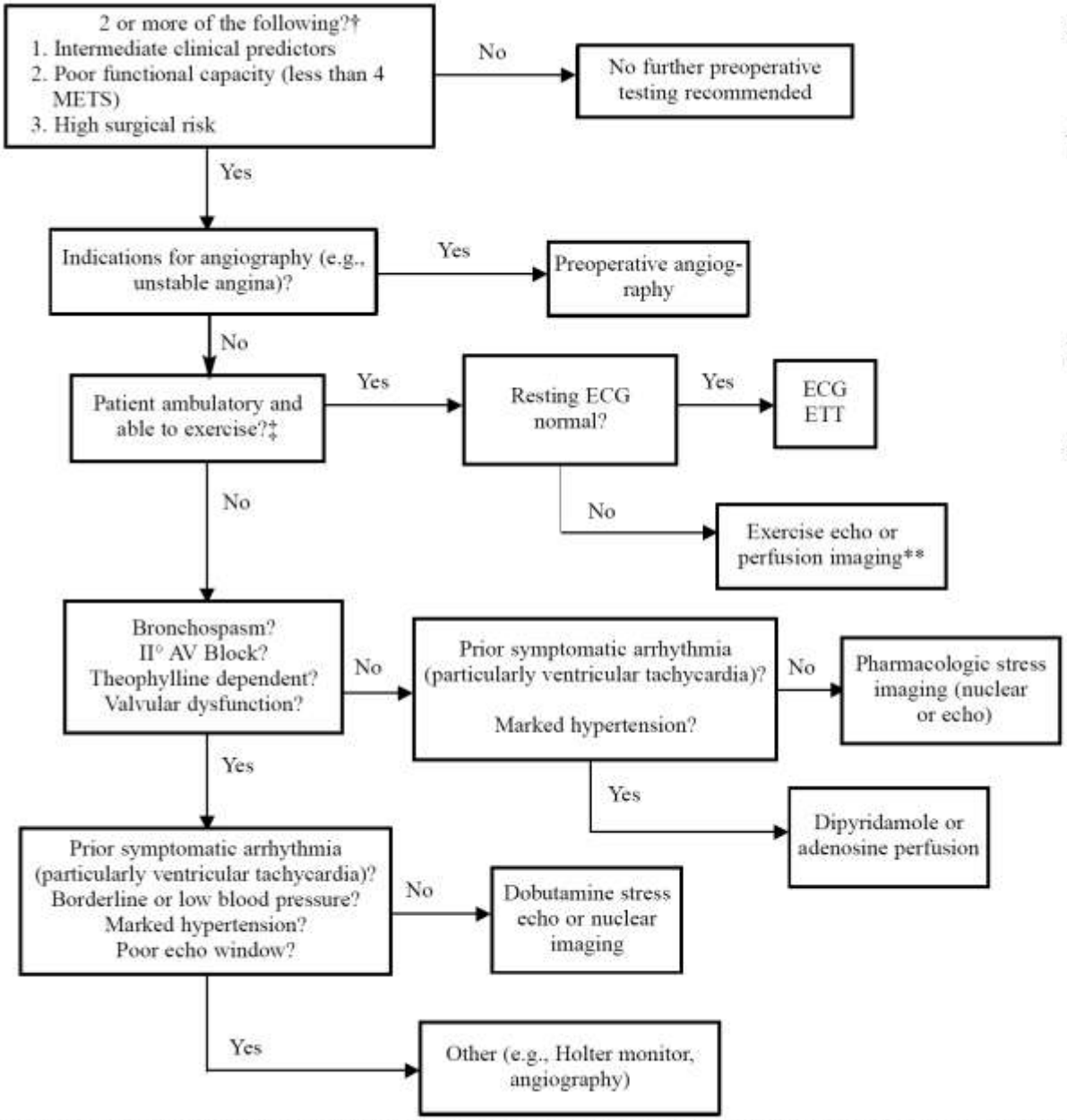
Table 5. Shortcut to Noninvasive Testing in Preoperative Patients if Any Two Factors Are Present

1. Intermediate clinical predictors are present (Canadian class 1 or 2 angina, prior MI based on history or pathologic Q waves, compensated or prior heart failure, diabetes, or renal insufficiency)
2. Poor functional capacity (less than 4 METs)
3. High surgical risk procedure (emergency major operations*; aortic repair or peripheral vascular surgery; prolonged surgical procedures with large fluid shifts or blood loss)

HF indicates heart failure; METs, metabolic equivalents; MI, myocardial infarction.

*Emergency major operations may require immediately proceeding to surgery without sufficient time for noninvasive testing or preoperative interventions.

ACC/AHA Guideline Perioperative CV Eval. 2002



*Testing is only indicated if the results will impact care.

†See Table 1 for the list of intermediate clinical predictors, Table 2 for the metabolic equivalents, and Table 3 for the definition of high-risk surgical procedure.

‡Able to achieve more than or equal to 85% MPHR.

**In the presence of LBBB, vasodilator perfusion imaging is preferred.

Figure 3. Supplemental Preoperative Evaluation: When and Which Test. Testing is only indicated if the results will impact care.

ACC/AHA Guideline Perioperative CV Eval. 2002

Table 3. Cardiac Risk* Stratification for Noncardiac Surgical Procedures

High	(Reported cardiac risk often greater than 5%) • Emergent major operations, particularly in the elderly • Aortic and other major vascular surgery • Peripheral vascular surgery • Anticipated prolonged surgical procedures associated with large fluid shifts and/or blood loss
Intermediate	(Reported cardiac risk generally less than 5%) • Carotid endarterectomy • Head and neck surgery • Intraperitoneal and intrathoracic surgery • Orthopedic surgery • Prostate surgery
Low†	(Reported cardiac risk generally less than 1%) • Endoscopic procedures • Superficial procedure • Cataract surgery • Breast surgery

*Combined incidence of cardiac death and nonfatal myocardial infarction.
†Do not generally require further preoperative cardiac testing.

ACC/AHA Guideline Perioperative CV Eval. 2002

Basic Concepts of Risk Optimization

1. Clinical context is supreme
   a) Risk factors (tobacco, Htn, Lipid, DM, FH)
   b) Symptoms (dyspnea, chest discomfort, arrhythmia)
   c) Prior diagnostic and therapeutic procedures (noninvasive, catheterization, PCI, CABG, other)
   d) Comorbidity (renal, endocrine, pulmonary, hematologic)

Basic Concepts of Risk Optimization - 2

2. Noninvasive evaluation **benefits**
   a) Diagnostic value
   b) Prognostic value
   c) Management recommendations (further diagnostic or therapeutic steps)
3. Noninvasive evaluation **limits**
   a) False results
   b) Costs and risks of tests and of subsequent provoked steps

Basic Concepts of Risk Optimization - 3

3. Analysis of the clinical situation
   a. Know outcomes expected of surgical procedure, of projected preoperative therapy, of natural history
   b. Know the gaps in the literature
   c. Clinical Judgment is Crucial

"It isn't what we don't know that gives us trouble, it's what we know that ain't so!"
Will Rogers

High Risk Clinical Indicators*

- Unstable coronary syndrome
  - Acute (<7da) or recent (7-30 days) MI with important ischemia by symptom or noninvasive test
  - Unstable or severe (CCS III-IV) angina
- Decompensated CHF
- Significant arrhythmia
  - High grade AV block
  - Symptomatic ventricular arrhythmia with underlying heart disease
  - Supraventricular arrhythmia with uncontrolled rate
- Severe valvular heart disease, esp. severe Sx AS

*Mandate intensive management, may delay surgery

Intermediate Risk Clinical Indicators*

- Mild angina (CCS I-II)
- Prior MI by history or ECG Q wave
- Compensated or prior CHF
- Diabetes Mellitus (esp. insulin dependent)
- Renal insufficiency

*Well-validated markers of enhanced risk of perioperative cardiac complications and justify careful assessment of the patient's current status.

Low Risk Clinical Indicators*

- Advanced age (>70, >75?)
- Abnormal ECG (LVH, LBBB, ST-T abnormality)
- Rhythm not sinus (e.g. atrial fibrillation)
- Low functional capacity (<4 METs)
- History of stroke
- Uncontrolled systemic hypertension

*Not proven to independently increase perioperative risk - further preoperative cardiac testing is not

Canadian Cardiovascular Society Classification System

- **Class I**: Ordinary physical activity does not cause angina, such as walking, climbing stairs. Angina with strenuous, rapid, or prolonged exertion at work or recreation.
- **Class II**: Slight limitation of ordinary activity. Angina occurs on walking or climbing stairs rapidly, walking uphill, walking or stair climbing after meals, or in cold, or in wind, or under emotional stress, or only during the few hours after awakening. Angina occurs on walking more than 2 blocks on the level and climbing more than one flight of ordinary stairs at a normal pace and in normal condition.
- **Class III**: Marked limitations of ordinary physical activity. Angina occurs on walking one to two blocks on the level and climbing one flight of stairs in normal conditions and at a normal pace.
- **Class IV**: Inability to carry on any physical activity without discomfort – anginal symptoms may be present at rest.

Energy Requirements in Activity

1 MET to 4 METs

- Self care
- Eat, dress, use toilet
- Walk indoors around the house
- Walk a block or 2 at 2-3 mph
- Light housework, dusting, dishes

4 METs to 10 METs

- Climb flight of stairs or walk up a hill
- Walk on level ground at 4 mph
- Run a short distance
- Heavy housework, moving furniture, scrub floor
- Golf, tennis, bowling
- Swimming, football

- Unknown
- Poor (<4)
- Good (4-7)
- Excellent (>7)

Surgical Cardiac Risk*

- **High risk** (>5%):
  - Emergent major operations, esp. in elderly
  - Aortic and other major and peripheral vascular
  - Anticipated prolonged procedure or large fluid or blood shifts
- **Intermediate risk** (1-5%)
  - Carotid endarterectomy, head and neck surgery
  - Intraperitoneal and thoracic
  - Orthopedic and
- **Low risk**** (<1%)
  - Endoscopic
  - Superficial
  - Cataract
  - Breast

*Combined cardiac death or nonfatal MI

** Generally needs no further

Highlights of Assessment and Management

- Patient Characteristics
  - Ischemia ⟷
    - Amount of jeopardized myocardium
    - Ischemic threshold
    - LV function
  - Pump function
  - Rhythm
  - Other
- Procedure characteristics
  - Risk features
  - Particular stresses

Highlights of Assessment and Management - 2

- Step 1: Urgency of procedure - if urgent, goals become perioperative medical recommendations and surveillance, but cardiac risk is (2-5 times) higher in emergent operations
- Step 2: Prior revascularization - if within 5 yr and no recurrent symptoms or signs, proceed to surgery
- Step 3: Prior coronary risk evaluation - if angiography or stress test within 2 yr, favorable and stable, proceed to surgery

Highlights of Assessment and Management - 3

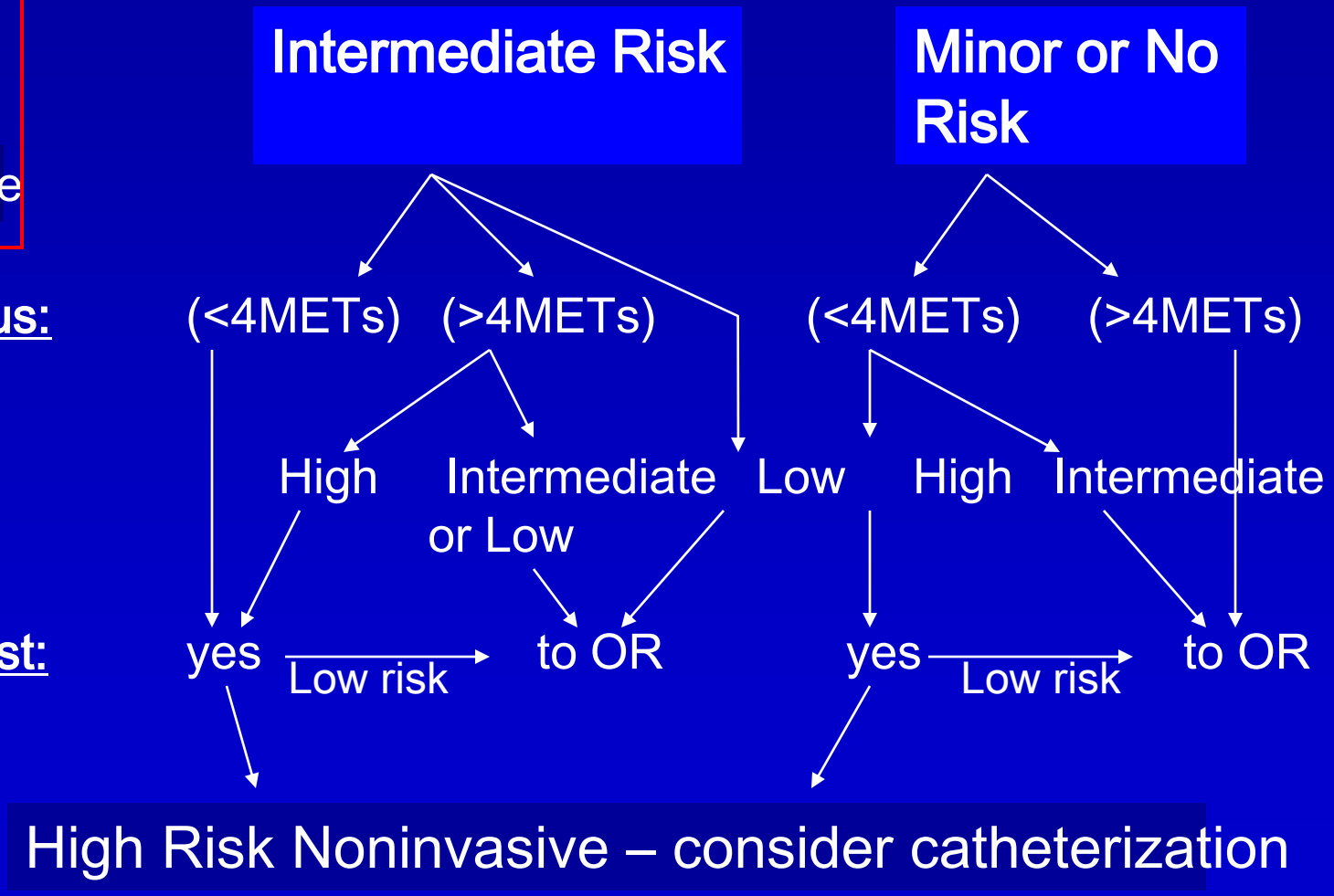
- **Step 4: Assess Risk**
  - **Major Clinical Risk** (unstable coronary syndrome or severe angina, decompensated CHF or arrhythmia or severe valve disease) generally delay surgery until stable, may need catheterization. NOTE: It is almost never appropriate to recommend CABG or PCI to reduce the risk of surgery when they would not otherwise be indicated.
  - **Intermediate Clinical Risk** (mild angina, prior MI, compensated CHF, DM) assess functional capacity and surgical risk to determine management.
  - **Minor Clinical Risk** (age >70, abnormal ECG, non-sinus rhythm, low functional capacity, prior stroke, uncontrolled Htn) assess functional capacity and surgical risk to determine management.

Highlights of Assessment and Management - 4

Major Risk

↓

Delay Procedure



Duke Treadmill Score

- Bruce Protocol Exercise time (min)
- -5*ST depression (mm)
- -4*Angina index
  - No angina – 0
  - Angina – 1
  - Limiting angina – 2
- Risk stratification:
  - Low risk (62% prevalence, 0.25% ann mort) >+4
  - Mod risk (34% prevalence, 1.25% ann mort) –10 to +4
  - High risk (4% prevalence, 5.0% ann mort) < -10

ACC/AHA Chronic Stable Angina Guidelines, JACC, 2002 p. 2126

Results of Noninvasive Testing

- **High Risk** (**>3%** ann mort)
  - LVEF <35%
  - Duke treadmill score <-10
  - Large reversible defect (esp anterior)
  - Multiple moderate reversible defects
  - Large fixed defect with LV dilation or lung uptake
  - Moderate reversible defect with LV dilation or lung uptake
  - Echo hypokinesis (2 segs) at <10 dobutamine or HR<110
  - Echo extensive stress hypokinesis
- **Intermediate Risk** (**1-3%** ann mort)
  - LV EF 35-45
  - Duke treadmill score 4 to –10
  - Moderate reversible defect
  - Echo hypokinesis of 1-2 segments at higher stress
- **Low Risk** (**<1%**)
  - Duke treadmill score >5
  - Normal or small perfusion defect
  - Normal stress echo or mild resting wall motion abnormality without decrease during stress

ACC/AHA Chronic Stable Angina Guidelines, 2002.

Indications for Cardiac Catheterization

- **Class I**:
  - High-risk noninvasive test
  - Angina refractory to adequate medication
  - Unstable angina
  - Equivocal noninvasive test in high risk patient for high risk surgery
- **Class II**:
  - Intermediate-risk noninvasive test
  - Equivocal noninvasive test in low risk patient for high risk surgery
  - Recent MI and urgent surgery
  - Perioperative MI
- **Class III**:
  - Low risk surgery and low risk noninvasive test
  - Screening for CAD without noninvasive test
  - Mild stable angina with low risk noninvasive test
  - Patient not a revascularization candidate, with or without low LV EF, or unwilling to consent for revascularization
  - Prior normal coronary angiogram within 5 yr

Specific Clinical Situations

- Hypertension: should be controlled; if DBP>110, generally delay procedure
- Valvular disease: same as non-operative
- Myocardial disease: same as non-operative
- Arrhythmia: same as non-operative

Noninvasive testing

- Generally best – exercise testing
- Other coronary stress tests
- Resting LV EF: patients with current or poorly controlled CHF
- Holter: usual indications
- Catheterization, coronary angiography

Further Management

- Generally continue chronic medications, including beta-blockade, calcium blockers, diuretics, digitalis preparations, nitrates
- Preoperative ICU care: decompensated CHF patients, perhaps
- Thromboembolism prophylaxis: more to come
- Anesthetic and intraoperative recommendations: leave to anesthesia
- Postoperative recommendations:
  - ECG in patients with perioperative signs of cardiovascular dysfunction or known or suspected CAD
  - Enzymes in patients with ECG changes or other high risk subsets

Thromboembolism Prophylaxis

- Risks: Advanced age, prolonged immobility/paralysis, prior TE, malignancy, major operation (abd, pelv, lower ext), CHF, MI, stroke, fx pelvis or lower ext, coag disorder.

ACC/AHA Guidelines for Perioperative Cardiovascular Evaluation for Noncardiac Surgery, 1996

Thromboembolism Prophylaxis - 2

- Minor Surgery
- Nonmajor surgery
- Major surgery
  - Abdomen
  - Pelvis
  - Lower extremity
- Procedure-related risks: site, technique and duration, type anesthesia, infection, postoperative immobilization

6th ACCP Conference on Antithrombotic Therapy, Chest 119:Suppl 1, Jan 2001

Thromboembolism Prophylaxis - 3

- Clinical Risk Factors
  - Increasing age
  - Prolonged immobility, stroke or paralysis
  - Prior VTE
  - Cancer and its treatment
  - Major surgery
  - Trauma, esp. fx of pelvis, or lower ext
  - Obesity
  - Varicose veins
  - Cardiac dysfunction
  - Central venous catheters
  - Inflammatory bowel disease
  - Nephrotic syndrome
  - Pregnancy or estrogen use

6th ACCP Conference on Antithrombotic Therapy, Chest 119:Suppl 1, Jan 2001

Thromboembolism Prophylaxis - 4

- Thrombophilic disorders (hypercoagulable state)
  - Activated protein C resistance (Factor V Leiden)
  - Prothrombin variant 2010A
  - Antiphospholipid antibodies
  - Deficiency or dysfunction: Protein C or S or heparin cofactor II
  - Dysfibrinogenemia
  - Decreased plasminogen and plasminogen activator levels
  - Heparin-induced thrombocytopenia
  - Hyperhomocystinemia
  - Myeloproliferative disorders: polycythemia vera, primary thrombocytosis

6th ACCP Conference on Antithrombotic Therapy, Chest 119:Suppl 1, Jan 2001

Thromboembolism Prophylaxis - 5

- Low risk:
  - Minor surgery in pt <40 yr, no risks
- Moderate risk:
  - Minor surgery in pt, add'l risks
  - Nonmajor surgery in pt 40-60 yr, no add'l risks
  - Major surgery in pt <40 yr, no add'l risks
- High risk:
  - Nonmajor surgery in pt >60 yr or add'l risks
  - Major surgery in pt >40 yr or add'l risks
- Highest risk:
  - Major surg in pt >40 yr plus prior VTE, cancer, molecular hypercoagulability, hip or knee arthroplasty, hip fx surg, major trauma, spinal cord injury

6th ACCP Conference on Antithrombotic Therapy, Chest 119:Suppl 1, Jan 2001

Thromboembolism Prophylaxis - 6

- Low risk:
  - Early ambulation
- Moderate risk:
  - Low dose unfractionated heparin or LMW heparin or Elastic (graduated compression) stockings or Intermittent Pneumatic compression
- High risk:
  - Low dose unfractionated heparin or LMW heparin or Intermittent Pneumatic compression (no Elastic (graduated compression) stockings)
- Highest risk:
  - Low dose unfractionated heparin or LMW heparin PLUS Elastic (graduated compression) stockings or Intermittent Pneumatic compression

6th ACCP Conference on Antithrombotic Therapy, Chest 119:Suppl 1, Jan 2001

Thromboembolism Prophylaxis - 7

- Low molecular weight heparin versus unfractionated heparin
  - Recommendation preference depends on specific condition
  - Preference to unfractionated heparin:
    - Gynecologic surgery not highest risk
  - Preference to LMW heparin:
    - Orthopedic surgery
    - Trauma
    - Acute spinal cord injury (strong preference)
  - No preference:
    - General surgery
    - Urologic surgery

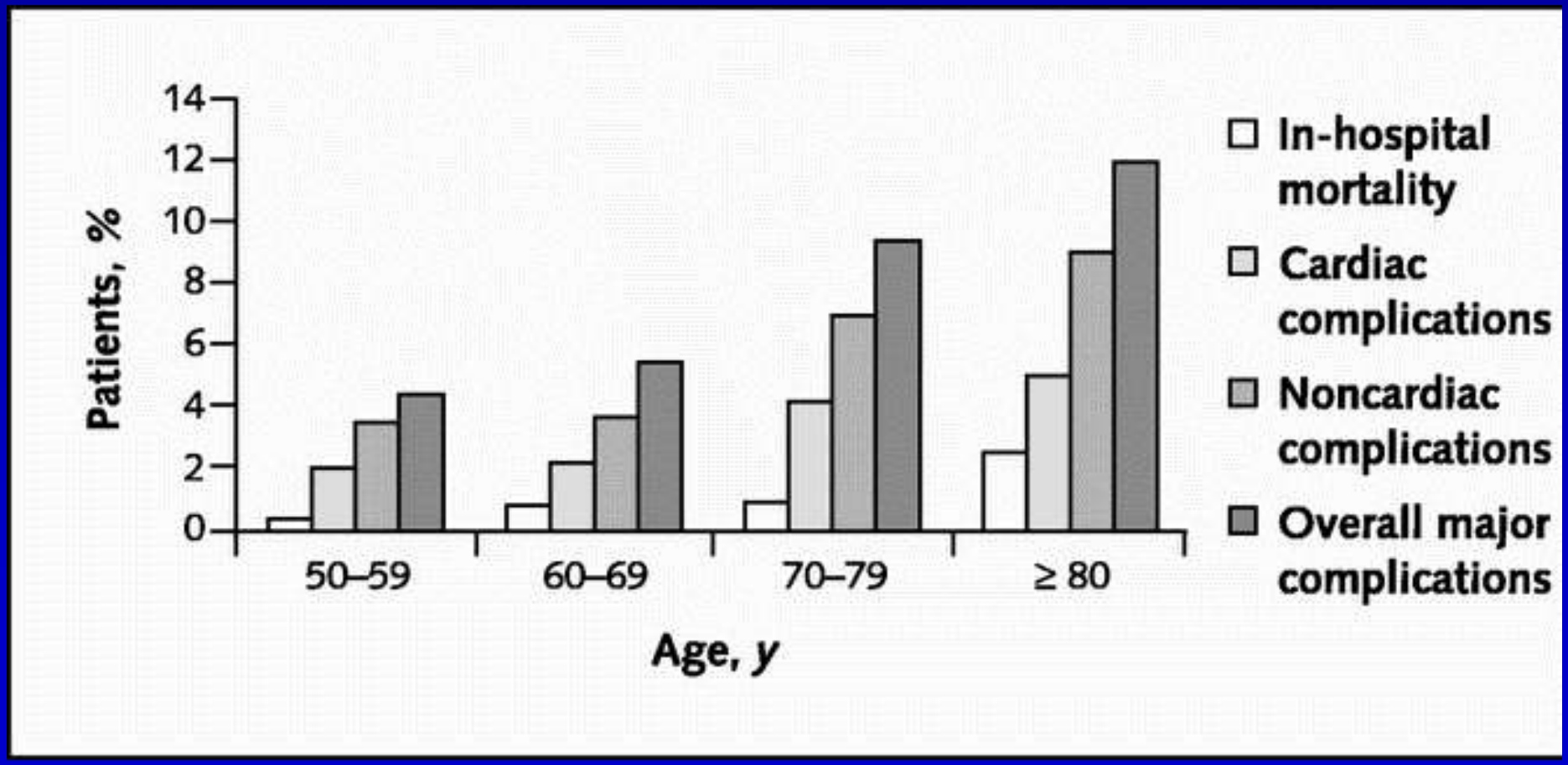
6th ACCP Conference on Antithrombotic Therapy, Chest 119:Suppl 1, Jan 2001

Age and Perioperative Risk

- Surgery 1989-1994
- 4315 Patients >50 yo
- 4898 Surgical procedures
  - Elective
  - Major (estimated hosp stay at least 2 days)
  - Orthopedic 30%, Intrathoracic 11%, AAA 4%, Abdominal 11%, Vascular 15%, Other 29%

Polanczyk, Carisi A. MD, ScD et al. Impact of Age on Perioperative Complications and Length of Stay in Patients Undergoing Noncardiac Surgery. Ann Intern Med, April 17, 2001;134:637-643.

Age and Perioperative Risk



Polanczyk: Ann Intern Med, Volume 134(8).April 17, 2001.637-643

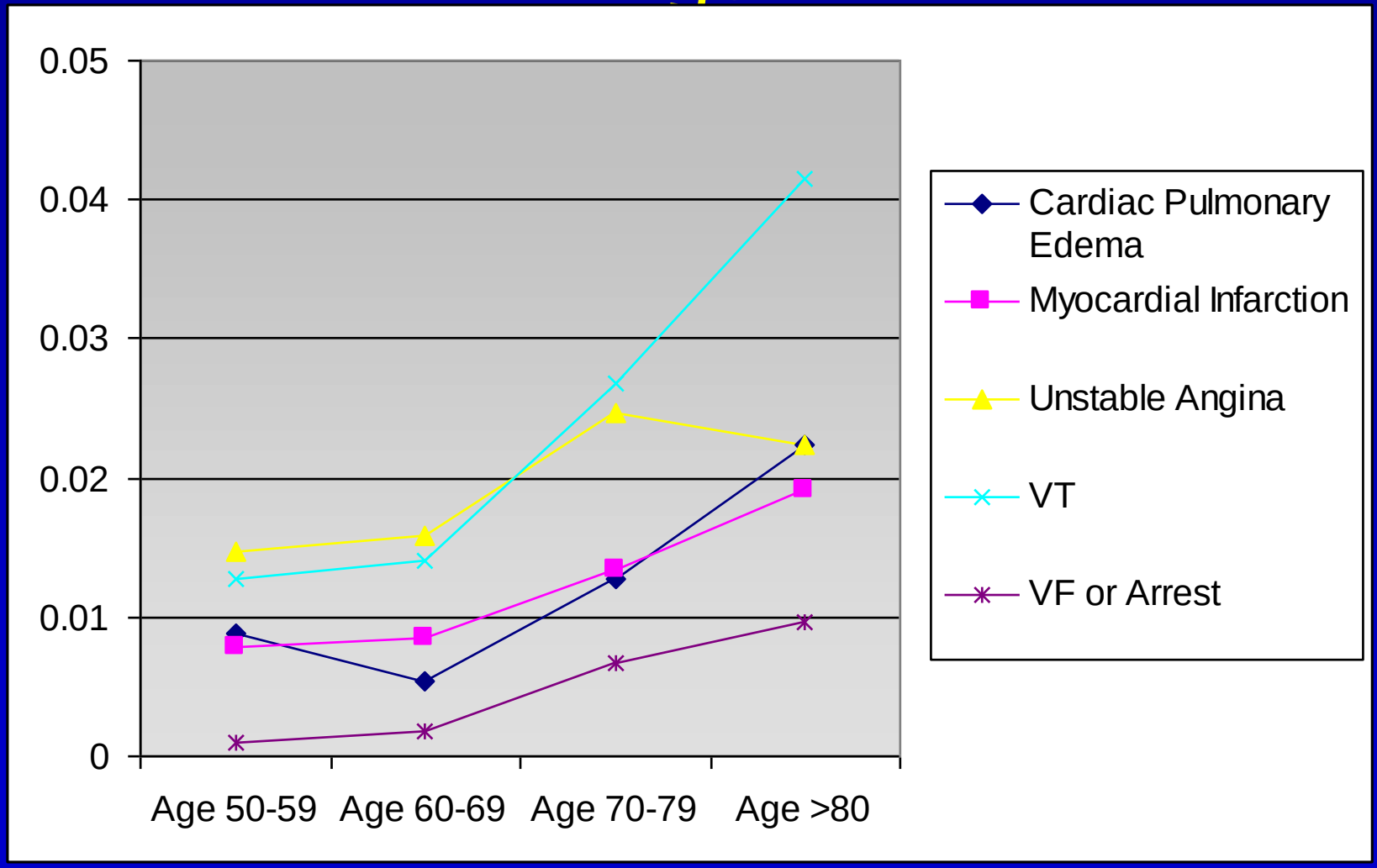
Age and Perioperative Risk

Table 2. **Postoperative Complications and Mortality**

Postoperative Complication	Age Group				*P* Value
	50–59 Years (*n* = 1015)	60–69 Years (*n* = 1646)	70–79 Years (*n* = 1341)	≥80 Years (*n* = 313)	
	← *n* (%) →				
Acute cardiac event					
Cardiogenic pulmonary edema	9 (0.9)	9 (0.5)	17 (1.3)	7 (2.2)	0.03
Myocardial infarction	8 (0.8)	14 (0.9)	18 (1.3)	6 (1.9)	0.05
Unstable angina	15 (1.5)	26 (1.6)	33 (2.5)	7 (2.2)	0.07
Ventricular tachycardia	13 (1.3)	23 (1.4)	36 (2.7)	13 (4.2)	<0.001
Ventricular fibrillation or cardiac arrest	1 (0.1)	3 (0.2)	9 (0.7)	3 (1.0)	0.003
Noncardiac event					
Bacterial pneumonia	11 (1.1)	10 (0.6)	23 (1.7)	7 (2.2)	0.02
Noncardiogenic pulmonary edema	0	5 (0.3)	6 (0.5)	1 (0.3)	0.08
Respiratory failure requiring intubation	9 (0.9)	19 (1.2)	31 (2.3)	12 (3.8)	<0.001
Renal failure requiring dialysis	1 (0.1)	7 (0.4)	7 (0.5)	0	>0.2
Cerebrovascular accident	4 (0.4)	6 (0.4)	10 (0.7)	2 (0.6)	0.2
Pulmonary embolism	1 (0.1)	5 (0.3)	4 (0.3)	2 (0.6)	0.16
In-hospital mortality	3 (0.3)	14 (0.8)	12 (0.9)	8 (2.6)	0.002
One or more postoperative complications or death	44 (4.3)	93 (5.7)	129 (9.6)	39 (12.5)	<0.001

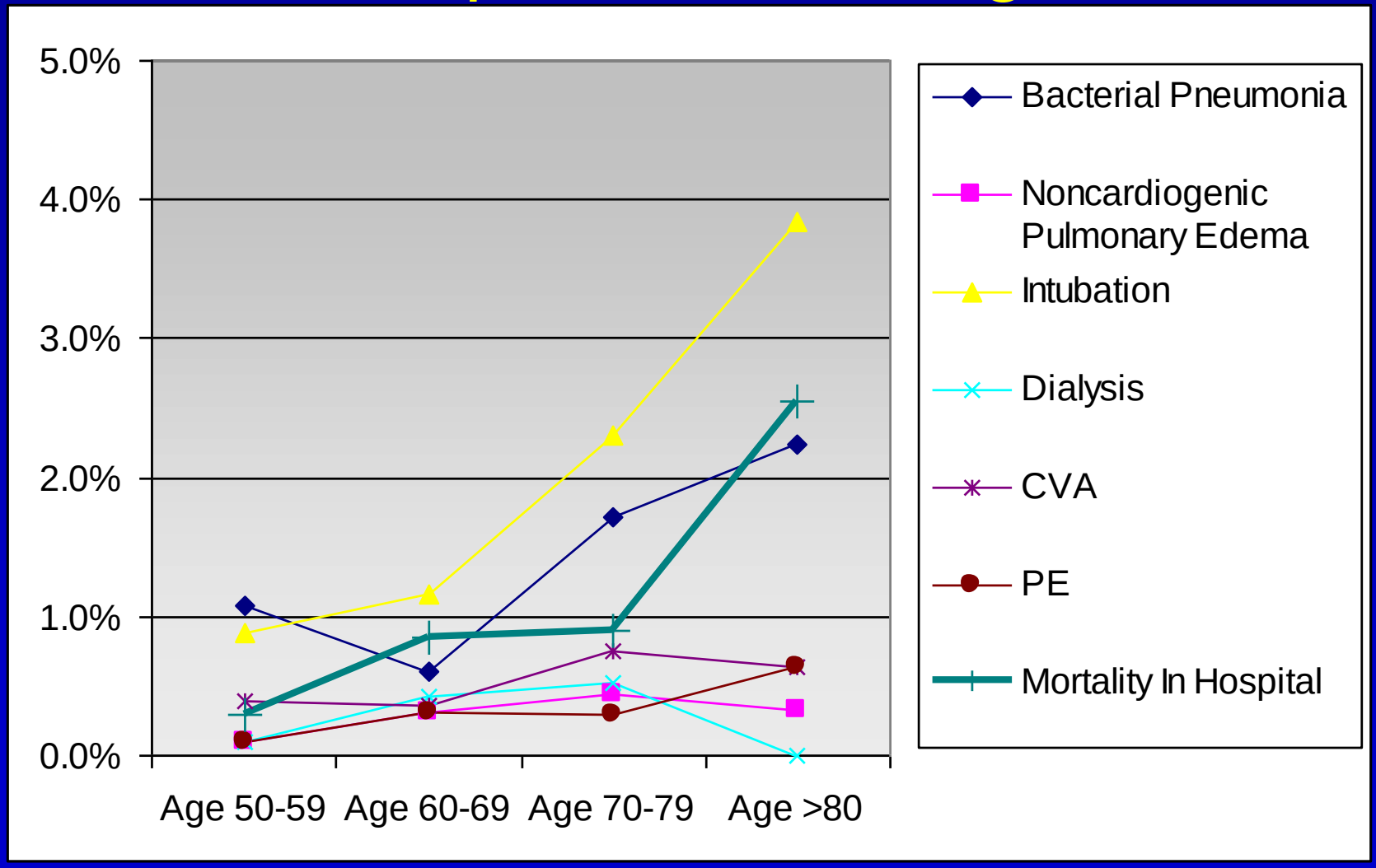
Polanczyk: Ann Intern Med, Volume 134(8).April 17, 2001.637-643

Perioperative Cardiac Complication and Age



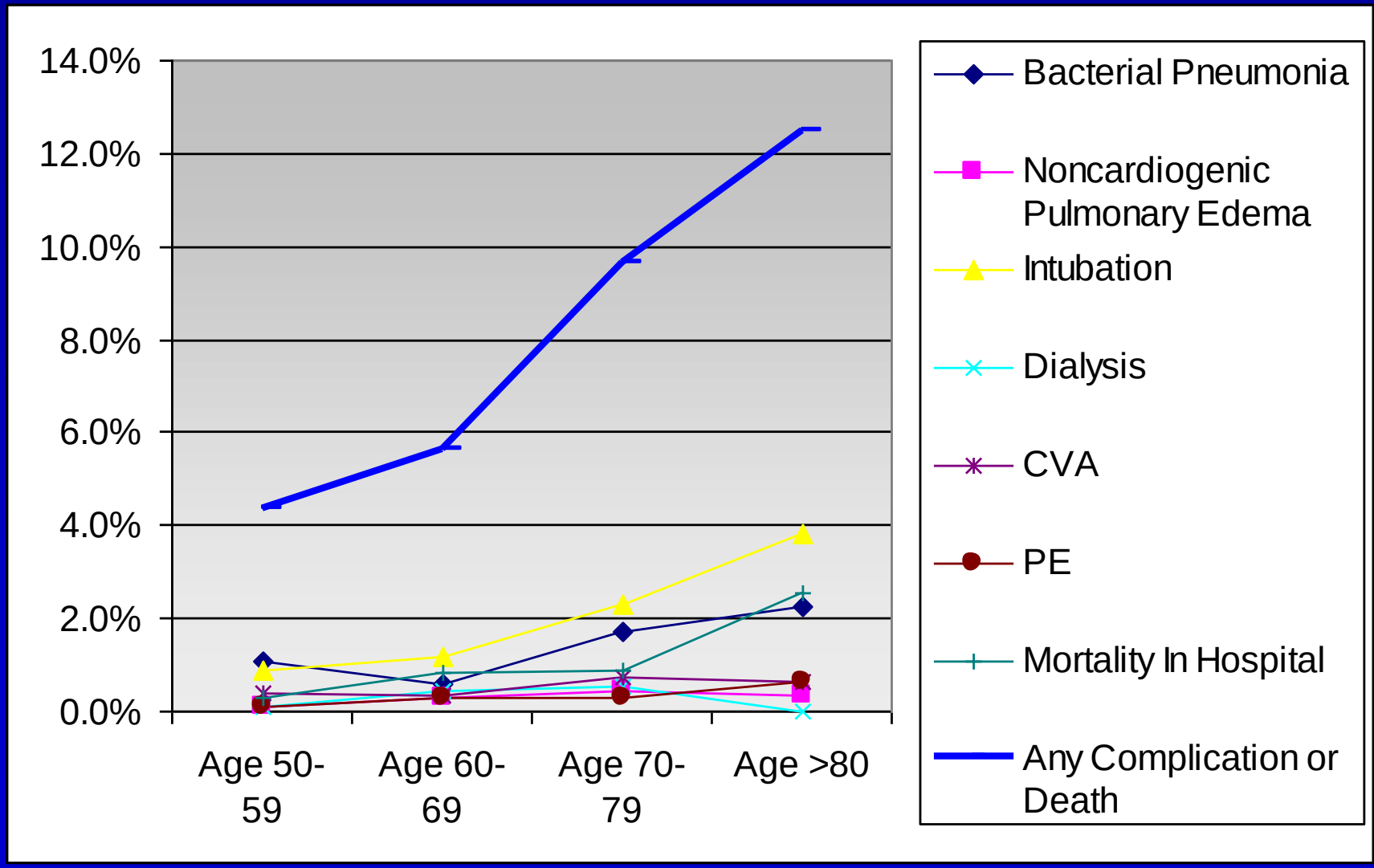
Polanczyk: Ann Intern Med, Volume 134(8).April 17, 2001.637-643

Perioperative NON-Cardiac Complication and Age



Polanczyk: Ann Intern Med, Volume 134(8).April 17, 2001.637-643

Perioperative NON-Cardiac Complication and Age



Polanczyk: Ann Intern Med, Volume 134(8).April 17, 2001.637-643

Age and Perioperative Risk: Risk Factors for Complications

- Age (70-79 RR 1.8, >80 RR 2.1)
- Nonwhite ethnicity (Boston) 1.8
- CHF borderline 1.4
- Cerebrovascular Dz 1.8
- Thoracic Procedure 2.6
- AAA Repair 3.3
- Not ischemic heart disease, gender, hypertension, diabetes, chronic lung disease, CRF, PUD

Polanczyk: Ann Intern Med, Volume 134(8).April 17, 2001.637-643

“Simple” Risk Index

- High risk surgery
- Ischemic heart disease
- CHF
- Cerebrovascular disease
- Preoperative insulin
- Creatinine >2.0

Major cardiac complication rate

- 0 factors – 0.3%
- 1 factor – 1.3%
- 2 factors – 4.0%
- >2 factors – 9.0%

Lee TH et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiovascular surgery. Circulation 1999;100:1043

Prevalence and Impact of Risk Factors

- High-risk surgery (31%, risk 3%): intraperitoneal, intrathoracic, or suprainguinal vascular
- Ischemic heart disease (33%, risk 4%): prior MI, prior +ETT, current angina, NTG use, pathol Q's (not ST-T abnl or prior CABG or PCI only)
- CHF (15%, risk 5%): CHF, pulm edema or PND by hx, bilateral rales or S3, CXR pulm redist
- Cerebrovascular dz (10%, risk 6%): history of TIA or stroke
- Insulin therapy (4%, risk 6%)
- Creatinine >2.0 (4%, risk 9%)

(Not assessed: recent MI or critical AS, UA, class 4 CHF, or active TIA)

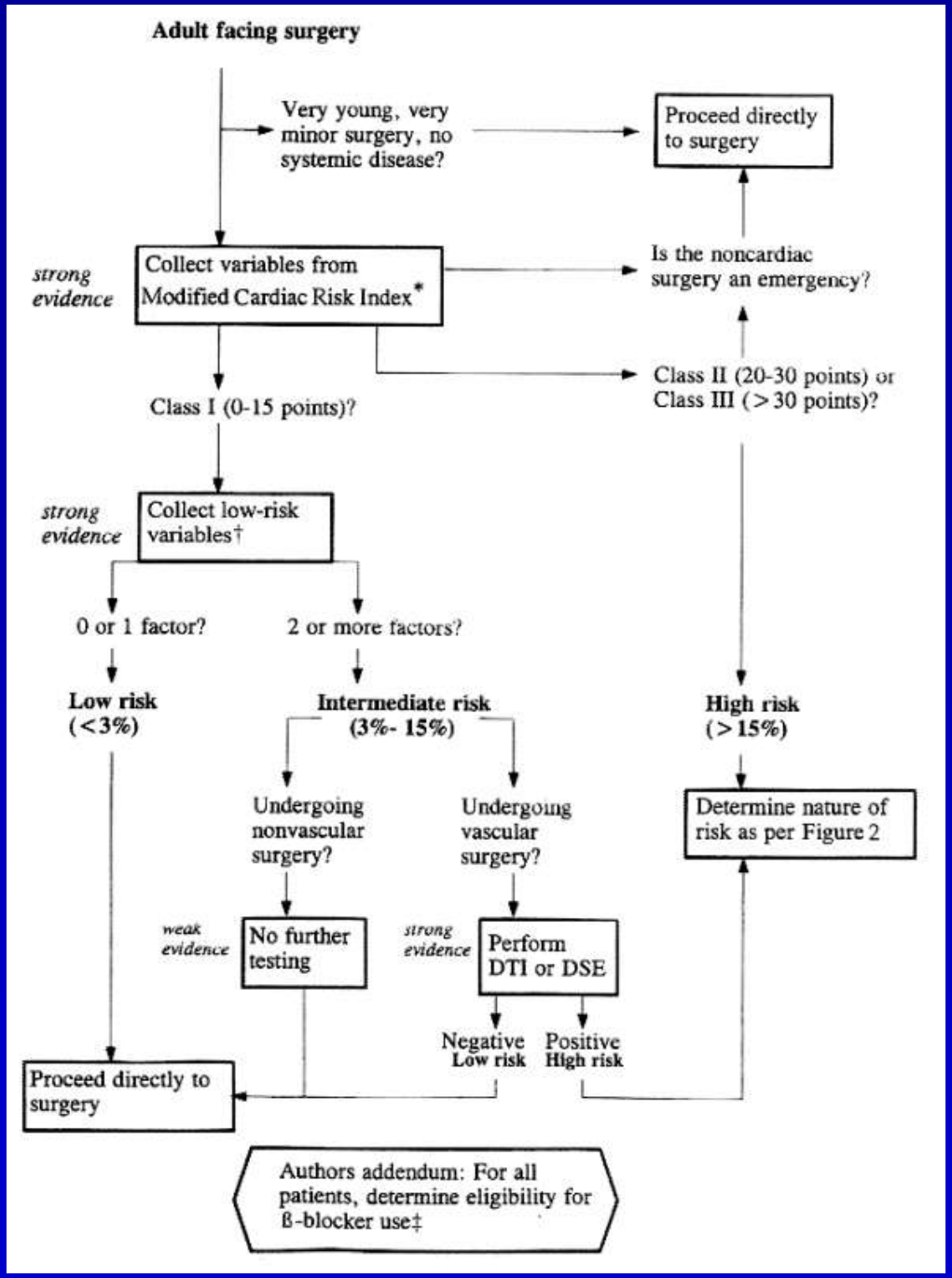
Lee TH et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiovascular surgery. Circulation 1999;100:1043

ACP Guideline - 1997

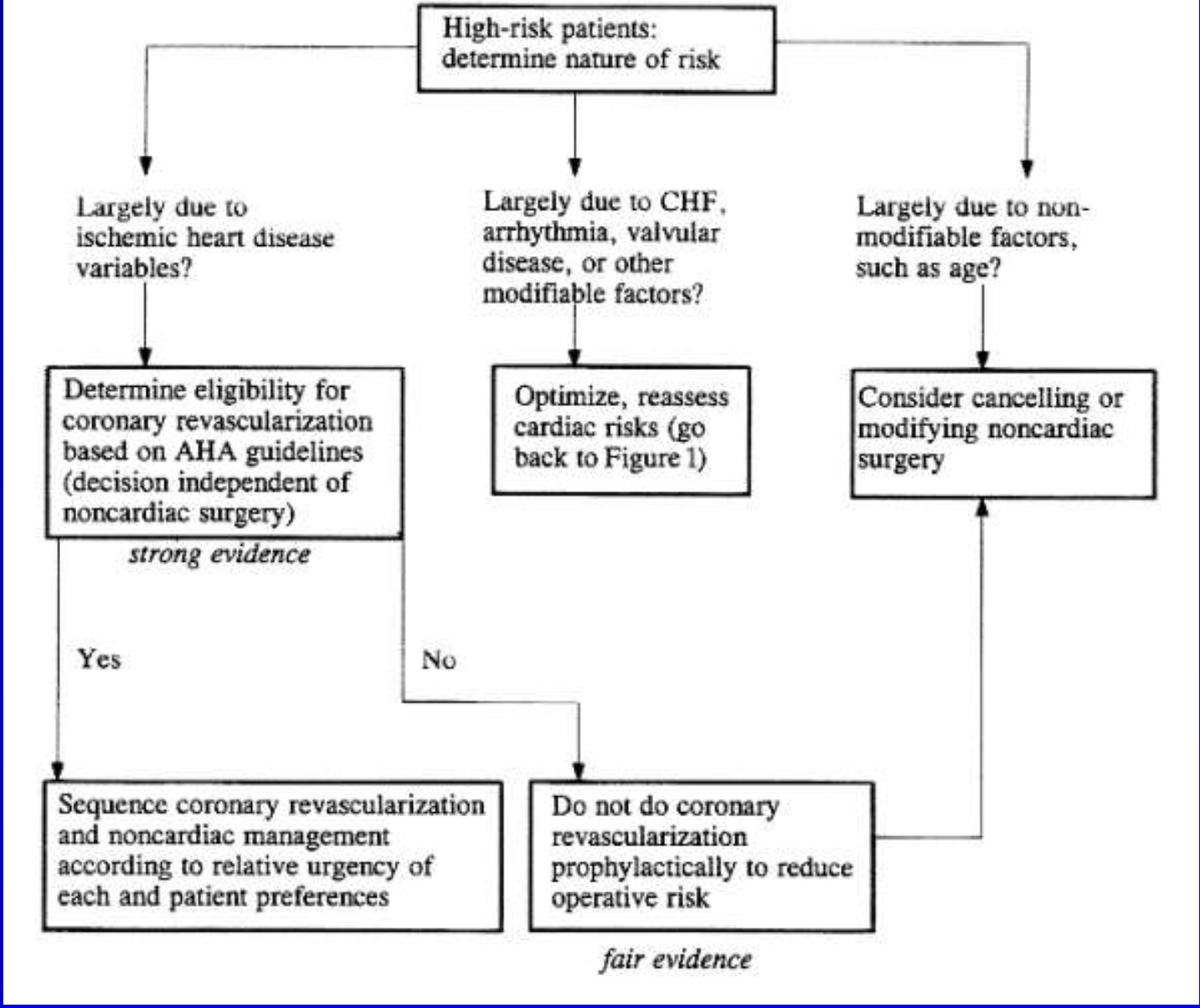
- Also available
- Similar in impact

Guidelines for assessing and managing the perioperative risk from coronary artery disease associated with major noncardiac surgery. American College of Physicians. ***Annals of Internal Medicine***. *127(4):309-12, 1997 Aug 15.*

American College of Physicians Guideline - 1



American College of Physicians Guideline - 2



American College of Physicians Guideline - 3

Variable	Points, *n*
Coronary artery disease	
Myocardial infarction <6 months earlier	10
Myocardial infarction >6 months earlier	5
Canadian Cardiovascular Society angina classification‖	
Class III	10
Class IV	20
Alveolar pulmonary edema	
Within 1 week	10
Ever	5
Suspected critical aortic stenosis	20
Arrhythmias	
Rhythm other than sinus or sinus plus atrial premature beats on electrocardiogram	5
>5 premature ventricular contractions on electrocardiogram	5
Poor general medical status, defined as any of the following: Po_2 < 60 mm Hg, Pco_2 > 50 mm Hg, K^+ level < 3 mmol/L, blood urea nitrogen level > 50 mmol/L, creatinine level > 260 μmol/L, bedridden	5
Age >70 years	5
Emergency surgery	10

§ Class I = 0 to 15 points; class II = 20 to 30 points; class III = more than 30 points.
‖ Canadian Cardiovascular Society classification of angina (2): 0 = asymptomatic; I = angina with strenuous exercise; II = angina with moderate exertion; III = angina with walking 1 to 2 level blocks or climbing 1 flight of stairs or less at a normal pace; IV = inability to perform any physical activity without development of angina.

American College of Physicians Guideline - 4

Criteria of Eagle et al. (3)	Criteria of Vanzetto et al. (4)
Age >70 years	Age >70 years
History of angina	History of angina
Diabetes mellitus	Diabetes mellitus
Q waves on electrocardiogram	Q waves on electrocardiogram
History of ventricular ectopy	History of myocardial infarction
	ST-segment ischemic abnormalities during resting electrocardiography
	Hypertension with severe left ventricular hypertrophy
	History of congestive heart failure

‡ Criteria used by Mangano and colleagues (5) to define eligibility for β-blocker use were coronary artery diseae (defined as a previous myocardial infarction, typical angina, or atypical angina with positive results on a stress test) or risk for coronary artery disease (defined as the presence of at least two of the following: age ≥ 65 years, hypertension, current smoking, serum cholesterol level ≥ 240 mg/dL [6.2 mmol/L], and diabetes mellitus). Administration of the drug at each time point required that the heart rate be at least 55 beats/min and the systolic blood pressure be at least 100 mm Hg with no evidence of congestive heart failure, third-degree heart block, or bronchospasm. Patients received two 5-mg doses administered of intravenous atenolol, each over 5 minutes 30 minutes before surgery and again immediately after surgery. After surgery, patients were given oral atenolol, 100 mg (if heart rate was ≥65 beats/min) or 50 mg (if heart rate was 55 to 64 beats/min). If the patient was unable to take oral medication, two 5-mg doses were given intravenously every 12 hours. Atenolol was given until hospital discharge (maximum, 7 days).

American College of Physicians Guideline - 5

Study (Reference)	Year	Patients	Type of Surgery	Quality Rating	End Point	Pretest Probability
		n				%
Cardiac Risk Index						
Goldman et al. (29)	1977	1001	General, orthopedic, urologic	Fair	MI, cardiac death, CHF, VT	6
Detsky et al. (28)	1986	455	Mixed‡	Strong	MI, cardiac death, CHF	10
Jeffrey et al. (44)	1983	99	Vascular	Fair	MI, cardiac death, CHF, VT	11
Zeldin (45)	1984	1140	General, vascular, thoracic	Fair	MI, death, CHF, VT	3
Lundqvist et al. (31)	1989	78	Vascular	Fair	MI, cardiac death	17
Lette et al. (46)	1991	360	Mixed major	Weak	MI, cardiac death	10
Modified Cardiac Risk Index						
Detsky et al. (28)	1986	455	Mixed‡	Strong	MI, cardiac death, CHF	10
Lette et al. (46)	1991	360	Mixed major	Weak	MI, cardiac death	10

* References 47 and 48 represent the same population as reference 46. References 30, 32, 43, and 49 are not included because likelihood ratios could not be calculated from the data. CHF = congestive heart failure; MI = myocardial infarction; NA = not applicable; VT = ventricular tachycardia.
† Patients having minor surgery were excluded.
‡ Patients presenting with a "question of cardiac risk."

American College of Physicians Guideline - 6

Likelihood Ratio				Post-Test Probability			
Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV
				← % →			
0.16	1.16	2.62	57	1	7	14	78
0.56	0.62	2.25	∞	5	6	24	100
0.61	1.03	4.75	No patients	7	11	38	No patients
0.22	0.93	5.44	14	1	3	15	30
0.43	2.38	2.45	∞	8	31	30	100
0.71	1.20	3.88	No patients	6	10	26	No patients
0.43	3.38	10.6	NA	5	27	60	NA
0.89	2.50		NA	8	19		NA

American College of Physicians Guideline - 7

Multivariate Cardiac Risk Indicator Variables	Cardiac Risk Index (28, 29, 31, 51–53)			Modified Cardiac Risk Index (28)		
	Variable	Points† (0–53)‡	Post-Test Probability	Variable	Points† (0–110)‡	Post-Test Probability
		n	%		*n*	%
Age	>70 years	5‡		>70 years	5	
History of MI or Q-wave on ECG	Within 6 months	10		Within 6 months	10	
				More than 6 months previously	5	
History of angina	Not independently predictive			CCS class III	10	
				CCS class IV	20	
Left ventricular dysfunction or CHF	S3 or jugular venous distention	11		Pulmonary edema within 1 week	10	
				Any previous pulmonary edema	5	
Arrhythmia	Any rhythm other than sinus	7		Any rhythm other than sinus	5	
	>5 PVCs	7		>5 PVCs	5	
Other heart disease	Important aortic stenosis	3		Critical aortic stenosis	20	
Other medical problems	Any of the following: Po_2 < 60 mm Hg, Pco_2 > 50 mm Hg, K^+ concentration < 3 mmol/L, BUN level > 50 mmol/L, creatinine concentration > 260 μmol/L, bedridden	3		Any of the following: Po_2 < 60 mm Hg, Pco_2 > 50 mm Hg, K^+ concentration < 3 mmol/L, BUN level > 50 mmol/L, creatinine concentration > 260 μmol/L, bedridden	5	
Findings for ischemia on ECG	Not independently predictive			Not independently predictive		
Type of surgery	Emergency	4		Emergency	10	
	Intrathoracic or abdominal	3				
Scores and post-test probabilities	Class I	0–5	1–8	Class I	0–15	5
	Class II	6–12	3–30	Class II	20–30	27
	Class III	13–25	14–38	Class III	>30	60
	Class IV	>25	30–100			

* End points assessed were as follows: MI, death, pulmonary edema, and ventricular tachycardia for the Cardiac Risk Index; MI, death, and CHF for the Modified Cardiac Risk Index; MI, death, UA, and pulmonary edema (57, 58) for the Eagle et al. index; and MI and cardiac death for the Vanzetto et al. index. BUN = blood urea nitrogen; CCS = Canadian Cardiovascular Society; CHF = congestive heart failure; ECG = electrocardiogram; LV = left ventricular; MI = myocardial infarction; PVC = premature ventricular contractions on preoperative electrocardiogram.

† Weight assigned to each variable.

‡ Range of possible scores.

American College of Physicians Guideline - 8

Low-Risk Index: Eagle et al. (57, 58)			Low-Risk Index: Vanzetto et al. (59)		
Variable	Points† (0–5)‡	Post-Test Probability	Variable	Points† (0–8)‡	Post-Test Probability
	n	%		*n*	%
>70 years	1		>70 years	1	
Q-wave on ECG	1		Q-wave on ECG	1	
			Any previous MI	1	
Any angina	1		Any angina	1	
			ST-segment abnormalities on resting ECG	1	
Not independently predictive			History of CHF	1	
History of ventricular ectopy	1		Not assessed		
Not assessed			Hypertension with severe LV hypertrophy	1	
History of diabetes	1		History of diabetes		
Not assessed			Not independently predictive		
All vascular surgery			All vascular surgery		
0 factors		0–3	0 factors		2
1–2 factors		6–16	1 factor		4
>3 factors		29–50	2–4 factors		4
			>5 factors		16

American College of Physicians Guideline - 9

Study (Reference)	Year	Patients	Type of Surgery	Quality Rating	Pretest Probability	Sensitivity	Specificity	Likelihood Ratio		Post-Test Probability		Blinding	
								Positive	Negative	Positive	Negative	Test	Outcome
		n			%					%			
Vanzetto et al. (59)	1996	134†	Vascular	Strong	9	0.92	0.70	3.02	0.12	23	1	+	+
Baron et al. (33)	1994	457	Vascular	Fair	5	0.32	0.65	0.91	1.05	4	5	−‡	−
Mangano et al. (68)	1991	60	Vascular	Fair	5	0.33	0.63	0.90	1.06	5	5	+	+
Sachs et al. (111)	1988	46	Vascular	Fair	4	1.00	0.73	3.70	0.00	14	0	+	+

* All studies were prospective. + = positive; − = negative.
† One hundred thirty-four patients had two or more clinical risk markers; total study sample was 457 patients.
‡ Interpreter of test result was blinded to patient identity, but clinicians were aware of thallium test results. Analysis for change in anesthetic management was done and showed no difference between groups, decreasing chances that unblinding affected management.

American College of Physicians Guideline - 10

Study (Reference)	Year	Patients	Type of Surgery	Quality Rating	Pretest Probability	Sensitivity	Specificity	Likelihood Ratio		Post-Test Probability		Blinding	
								Positive	Negative	Positive	Negative	Test	Outcome
		n			%					%			
Mangano et al. (148)	1990	474	Vascular, general	Strong	18†	0.37	0.84	2.30	0.75	33	14	+	+
Raby et al. (147)	1990	176	Vascular	Strong	7‡	0.92	0.88	7.52	0.09	38	1	+	+
Landesberg et al. (150)	1993	151	Vascular	Fair	9§	0.46	0.75	1.82	0.72	15	6	+	–
Pasternack et al. (145)	1992	385	Vascular	Fair	5	0.84	0.72	3.00	0.22	13	1	–	–
Marsch et al. (156)	1992	52	Orthopedic	Fair	12‖	0.50	0.72	1.47	0.69	19	8	–¶	–

* All studies were prospective.
† Includes congestive heart failure, unstable angina, and ventricular tachycardia.
‡ Includes ischemic pulmonary edema and unstable angina.
§ Includes unstable angina and congestive heart failure.
‖ Includes myocardial infarction, unstable angina, and atrial fibrillation.
¶ Holter monitoring was used in this study.

Ischemic Cascade

1. Supply/demand imbalance
2. Diastolic dysfunction (4 sec)
3. Systolic dysfunction (6 sec)
4. Elevated LV filling pressure
5. ECG changes (20 sec)
6. Angina (25 sec)

From Sigwart U, et al, Silent Myocardial Ischemia 1984 and Armstrong WF, Prog Cardiov Dis 1997;39:499-522

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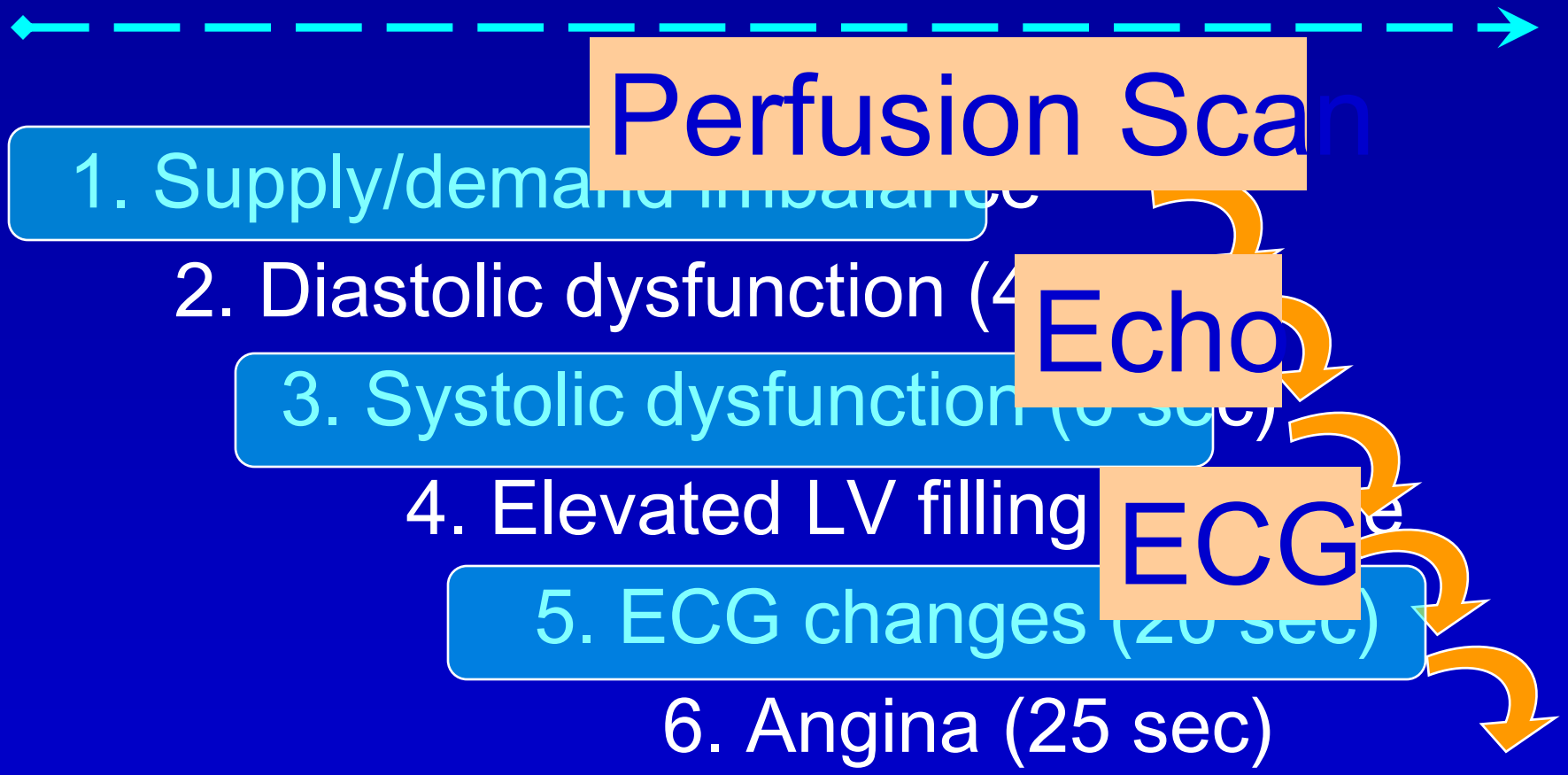
Ischemic Cascade



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