PREOPERATIVE CARDIAC RISK ASSESSMENT

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INTRODUCTION - THE SCOPE OF THE PROBLEM

Cardiovascular disease is a major health care problem in the United States, affecting one in four Americans. Of all forms of cardiovascular disease, coronary artery disease (CAD) causes the highest morbidity and mortality. It is estimated that in 1995, CAD affected 7.6 million Americans and resulted in 568,000 deaths (48). The prevalence of CAD is increasing. The prevalence of coronary artery disease is increasing largely because of a continued increase in the population of older Americans. It is estimated that 25 million people are now over the age of 65, including 2.7 million who are older than 85. By the middle of the next century, it is expected that 66 million people will be older than 65 (48). Furthermore, with advances in the medical and surgical approaches for management of cardiac disease, more patients with cardiac disease are alive and well. It is estimated that of the 27 million patients who undergo surgery in the United States each year, one million have known CAD, 2-3 million have two or more risk factors for CAD and 4 million are over the age of 65 years. Approximately one million patients develop perioperative cardiac complications which result in annual costs of $20 billion dollars for in-hospital and long-term care (50). Not surprisingly then, one of the most common reasons for which the general internists and cardiologists are consulted by their surgical colleagues is to assess the risk of postoperative cardiac events in the surgical patient. As will be discussed in more detail later, the cardiac risk is influenced significantly by the type of the surgical procedure. Patients undergoing surgery for peripheral vascular disease are at a much higher risk than the average general surgical patient. In this presentation, studies relating to a mixed population of surgical patients will be considered first, to be followed by a separate discussion of patients undergoing peripheral vascular surgery.

Prior to 1977, several retrospective studies had reported that patients with heart disease were at an increased risk for developing postoperative cardiac complications such as congestive heart failure (CHF), unstable angina (USA), myocardial infarction (MI), atrial and ventricular dysrhythmias and death from cardiac causes. In 1964, Skinner and Pearce, in a retrospective study of 766 cardiac patients (who had a preoperative evaluation of cardiovascular status by the medical service during the years 1953-1959) reported that the following factors were related to postoperative mortality (70):

1) **Type of Operative Procedure:** The mortality from relatively minor procedures such as inguinal herniorrhaphy (IH) and transurethral resection of prostate (TURP) was not increased in the cardiac patient. As the procedure became more extensive (e.g., cholecystectomy, bowel resection, subtotal gastrectomy), the mortality in the cardiac patient increased (Figure 1). Mortality was also low in patients with procedures involving the eye, head and neck and neurosurgical procedures other than craniotomy. The overall mortality in these 766 patients was 13.5%. Mortality was higher with craniotomy (50%), orthopedic procedures (22-36%), intrathoracic procedures (30%) and intraabdominal and intraperitoneal procedures (12-30%). Mortality from cholecystectomy (12%) was lower than with other intraabdominal procedures (23-30%).

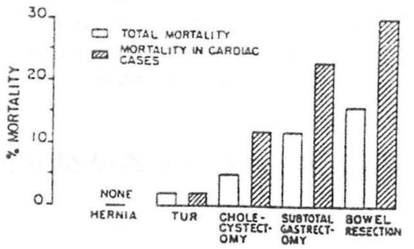


FIG. 1. A comparison of surgical mortality in cardiac cases with total surgical mortality in five selected operations.

(SKINNER, 1964)

2) **Recent Myocardial Infarction:** Mortality was 40% in patients with myocardial infarctions less than 3 months before the surgery. In patients with myocardial infarction, more than three months prior to surgery, the mortality was 14%.

3) **Hypertension:** Systolic blood pressure (BP) of >200 mmHg and diastolic BP of >110 mmHg were associated with a higher mortality following intraabdominal procedures. No increased mortality was seen with intrathoracic procedures, but most such procedures were sympathectomies.

4) **Duration of Surgery:** The mortality increased with duration of surgery. However, after controlling for the type of surgery, the length of surgery had an inverse correlation with mortality.

5) **Type of Anesthetic:** The mortality with local anesthesia (LA), spinal anesthesia (SA), and general anesthesia (GA) was 8%, 9%, and 23%, respectively. Since the type of anesthesia was directly related to the type of surgery, it was difficult to determine any direct effect of the anesthetic technique.

Other risk factors associated with high mortality were also identified: 1) Corpulmonale was associated with a mortality of 29.2%; 2) Aortic valve disease was associated with a higher mortality as compared to mitral valve disease. Overall, patients with valvular heart disease tolerated surgery better than patients with CAD or hypertensive heart disease; 3) Decreased functional capacity; the mortality increased with increasing New York Heart Association class; 4) Emergency surgery; and 5) Abnormal EKG: including atrial fibrillation (A. Fib.), first degree heart block, left bundle branch block (LBBB), right bundle branch block (RBBB), and other intraventricular conduction defects. Mitral valve disease and age of the patient were not associated with increased mortality.

All these associations were made by univariate or bivariate analysis. Multivariate analysis was not done. The problem with such an approach is that with a good history, physical examination, chest x-ray, EKG and other laboratory tests, there are more than 100 prospective variables available to be accounted for.

CARDIAC RISK ASSESSMENT IN GENERAL SURGICAL PATIENTS

THE GOLDMAN INDEX

In 1977, Goldman and his colleagues published a landmark prospective multifactorial approach for cardiac risk assessment of patients undergoing noncardiac surgery (26). The study group included 1001 patients over the age of 40 years who underwent general, orthopedic or urologic procedures. Minor operative procedures under local anesthetic, transurethral resection of prostate, and endoscopies were excluded. The authors analyzed 45 variables including age, signs and symptoms (s/s) of coronary artery disease (CAD), and CHF, functional status, DM, HTN, aortic stenosis, known cancer, signs of chronic liver disease, several variables on the EKG and chest x-ray, all available preoperative laboratory tests, the type and urgency of the operative procedure, the type of anesthesia and the training level of the surgeon. Multivariate discriminant analysis identified nine variables that had statistically significant and independent correlation with cardiac outcome. A relative weight derived from the respective discriminant function coefficients was assigned to each variable. These risk variables (with the relative weight in parentheses) in descending order of significance are:

1) S^3 gallop or jugular vein distension on preoperative examination. (11)
2) Myocardial infarction in preceding 6 months. (10)
3) Rhythm other than sinus or premature atrial contractions on preoperative electrocardiogram. (7)
4) >5 premature ventricular contractions per minute documented at any time before operation. (7)
5) Intraperitoneal, intrathoracic or aortic operation. (3)
6) Age >70 years. (4)
7) Important valvular aortic stenosis. (3)
8) Emergency operation. (4)
9) Poor general medical condition as defined by partial pressure of oxygen <60 mmHg, partial pressure of carbon dioxide >50 mmHg, potassium <3.0 or bicarbonate <20 mEq/l, blood urea nitrogen >50 or creatinine >3.0 mg/dl, elevated AST, signs of chronic liver disease or patient bed ridden from noncardiac causes. (3)

The cardiac risk of a particular patient was assessed by adding the weights of the risk factors applicable to that patient. The preoperative cardiac risk score or class clearly correlated with perioperative cardiac complications (Table 1).

TABLE 1. GOLDMAN'S CARDIAC RISK INDEX

CLASS	POINT TOTAL	LIFE-THREATENING COMPLICATIONS* N=39	CARDIAC DEATHS N=19
I (N=537)	0-5	0.7%	0.2%
II (N=316)	6-12	5%	2%
III (N=130)	13-25	11%	2%
IV (N=18)	>26	22%	56%

* Documented myocardial infarction, pulmonary edema or ventricular tachycadia without progression to cardiac death. (Goldman et al NEJM 297:845-850, 1977).

Five additional prospective studies have taken a multifactorial approach to this problem with conclusions somewhat different from those of Goldman (1,19,41,68,72). This is not surprising since there were many differences in these studies, detailed in Table 2, and summarized below:

1) **Patient Population:** The inclusion criteria for some of these studies were different from those of Goldman et al. Three studies included patient populations that would be considered to have a higher prevalence of CAD and, thus, a higher risk of postoperative cardiac complications. vonKnorring et al included patients only if they had history of a prior MI or had an abnormal EKG. (In fact, they excluded patients with chest pain with normal EKG.) Shah et al only enrolled patients with "cardiac disease" or those older than 70 years, while Detsky et al included patients referred for a medical consultation. The patient populations of Larsen and Ashton appear to be similar to the patient population of Goldman and had the same general criteria (age > 40 years). Definition of patient population included in the study is important because risk indices generated in one patient population may not be applicable to a different patient population.

2) **Types of Surgical Procedures Included:** vonKnorring, Larsen and Ashton included patients with major surgery only, whereas Detsky and Shah enrolled patients with major and minor surgery.

3) **Outcomes Measured:** The outcomes measured by the investigators varied also. Myocardial infarction was included as an outcome event by all investigators while cardiac death was included by only three investigators. Larsen and Detsky included other variables also, as detailed in Table 1. Exclusion of certain outcomes can affect the predictive ability of a risk variable. For example, in Goldman's study, preoperative CHF was found to be the best predictor of postoperative CHF. Therefore, if postoperative CHF is not included as an endpoint, significance of preoperative CHF would go unrecognized.

TABLE 2

AUTHOR # OF PTS PTS INCLUDED	vonKnorring (72) 214 H/O MI, Abnormal EKG	Detsky (19) 455 "Question of cardiac problem"	Larsen (41) 2609 Age >40 years	Shah (68) 688 Cardiac Disease or age >70 years	Ashton (1) 837 Age >40 years
Patients excluded	Chest pain with normal EKG				
Surgical procedures included	Major	Major and minor	Major	Major and minor	Major
Endpoints Measured	MI	MI,CD,PE,new or worse CHF, ACI,VT,VF	MI,CD,PE,VT, VF	MI, CD	MI
Risk Variables 1. S_3,↑ JVD(CHF,PE) 2. Prior MI (CAD) 3. Dysrhythmias atrial, ventricular 4. Type of procedure 5. Age >70 yrs 6. Aortic stenosis 7. Emergency Op. 8. Poor G.M. status	 NE YES NE NE NE NE NE NE	 YES* YES YES YES YES YES YES YES	 YES YES NO YES NO NO$ YES Cr >1.5 mg/dl	 NO YES NO*** YES YES NO$ YES K^+ <3.5 mEq/L	 YES YES** NE YES AGE>75YRS NE NE NE
Time of Prior MI Important	YES	YES	YES	NO (MI <3 MO)	NE
Hypertension	YES	NE	NO	NO	NO
Diabetes	NO	NE	YES	NO	NO
CVD	NE	NE	NO	NE	NO
USA	NE	YES	NO$	NO$	NE
Stable Angina	NO	NE	NO	NO	See above (CAD)**
No. of variables tested	8	13	70	24	4 risk categories, 12 variables
No. of endpoints measured	38	47	68	40	15
No. of endpoints necessary	40	65	350	120	60

ACI	=	Acute coronary insufficiency	CD	=	Cardiac Death
CHF	=	Congestive heart failure	JVD	=	Jugular venous distension
MI	=	Myocardial infarction	NE	=	Not evaluated
PE	=	Pulmonary edema	VF	=	Ventricular fibrillation
VT	=	Ventricular tachycardia	$	=	Few patients with risk variable
YES	=	evaluated and found significant	NO	=	evaluated and not found significant

* Defined as alveolar pulmonary edema

** Defined as history or EKG evidence of MI, angina, CAD by coronary angiogram or history of coronary artery bypass graft

*** Atrial dysrhythmias defined as PACs, atrial fibrillation or atrial flutter on <u>any</u> preoperative EKG

4) **Risk Variables Included:** Not all investigators included all the risk variables of the Goldman cardiac risk index. Some investigators tested variables not tested or labelled unimportant in Goldman's study, e.g., stable angina, diabetes, hypertension, cerebrovascular disease, unstable angina.

5) **Number of Outcome Events:** None of the studies had adequate numbers of outcome events to rigorously examine the number of variables tested. It is generally recommended that for every potential variable tested there should be at least 5 outcome events.

The results of these studies are shown in Table 3 and summarized below:

TABLE 3.

RISK PREDICTOR	NUMBER OF STUDIES TESTING IT	NUMBER OF STUDIES SHOWING POSITIVE CORRELATION
PRIOR MI	5	5
TYPE OF SURGERY	4	4
EMERGENCY OPERATION	3	3
POOR G.M. STATUS	3	3
CHF/PULMONARY EDEMA	4	3
AGE	4	3
DYSRHYTHMIAS*	3	1
AORTIC STENOSIS**	3	1
USA**	3	1
HYPERTENSION	4	1
DIABETES	4	1
CVD	2	0

* Differences in definition
** Numbers of patients with risk variable very small

All studies confirmed the significance of a previous myocardial infarction or some measure of CAD as a risk variable. Four studies examined the "type of surgical procedure" and three evaluated the "emergent nature" of the surgical procedure as risk variables, and all found positive correlation with adverse outcome. Three studies examining it, found "poor general medical status" or some measure thereof to be an important risk predictor. Three of four studies found CHF and/or pulmonary edema in the remote past or in the immediate preoperative period to be a significant predictor of adverse postoperative cardiac outcome. Shah et al did not confirm this. However, they did not include CHF or pulmonary edema as an outcome variable which may explain the lack of correlation of CHF in their study. The increasing risk with age was confirmed by 3 of 4 studies. Dysrhythmias and aortic stenosis were found to be important predictors only by Detsky et al. However, the definition of dysrhythmias by Shah et al differed from that used by Goldman and Detsky. To be characterized as a risk variable by Shah et al, atrial dysrhythmias could be present on any preoperative EKG, while Goldman and Detsky included it only if the dysrrhythmias were present in the immediate preoperative period. Thus, it is likely that by Detsky and Goldman's definition, the patients had more severe or more unstable cardiac status in the immediate preoperative period. Aortic stenosis was found to be important by Detsky only but the criteria used to include aortic stenosis as a risk variable by Shah are not clear. Both Goldman and Detsky included patients with severe aortic stenosis. Further, both Shah and Larsen had very few patients with aortic stenosis in their study populations (16 and 9, respectively). Unstable angina was also found to be important only by Detsky. The numbers of patients with unstable angina were also very small in the other two studies. Larson had only 9 patients (out of a total of 2609 patients) with USA and Shah had 25 patients. Hypertension was found to be an important predictor by vonKnorring and diabetes by Larsen. Neither of the two series examining cerebrovascular disease as a risk predictor found it to be important. *In summary, certain risk predictors including prior MI, type of surgery, emergency operation, poor general medical status, CHF and pulmonary edema and age were found to be significant in all or most investigations. There was less unanimity on other risk predictors, including USA and aortic stenosis. Most of these differences are probably secondary to differences in the study design. However, aortic stenosis and USA cannot be discounted as risk variables, because very few patients with these predictors were included in the studies that failed to find these significant.*

As discussed above, the type of surgical procedure as a risk variable was found to be important by all five investigators who examined its significance. In fact, in Goldman's study, 3 points were assigned for this risk variable. However, this did not adequately reflect the increased risk associated with abdominal aortic surgery. This was addressed by Jeffrey et al in a study of 99 consecutive patients with elective aortic surgery (34). The Goldman's index was useful in stratifying the cardiac risk of these patients but for each Goldman class, the incidence of cardiac complications was much higher in the aortic surgery group than in the original Goldman study patients (see Table 4). This investigation was carried out in the same institution where Goldman's CRI was generated, therefore, the difference could not be attributed to different patient management style or other institutional differences. *The authors concluded that Goldman's CRI grossly underestimated the risk in patients with aortic* *surgery, despite the fact that Goldman et al had assigned 3 points for aortic surgery. Thus, while Goldman's index attempted to account for type of surgery by changing the score, it did not deal adequately with changes in overall complication rates related to various types of surgery.*

TABLE 4. COMPLICATION RATES IN A PREDOMINANTLY GENERAL SURGICAL POPULATION COMPARED WITH PATIENTS WITH AORTIC SURGERY

TYPE OF SURGERY	**PREDOMINANTLY GENERAL SURGERY PATIENTS**		**PATIENTS WITH AORTIC SURGERY**		
Goldman Class	**# of pts**	**Cardiac Complications (%)**	**# of pts**	**Cardiac Complication (%)**	**P value**
1 (0-5 points)	537	1%	56	7%	0.01
2 (6-12 points)	316	7%	35	11%	NS
3 (13-25 points)	130	14%	8	38%	NS
TOTAL	983	4%	99	12%	0.01

THE DETSKY INDEX

In 1986, Detsky, et al, modified the Goldman index to include certain important variables such as USA and CCSA class (see Table 5). In addition, Detsky et al did not consider the type of surgery as a patient risk characteristic, but rather a pretest probability defined as the probability of development of cardiac complications in the entire patient population undergoing a particular surgical procedure in a particular hospital. By contrast, the post test probability is the likelihood of development of cardiac complications in a given patient and is related to the risk variables (e.g., MI, CHF, etc.) present in that patient. As shown in Table 6, the authors established overall complication rates (i.e., pretest probabilities) for various types of surgical procedures. They then calculated likelihood ratios for various score values and developed a simple nomogram (Figure 2) which enables conversion of pretest probabilities into post test probabilities. For example, the rate of severe cardiac complications in all patients undergoing carotid artery surgery at Detsky's institution is 14.8%. If a given patient has a cardiac risk score of 5, then the likelihood of a severe cardiac complication in this patient is just below 5%. On the other hand, the likelihood would be 15% for another patient with a risk score of 10 undergoing the same procedure. Thus, Detsky's index is designed to provide a more accurate prognostication for individual patients. Detsky et al, however, cautioned the clinicians to determine overall complication rates (i.e., pretest probabilities) for individual patient populations in specific settings before applying the modified index.

TABLE 5

MODIFIED MULTIFACTORIAL VARIABLES	
Variables	**Points**
Coronary artery disease Myocardial infarction within 6 mo	10
Myocardial infarction more than 6 mo	5
Canadian Cardiovascular Society angina Class III Class IV	 10 20
Unstable angina within 3 mo	10
Alveolar pulmonary edema Within 1 week Ever	 10 5
Valvular disease Suspected critical aortic stenosis	20
Arrhythmias Sinus plus atrial premature beats or rhythm other than sinus on last preoperative electrocardiogram	5
More than 5 ventricular premature beats at any time prior to surgery	5
Poor general medical status*	5
Age over 70 years	5
Emergency operation	10

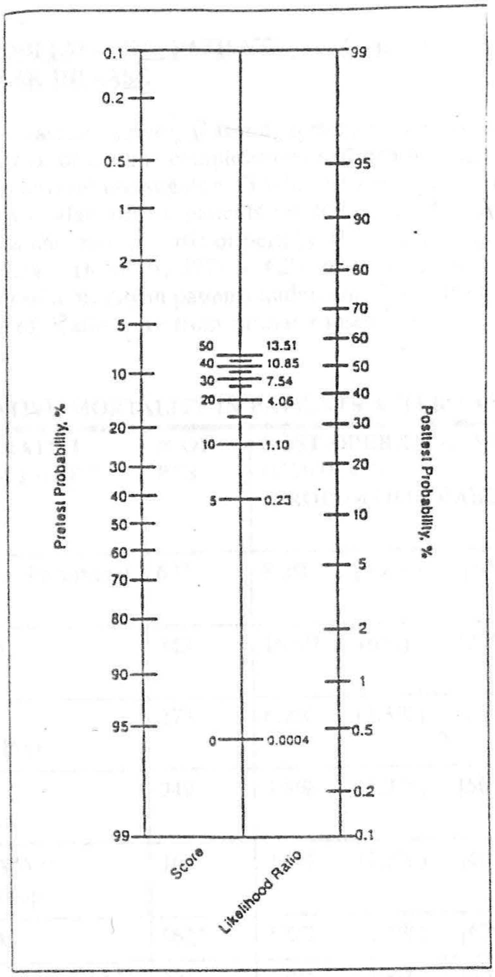
*Oxygen pressure ◄60 mm Hg; carbon dioxide pressure ►50 mm Hg; serum potassium ◄3.0 mEq/L (◄3.0 mmol/L); serum bicarbonate ◄20 mEq/L (◄20 mmol/L); serum urea nitrogen ►50 mg/dL (►18 mmol/L); serum creatinine ►3 mg/dL (►260 mmol/L); aspartate aminotransferase, abnormal; signs of chronic liver disease; and/or bedridden from noncardiac causes.

TABLE 6

PRE-TEST PROBABILITIES FOR TYPES OF SURGERY				
	SEVERE CARDIAC COMPLICATIONS*		**SERIOUS CARDIAC COMPLICATIONS†**	
Major Surgery				
Vascular	10/76	(13.2%)	16/76	(21%)
Aortic	5/32	(15.6%)	8/32	(25%)
Cartoid	4/27	(14.8%)	5/27	(18.5%)
Peripheral	1/17	(5.8%)	3/17	(17.6%)
Orthopedic	9/66	(13.6%)	12/66	(18.2%)
Intrathoracic / Intraperitoneal	7/88	(8.0%)	11/88	(12.55%)
Head and neck	1/38	(2.6%)	3/38	(7.8%)
Minor Surgery (eg. Turp. cataracs)	3/187	(1.6%)	4/187	(2.1%)

*Cardiac death, myocardial infarction, or alveolar pulmonary edema.
†Above plus coronary insufficiency and new or worsened congestive heart failure without alveolar pulmonary edema.

FIGURE 2



* Reference 19 from Detsky

The Patient with Limited Activity: "Limited activity" as a risk variable was not evaluated in any of the studies reviewed above. However, Gerson et al reported that in patients older than 65, inability to exercise for 2 minutes on a bicycle ergometer in a supine position at 50 revolutions/minute to raise the heart rate above 99 beats per minute was a very strong predictor of postoperative cardiac outcome (23,24). It gave better predictive information when compared with the Goldman indicators, left ventricular regional wall motion, and left ventricular ejection fraction at rest and with exercise. This fact must be taken into consideration when assessing patients preoperatively.

CARDIAC RISK PROBLEMS IN PATIENTS UNDERGOING SURGERY FOR PERIPHERAL VASCULAR DISEASE

Patients who have vascular surgery (carotid, aortic and peripheral vascular surgery) have an especially high risk of cardiac complications and death in the days, months and years following surgery. Several investigators (Table 7) have reported that 40-60% of all postoperative deaths in vascular surgery patients result from cardiac complications. The total mortality in patients undergoing aortic or peripheral vascular surgery in these studies ranged from 3.1% to 8.2%. However, 37% to 62% of these deaths were secondary to cardiac causes. The overall mortality in patients undergoing carotid surgery was somewhat lower but again 60-67% of deaths were from cardiac causes.

TABLE 7. POSTOPERATIVE MORTALITY IN PATIENTS AFTER VASCULAR SURGERY

AUTHOR INSTITUTION	OPERATIVE PROCEDURE	# OF PTS	POST-OPERATIVE MORTALITY TOTAL (CARDIAC) [PROPORTION CARDIAC MORTALITY]
Cooperman 1978 (9) Ohio State University	Aortic Peripheral	627	8.2% (5.1%) [62%]
Hertzer 1980 (29) Cleveland Clinic	AAA	343	16.6% (6%) [37%]
Hertzer 1981 (31) Cleveland Clinic	AoI FemPop	273	6.2% (3.3%) [53%]
Crawford 1981 (11) Baylor, Houston	AoI	949	3.8% (1.9%) [50%]
Jamieson 1982 (33) Vancouver	AAA,AoI FemPop	161	3.1% (1.2%) [40%]
Musser 1994 (54)	CEA	562*	1.6% (1.1%) [67%]
Hertzer 1981 (30)	CEA	335	3.0% (1.8%) [60%]

AAA = Abdominal aortic aneurysm repair
CEA = Carotid end arterectomy
AOI = Aorto-iliac bypass
Fem-Pop = Femoral-popliteal bypass
* 102 patients post CABG

The late mortality in these patients is also high. By 3.7 to 5 years, 20 to 42% of all patients had died and by 8-11 years, 43 to 60% of all patients had died. By 8-11 years, 19% to 24% (absolute mortality rate) of these patients had died of cardaic causes (Table 8).

TABLE 8. LATE MORTALITY IN PATIENTS AFTER VASCULAR SURGERY

AUTHOR	OPERATIVE PROCEDURE	# OF PATIENTS	3.7-5 YEARS TOTAL (CARDIAC)	8-11 YEARS TOTAL (CARDIAC)
Hertzer 1980 (29)	AAA	343	42% (16%)	60% (24%)
Hertzer 1981 (31)	AoI, Fem Pop	273	24.5% (12.5%)	43% (23%)
Hertzer 1981 (30)	CEA	335	29% (11.3%)	49% (19.4%)
Crawford 1981 (11)	AoI	949	26%	50%
Jamieson 1982 (33)	AAA, AoI, Fem Pop	161	19.8% (11%)	NA
Roger 1989 (65)	AAA	122	NA	51% (22%)

When compared with normal subjects in Olmstead County, patients with AAA repair had a poorer survival at 8 years (66% vs. 49%, P = 0.02) (65). Criqui et al reported that 10 year survival in patients with peripheral vascular disease was 52% compared with 86% in subjects without peripheral vascular disease (12). Mortality from CAD was also higher (22.4% vs. 3.7%) in patients with vascular disease [RR 5.9, CI 3.0-11.4)] (12) (Table 9). The high short term and long term mortality in vascular surgery patients is related to several factors: 1) The high prevalence of CAD in these patients, 2) The high prevalence of other co-morbid illnesses such as diabetes mellitus and 3) The high surgical stress of a vascular procedure.

TABLE 9. SURVIVAL OF PATIENTS WITH VASCULAR DISEASE COMPARED WITH NORMAL SUBJECTS DURING AN OBSERVATION PERIOD OF 8-10 YEARS

REFERENCE	PATIENTS WITH VASCULAR DISEASE	NORMAL SUBJECTS
Roger 1989 (65)	49%	66%
Criqui 1992 (12)	52%	86%

Prevalence of CAD in Patients with Peripheral Vascular Disease. The high rate of postoperative cardiac mortality led several investigators to perform coronary angiograms in all patients with peripheral vascular disease. Not surprisingly a very high proportion of patients had significant CAD, but more importantly it was found that many patients with no clinical suspicion had significant CAD. In a classic study, coronary angiography, was performed in 1000 consecutive patients who were referred to Cleveland Clinic for elective peripheral vascular surgery (32) (Table 10). Fifteen per cent of the patients had a 3 vessel disease (>70% stenosis) or left main (>50% stenosis). In addition, 57% had at least one-vessel disease, and only 8% had normal coronary arteries. As expected, the prevalence of more serious CAD was higher in patients with clinical suspicion of CAD (prior MI, angina, or abnormal EKG) than those without (Tables 10 and 11). Other investigators have reported similar findings (3,56) (Table 11).

TABLE 10. PREVALENCE OF CAD IN PATIENTS WITH PERIPHERAL VASCULAR DISEASE

	ALL PATIENTS	CAD SUSPECTED	CAD NOT SUSPECTED (446 PTS)
Normal coronary arteries.	8%	4%	14%
Mild to moderate CAD. No lesion >70% stenosis.	32%	18%	49%
Advanced but compensated CAD. At least one lesion >70% stenosis. No myocardium at jeopardy.	29%	34%	22%
Severe correctable disease ≥1 coronary artery. >70% stenosis. Myocardium at jeopardy.	25%	34%	14%
Severe inoperable disease. ≥1 coronary artery. >70% stenosis. Disease distal or diffuse or severely decreased EF.	6%	10%	1%

(HERTZER ET AL, ANNALS OF SURGERY 199,223-233, 1984)

TABLE 11. PREVALENCE OF CAD IN PATIENTS WITH VASCULAR DISEASE

REFERENCE	SEVERITY OF CAD	NUMBER OF VESSELS INVOLVED			
		1	2	3	LEFT MAIN
Hertzer 1984 (32)	>70% stenosis	27%	19%	11%	2%
" (32)	>50% stenosis	23%	20%	18%	4%
Blombery 1987 (3)	>50% stenosis	20%	29%	21%	10%
Orechhia 1988 (56)	>70% stenosis	32%	11%	32%	

<u>Prevalence of CAD in Asymptomatic Patients.</u> More significantly, several investigators have established that many patients with no clinical suspicion of CAD, have significant CAD. Sixteen to 64% of patients have been reported to have at least one vessel disease and 14% to 29% have been reported to have 3 vessel or left main disease (Table 12).

TABLE 12. PREVALENCE OF CAD IN ASYMPTOMATIC PATIENTS WITH VASCULAR DISEASE

REFERENCE	SEVERITY OF CAD (PERCENT STENOSIS)	NUMBER OF VESSELS INVOLVED	
		AT LEAST ONE	3 OR LEFT MAIN
Hertzer 1984 (32)	>70%	37%	15%
Tomatis 1972 (71)	>50%	28%	NR
"	>70%	16%	NR
Blombery 1987 (3)	>50%	NR	14%
Orechhia 1988 (56)	>70%	64%	29%

NR = not reported

There are varied reasons for the absence of cardiac symptoms in patients with peripheral vascular disease and concomitant CAD. Patients are usually older with limited physical activity due to claudication or other disorders such as degenerative joint disease, chronic obstructive pulmonary disease, neurologic impairment, amputations or sedentary life style. Many patients have diabetes and are, therefore, more prone to suffer from silent ischemia.

HOW TO RECOGNIZE THE VASCULAR SURGERY PATIENT AT RISK?

As discussed earlier, the clinical risk index of Goldman did not perform well in AAA repair patients (34). Other investigators have corroborated this lack of correlation with Goldman index (43,51). Lack of correlation with the Detsky index (20) and clinical markers of CAD has also been reported (4,5,8,14,20,42,67).

Several tests have, therefore, been devised to assess the cardiac status of patients undergoing peripheral vascular surgery. Some of the noninvasive strategies that have been extensively studied and found useful are:

1) Exercise stress test.

2) Stress myocardial scintigraphy (Dipyridamole Thallium Scanning).

3) Stress echocardiography (Dobutamine Stress Echocardiography).

4) Ambulatory EKG monitoring assessment of ischemia.

Exercise Stress Test. Exercise test (ETT) can be helpful in those patients who are able to exercise despite peripheral vascular disease. In a study of 130 patients, Cutler et al observed that such patients could be grouped into 4 categories (Table 13) (13). Patients with a positive ETT at low workload [heart rate achieved <75% of maximum predicted heart rate (MPHR)] had a very high incidence of adverse cardiac events (mortality 18.5%, nonfatal MI 7.4%). On the other hand, patients with a negative test at a high workload had no complications. Further, the patients could be stratified by their ability or inability to achieve a heart rate >75% MPHR. Only one of 58 patients (1.7%) who were able to achieve a heart rate >75% MPHR had a nonfatal MI. On the other hand, in the group of 72 patients unable to achieve >75% MPHR 6 patients (8.3%) had fatal MI and 2 patients (2.7%) had nonfatal MI. McPhail et al reported similar experience in their patients (52).

TABLE 13.
POSTOPERATIVE COURSE OF PATIENTS COMPARED WITH RESULTS OF ETT

NO. OF PTS.	MPHR	EKG	ALL CARDIAC EVENTS*	MI (FATAL)	MI (NON-FATAL)
27	<75%	Abnormal	10(37%)	5(18.5%)	2(7.4%)
35	>75%	Normal	0(0%)	0(0%)	0(0%)
23	>75%	Abnormal	6(26%)	0(0%)	1(4.3%)
45	<75%	Normal	6(13%)	1(2.2%)	0(0%)

MPHR = Maximum predicted heart rate   * Fatal and nonfatal MI, CHF,ischemia

(CUTLER, AM J SURG 141:501-506, 1981)

The problem with this approach is that very few patients with vascular disease are able to exercise. In several large series, anywhere from 27% to 100% of the patients were unable to exercise (4,42,60).

<u>Dipyridamole Thallium Scanning (DTS).</u> Pharmacologic stress testing using dipyridamole with thallium perfusion imaging has been extensively studied in patients with vascular disease. Dipyridamole given intravenously causes coronary vasodilation in normal vessels, but fixed coronary stenosis prevents or attenuates this response. The coronary flow response to dipyridamole is similar to that obtained with exercise but without the accompanying increase in myocardial oxygen demand. The patients do not have to exercise or reach a target heart rate.

Briefly, study protocols have used dipyridamole 0.56 mg/kg infused over 4 minutes with thallium 201 injected 3 to 5 minutes later. Thallium myocardial scanning is done immediately after thallium injection and delayed scanning is done 3 to 4 hours later. A normal scan suggests that myocardial blood supply is preserved. The presence of initial myocardial defects that redistribute on delayed scans indicate viable but ischemic myocardium, and the presence of fixed defects on initial and delayed images in most cases represent myocardial scar.

Since 1985, several groups have investigated the value of dipyridamole-thallium 201 scanning in the preoperative assessment of the peripheral vascular surgery patients (4,5,8,10,14,20,22,42,43,49,51,53,67,73). The populations studied by most of these investigators were similar (most patients were referred for dipyridamole thallium by their physicians because of a high suspicion of CAD). However, the outcomes measured differed, e.g., some investigators only included myocardial infarction and death from cardiac causes as outcome events, while others included various combinations of additional outcomes such as CHF, pulmonary edema, unstable angina, ventricular tachycardia, ventricular fibrillation and myocardial revascularization. The sensitivity, specificity, positive predictive value and negative predictive values from some of these studies are listed in Table 14.

TABLE 14. DIPYRIDAMOLE THALLIUM IMAGING FOR PREOPERATIVE ASSESSMENT OF CARDIAC RISK

AUTHOR	# OF PTS	ENDPOINTS (MI/CD) (%)			
		SENS	SP	PPV	NPV
Brewster 1985 (5)	54	100	73	20	100
Boucher 1985 (4)	54	100	71	18	100
Leppo 1987 (42)	89	93	62	33	98
Cutler 1987 (14)	106	100	67	23	100
Sachs 1988 (67)	46	100	72	14	100
Fletcher 1988 (22)	67	100	93	33	100
Younis 1990 (73)	111	76	67	15	97
Lette 1991 (43)	125	100	56	21	100
Mangano 1991 (49)	60	33	63	4.5	95
McPhail 1993 (53)	100	67	74	20	96
Bry 1994 (8)	237	71	55	11	96
Baron 1994 (2)*	457	36*	65*	19*	83*

CD = Cardiac death
MI = Myocardial infarction
NPV = Negative predictive value
PPV = Positive predictive value
Sens = Sensitivity
Sp = Specificity

* = All cardiac events including all deaths, MI, CHF, VT, VF, prolonged ischemia.

To make reasonable comparisons across studies, only myocardial infarction and cardiac death were considered as outcomes and an abnormal DTS was defined as presence of reversible defects. With these criteria, dipyridamole thallium scanning was found to be superior to clinical markers of CAD (4,5,8,14,20,42,67) to the Goldman index (43,51), to the Detsky index (20), and to ETT (42,53).

Two studies reported recently have questioned the value of DTS (2,49) and deserve some comment. Both studies enrolled consecutive patients without regard to their clinical status (i.e., clinical risk markers, ability to exercise ...). It is likely, therefore, that low prior probability of CAD contributed to a low PPV in these investigations. In one of these investigations, the prevalence of several clinical risk variables was much lower than many other studies (2) (see Table 15). Further, in the study by Mangano et al (49), the perioperative hemodynamics were tightly controlled, resulting in less than 10% rate of tachycardia, hypotension or hypertension (intraoperative hypotension is associated with adverse postoperative cardiac outcome). This further complicates the interpretation of their data.

TABLE 15. PREVALENCE OF CLINICAL RISK VARIABLES IN PATIENTS

AUTHORS	AGE (YRS)	MI (%)	ANGINA(%)	CHF (%)	DM (%)	HTN (%)
Eagle 1989	66	23	29	9.5	18	-
Leppo 1987	68	39	45	10	18	69
Younis 1990	65	20	23	-	30	57
Bry 1994	66	31	18	11	34	68
Lette 1991	-	42	38	8	24	52
Costello 1993	66	42	30	8	21	-
Baron 1994	69	16	19	3	8.7	48

CHF = Congestive heart failure   DM = Diabetes mellitus
HTN = Hypertension   MI = Myocardial infarction

In conclusion, therefore, a normal DTS should reassure the physicians and their patients. A positive test indicates an increased risk (albeit less than 35%) for cardiac complications especially in selected patients with high suspicion of stable CAD. However, even though DTS is superior to clinical markers, the PPV value of the standard DTS is not particularly high. Several strategies have been devised to improve the PPV of DTS. These are detailed below:

1) Use of Clinical Criteria. Eagle et al demonstrated that PPV and the specificity of DTS can be improved by combining certain clinical variables with DTS (20) (Figure 3). The clinical predictors found to be associated with a

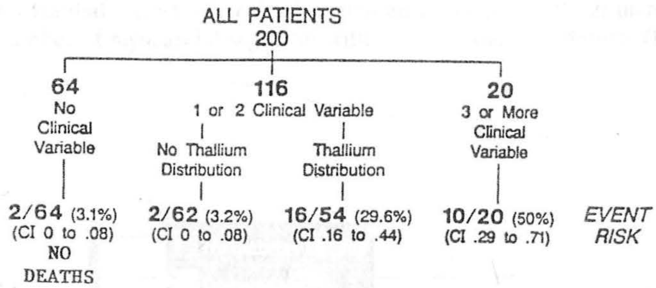


FIGURE 3

(EAGLE, ET AL. ANN INTERN MED 110:859-866, 1989)

high adverse cardiac outcome were: Q waves on the EKG, angina, history of ventricular ectopy that has required treatment, DM that has required treatment, and age greater than 70 years. In a group of 200 patients who underwent peripheral vascular surgery, patients with none of the above risk factors had only a 3.1% incidence of postoperative cardiac complication (with no deaths), whereas those with 3 or more risk factors had a 50% incidence of cardiac events. The DTS was useful primarily in patients with one or two risk factors. The patients with no thallium redistribution had a cardiac complication rate of 3.2%, similar to the low-risk patients who had no risk factors. In contrast, patients with one or two risk variables and evidence of redistribution on DTS were found to have a complication rate of 30%. Use of these risk predictors increased the PPV from 30% when the results of the DTS were used alone to 43% when clinical risk factors were included. Thus, it appears that results of DTS are most helpful in patients found clinically to be at intermediate risk of cardiac complications and patients who cannot exercise and hence their risk status cannot be estimated on the basis of clinical factors alone.

2) Quantitative and Semiquantitative Analysis of DTS. Recent reports suggest that it may be possible to further refine the predictive power of DTS based on a more quantitative analysis of the DTS images. For quantitative analysis, investigators have divided the myocardium into several segments, different coronary artery territories or simply assessed the number of views with thallium redistribution defects (38,45). The number of total segments varies with different investigators. Brown and Rowen divided the myocardium into 9 segments (3 segments in each planar view) (6). The risk of perioperative myocardial infarction or death increased in parallel with an increase in the number of myocardial segments with transient thallium defects (Figure 4).

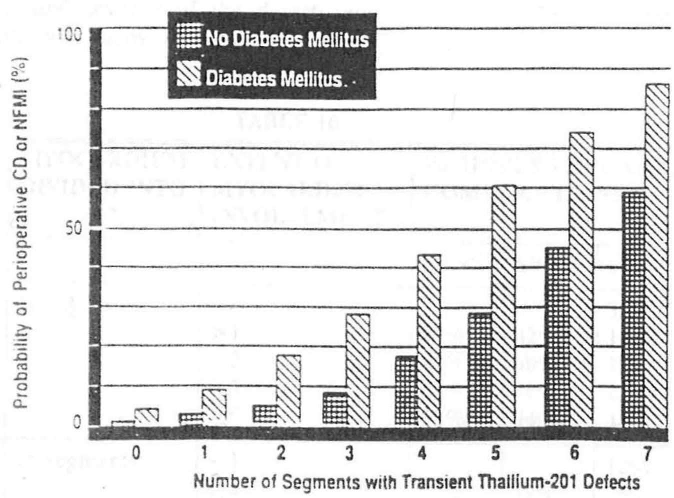


FIGURE 4

Lane, in a ten segment model, reported a greatly increased positive predictive value with increasing numbers of abnormal segments (38) (Table 16). However, as expected, as the positive predictive value of the test increased, the sensitivity fell. Levinson et al, analyzed the thallium scans for the number of segments out of 15, the number of thallium views out of 3 and number of coronary artery territories with redistribution. DTS predictors of ischemic complications included thallium redistribution in ≥ 4 myocardial segments, ≥2 of the 3 planar views and ≥ 2 coronary territories. Of these, thallium redistribution in >1 view was the strongest predictor regardless of the number of segments involved in that view. Lette et al 1992, developed a different model which divides the myocardium into 3 segments and not only considers the number of myocardial segments involved, but also the severity of the defects and the presence or absence of dipyridamole induced transient dilatation of the left ventricular cavity. The complication rate increased in parallel with the number of segments with thallium redistribution, with increased severity of the defects and with occurrence of transient left ventricular cavity dilation.

TABLE 16.

REFERENCE	NO. OF PTS.	MYOCARDIUM DIVIDED INTO	EXTENT OF MYOCARDIAL INVOLVEMENTS	PERIOPERATIVE CARDIAC COMPLICATIONS			
				SENS	SPEC	PPV	
Lane 1989** (38)	101*	10 segments	0			3.3%	
			≥1	91%	32%	14%	97%NPV
			≥2	81%	56%	18%	
			≥3	55%	76%	21%	
			≥5	36%	94%	44%	
Levinson 1990*** (45)	62	15 segments	≤3			12%	
			≥4	82%	49%	38%	88%NPV
		3 views	one view			0%	
			2-3 views****	100%	33%	36%	100%NPV
		3 coronary territories	one territory			13%$	
			2-3 territories	76%	62%	43%	87%NPV

* All had diabetes
** Outcomes = Cardiac deaths, non-fatal MI, unstable angina, CHF
*** Outcomes = cardiac deaths, MI, ischemic pulmonary edema, unstable angina
**** Strongest predictor
$ No MI or death

In conclusion, quantitative DDS analysis improves its PPV, but the test needs to be standarized.

3) Late Imaging and Reinjection Imaging. Another approach that has been used to improve the PPV of dipyridamole thallium is late imaging or reinjection imaging. Recent investigations indicate that nonreversible myocardial defects on DTS do not necessarily represent a scar. In early to mid 1980s, it was noted that some fixed imaging defects reversed after coronary angioplasty or CABG (25,46). Brunken et al found that several myocardial areas of non-reversing thallium defects were metabolically active by positron emission tomography (7). Work by Kiat et al 1988 has suggested that myocardial segments supplied by severely stenotic vessels are less likely to show reperfusion at 4 hours (37). Further, they suggest that a vast majority of such ischemic but viable myocardial segments can be identified by repeating images at 18 to 24 hours (37). The late reversibility has been shown to be associated with normal or hypokinetic wall motion and a paucity of Q waves (28). In Kiat's investigation of 21 patients studied before and after myocardial revascularization, there were a total of 122 myocardial segments with perfusion defects that were nonreversible at 4h imaging. Of these, 74 (60%) segments showed late reversibility and 48 did not. On postintervention images, 70/74 segments (95%) with late reversibility improved while only 18 of 48 (37%) late nonreversible defects showed improvement. Dilsizian et al showed that similar results could be achieved by giving a second dose of thallium immediately before the delayed images are taken (17).

McEnroe and Costello reported a relatively high incidence (27% and 13%, respectively) of perioperative cardiac events in vascular surgery patients with fixed defects on DTS, thus, diminishing the predictive accuracy of the test, if the test is defined as being abnormal only if thallium redistribution is present at three to four hours (10,51). It is possible that use of reinjection of thallium or delayed imaging at 18h to 24h will further improve the predictive accuracy of DTS.

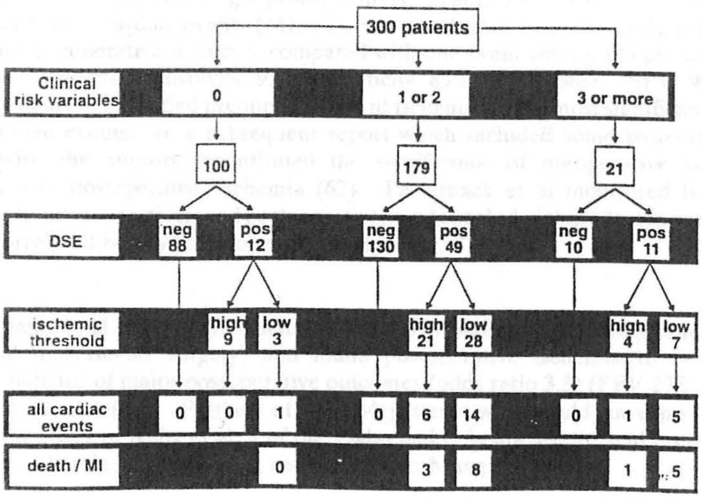
Dobutamine Stress Echocardiography. The use of dobutamine stress echocardiography (DSE) in preoperative evaluation of patients is still relatively new. Results from four studies are tabulated in Table 17. It appears that the PPV of the DSE is around 20% with a NPV of 100%. These results appear very similar to those during early experience with DTS. In a recent large study of 300 patients, Poldermans et al reported that the PPV of the test could be increased by considering the heart rate threshold at which ischemia occurred and by combining the results with the Eagle criteria (60) (Figure 5).

TABLE 17.
DOBUTAMINE STRESS ECHOCARDIOGRAPHY FOR PREOPERATIVE RISK ASSESSMENT IN PATIENTS WITH VASCULAR SURGERY

REFERENCE	# OF PTS	NWMA	MI/DEATH	SENSITIVITY	SPECIFICITY	PPV	NPV
Lane et al 1991*	38	19(≥2)	3	100%	56%	17%	100%
Langan 1993	72**	20(≥1)	3	100%	81%	19%	100%
Poldermans 1995	300	72(≥1)	17	100%	81%	24%	100%
Davila-Roman 1993	78**	10 (≥1)	2	100%	89%	20%	100%

MI = Myocardial infarction
NWMA = New wall motion abnormality with number of abnormal segments in parentheses
NPV = Negative predictive value
PPV = Positive predictive value

* 25 patients with vascular surgery and 13 patients with nonvascular procedures.
** Patients who underwent surgery without prior CABG.



(POLDERMANS ET AL, JACC 26:648-653, 1995)

FIGURE 5

Of 38 patients who developed ischemia at a low ischemic threshold (a heart rate <70% of the age-corrected maximal heart rate), 5 patients suffered a cardiac death and 8 had nonfatal infarction (34% combined CD and MI). In 34 patients with ischemia at a higher heart rate (>70% MPHR), 4 (12%) patients had myocardial infarction but none died. Using an approach similar to Eagle, the investigators found that only one of 100 patients with none of the five clinical factors of Eagle et al (angina, diabetes requiring drug therapy, age >70 years, Q waves on EKG and history of ventricular ectopic activity requiring treatment) had an ischemic event (USA). This occurred in a group of 3 patients with positive DSE at a low ischemic threshold. No infarctions or cardiac death were seen in this group. No events were seen in 9 patients with positive DSE at a high ischemic threshold in this group. Of 179 patients with 1 or 2 Eagle markers, no events were seen in 130 patients with negative DSE, whereas 11 of 49 patients (22.4%) with positive DSE suffered infarction or death. Further risk could be stratified by considering the ischemic threshold. Eight events (MI or death) were seen in 28 (28.5%) patients who developed an abnormal test at a low ischemic threshhold while only 3 events occurred in 21 patients (14%) with a high ischemic threshhold. The authors claim that even patients with 3 or more Eagle criteria can have their risk stratified further by DSE. Patients with 3 or more markers and abnormal DSE at a low ischemic threshhold had the highest risk (5/7 events PPV 71%). The initial experience with DSE reveals that this test probably has predictive accuracy similar to DTS.

<u>Ambulatory Ischemia Monitoring.</u> An alternative approach to DTS and DSE is ambulatory ischemia monitoring. Several investigators have monitored patients preoperatively, intraoperatively and postoperatively (Table 18). Raby et al, reported 12 major postoperative cardiac events (MI, CD, USA, ischemic PE) among 32 patients with asymptomatic preoperative ischemia, compared with one event among 144 patients without preoperative ischemia (sensitivity 92% specificity 89%, PPV 38%, NPV 99%) (61). Multivariate analysis identified preoperative silent ischemia as the most significant predictor of postoperative events. In a subsequent report which included some patients from the current report, the authors reconfirmed the significance of preoperative ischemia in comparison with postoperative ischemia (62). Pasternack et al monitored the patients preoperatively, intraoperatively and postoperatively and concluded that adverse perioperative outcomes correlated best with preoperative ischemia (58).

Mangano et al, on the other hand, studied 474 patients (including patients having vascular and nonvascular surgery) and found postoperative ischemia to be the most significant predictor of major postoperative outcomes (odds ratio 3.3) (PPV 27% all events, 7% ischemic events) (47). Further, of the 144 patients who would have met the entry criteria for the study of Ruby et al, 5 of the 7 who had ischemic events had no evidence of preoperative ischemia. Ouyang et al concurred with Mangano (57).

TABLE 18. AMBULATORY ELECTROCARDIOGRAM MONITORING FOR PREOPERATIVE CARDIAC RISK ASSESSMENT

TYPE OF OPERATIVE PROCEDURE (REF)	# OF PTS	BEST CORRELATION WITH	PPV		NPV	
			ALL EVENTS	MI/CD	ALL EVENTS	MI/CD
Vascular (Raby 1989) (62)	274	preoperative ischemia	38%	NA	99%	NA
Vascular (Pasternack 1989) (58)	200	preoperative ischemia	NA	8%	NA	100%
Vascular (Ouyang 1989) (57)	24	Postoperative ischemia	53%	13%	89%	100%
Vascular and Nonvascular (Mangano 1990) (47)	474	postoperative ischemia	27%	7%*	88%	99%*

* All ischemic events (cardiac death, nonfatal MI, unstable angina)

Overall, the positive predictive values of ambulatory EKG monitoring appears to be lower than that of DTS or DSE, and there is considerable controversy about the significance of preoperative, intraoperative and postoperative ischemia. Further, there are some technical limitations as well. In about 10% of patients, the electrocardiogram is inadequate for the detection of myocardial ischemia (due to baseline EKG changes or due to technical problems with monitoring process). The efficacy, incremental value, and cost effectiveness of silent ischemia monitoring in comparison with DTS and DSE is also not clear. Therefore, at the present time, its role in preoperative cardiac risk assessment is unclear. Its best use may very well be in postoperative monitoring of high risk patients.

HOW TO APPROACH A PATIENT SCHEDULED FOR SURGERY AND HOW TO MINIMIZE THE RISK

The following remarks represent an "empiric" approach derived from an extensive review of the literature and personal experience. At present, there are no definitive data available to provide firm guidelines. At the outset, it must be emphasized that although perioperative hemodynamic monitoring is suggested for many situations, no decisive data exist to make this an absolute recommendation. Its use seems to be logical and some uncontrolled investigations seem to support this recommendation (63,66). Further, there is no definite data available to indicate that the perioperative use of beta blockers or nitrates affects the outcome. Beta blockers have been shown to reduce the frequency and duration of perioperative ischemia (59). Further, in most situations, myocardial revascularization is advised for the usual indications that would apply to any patient, with or without a planned noncardiac procedure.

THE GENERAL SURGERY PATIENT

The cardiac risk indices of Goldman and Detsky have worked well for risk stratification of the general surgery patient. A good history, physical examination, chest x-ray, EKG and basic laboratory tests suffice for evaluation. In using these indices, the activity level of the patient must be specifically addressed to ensure reliable exclusion of angina. The goal then is to minimize the number of risk points accumulated by the patient. This can best be done by optimizing the patient's medical regimen and by selecting an appropriate time for the surgical procedure in a patient with a recent MI. Some specific issues that need to be addressed are:

1) Management of patients with ischemic heart disease.

2) Management of patients with congestive heart failure.

3) Management of patients with significant aortic stenosis.

Ischemic Heart Disease

Patient with recent MI. Most investigators agree that the patient with recent MI (within the last 3 to 6 months) are at a high risk, although the risk is much lower today as compared with the pre-1970's era (63,68). The risk is also modulated by the patient's post-MI course. The contemplated surgical procedures in these patients can be categorized as follows: 1) Emergent: If the planned surgical procedure is truly emergent and potentially life-saving, optimise medical treatment and consider aggressive perioperative hemodynamic monitoring and medical treatment with beta blockers and/or nitrates, 2) Elective: Purely elective procedures should be postponed for at least 3 months and preferably for 6 months or until the patient has reached his baseline, and 3) Semi-Elective: One example of such a procedure would be a potentially resectable tumor. The approach to these patients has to be individualized. If the patient had an uncomplicated MI and the post-myocardial infarction risk stratification finds the patient to be at low risk for recurrence, the surgery can probably be performed 6 weeks to 3 months after the MI. However, if the patient is unstable or has indicators of high risk, coronary angiography and myocardial revascularization should be considered prior to the noncardiac surgical procedure.

Unstable or Disabling Angina Despite Optimal Medical Regimen:

As discussed earlier, no specific data exist to assess the risk of such patients. Most physicians would give serious consideration to myocardial revascularization prior to noncardiac surgery. If the patient is not a suitable candidate for MR, and the operative procedure is absolutely necessary, then optimize medical regimen and consider aggressive perioperative monitoring and medical treatment as discussed below for the high risk vascular surgery patient.

Remote MI With Stable Angina:

These patients are at high risk also. The approach here depends on the planned operative procedure. If the procedure has a low prior probability of cardiac complications (e.g., cataract extraction), then it is safe to proceed with surgery. On the other hand, if the planned procedure has a high prior probability of cardiac complications (e.g., a retroperitoneal procedure), further risk stratification should be done with an exercise test, DTS or DSE. Patients judged to be at low risk can proceed to surgery. The options for the high risk patient, depending on the degree of risk include a) coronary angiography and revascularization if the anatomy is suitable and patient meets the usual indications for myocardial revascularization, or b) aggressive perioperative monitoring and treatment in the patient who is not a suitable candidate for myocardial revascularization.

Congestive Heart Failure:

These patients have a very high risk for occurrence of postoperative pulmonary edema. In addition, in Goldman's study, patients with decompensated CHF immediately prior to surgery had an extremely high mortality rate (26,27). Congestive heart failure needs to be adequately treated prior to elective surgery. Patients needing emergent surgery should have perioperative invasive hemodynamic monitoring.

Aortic Stenosis:

Patients with critical aortic stenosis are at a high risk, although data suggest that a majority of these patients can tolerate surgery under careful perioperative management (55). Patients who are candidates for valve replacement should have it done prior to elective noncardiac surgery. Balloon aortic valvuloplasty may be considered in symptomatic patients who are not candidates for aortic valve replacement.

THE VASCULAR SURGERY PATIENT

As discussed earlier, the patients undergoing peripheral vascular surgery have a high prevalence of CAD, a high perioperative cardiac mortality and a reduced survival compared with normal subjects. During the cardiac risk assessment of such patients, the question most commonly asked is: whether or not myocardial revascularization should be performed prior to the vascular procedure.

When considering this question, the short-term and long-term benefits of myocardial revascularization must be weighed against the collective risk of cardiac catheterization, coronary artery bypass grafting and the delaying of the vascular procedure. Cardiac catheterization in the general population is associated with a 0.1-0.2% mortality and 0.5% to 1.0% morbidity (MI, CVA, peripheral arterial thromboembolism and arterial dissection) (16,36,69). Further, delaying the vascular procedure in patients with abdominal aortic aneurysm, increases the risk of aneurysmal rupture (18,32). In addition, both the benefits and the risks from coronary artery bypass grafting may be higher in patients with peripheral vascular disease than patients without PVD. In the European Coronary Surgery Study, the 5 year survival of the patient <u>with</u> vascular disease in the surgical and medical arms was 89% and 66%, respectively, compared with 92.4% and 83.1% in the total group. At 10-12 years, the survival in the surgical and medical arms of patients with PVD was 65% and 46% respectively compared with 70.6% and 66.7% in the total sample. On the other hand, data from the Coronary Artery Surgery Study (CASS Registry), reveals that the operative mortality in patients with PVD was 4.2% as compared with 2.9% in patients without peripheral vascular disease (P = 0.02) (64).

All these facts must be taken into consideration when assessing such patients. One approach to the vascular surgery patients is described in the algorithm on page 30.

The cardiac risk of a patient is assessed by using Detsky criteria, the Eagle criteria and by assessing the patient's activity level.

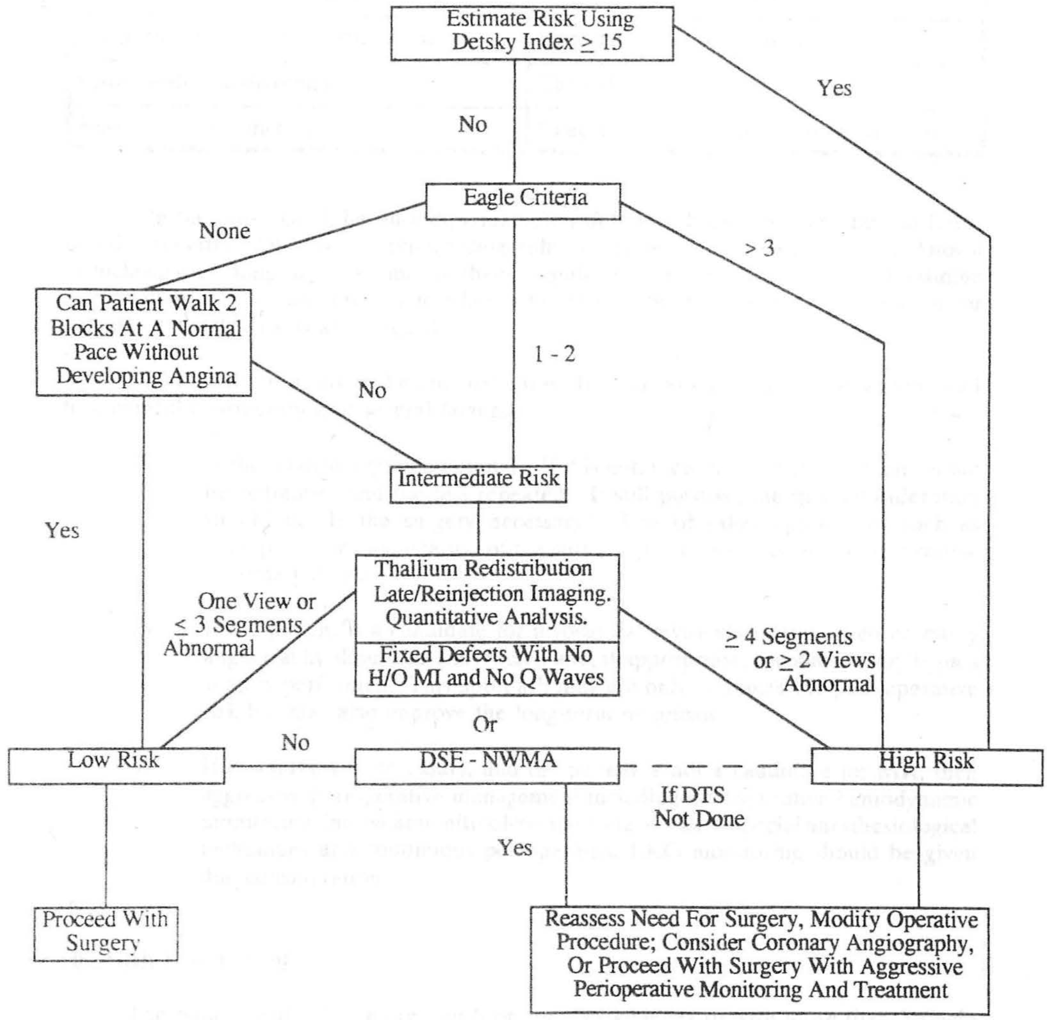
<u>The Low Risk Patient</u>

The patient who has 10 points or less on Detsky criteria, has none of the Eagle criteria and is capable of walking two blocks without angina, is at low risk and can proceed to surgery.

<u>The Intermediate Risk Patient</u>

If the patient described above is unable to walk 1-2 blocks, or has 1-2 Eagle criteria, the risk probably is at an intermediate level and further risk stratification is needed. This can be done either with a DTS or DSE, the predictive accuracy of the two tests is very similar. The test used will depend, in part, on local experience and expertise but there are some clinical situations where one method may be preferred. Because dobutamine can induce atrial and ventricular arhythmias and causes increases in blood pressure and myocardial contractility, DTS is the preferred test in patients with known cardiac arrhythmias and symptomatic or large aortic aneurysms. DTS is also preferable in patients with known left ventricular dysfunction, where the extent and severity of inducible ischemia is of paramount importance (35).

APPROACH TO CARDIAC RISK STRATIFICATION
FOR PATIENTS HAVING PERIPHERAL VASCULAR SURGERY



USE OF DIPYRIDAMOLE VERSUS DOBUTAMINE ECHO

DIPYRIDAMOLE THALLIUM	DOBUTAMINE ECHO
Large or symptomatic aortic aneurysm	Bronchospastic lung disease
Prior cardiac arrhythmias	Carotid artery stenosis
Known LV dysfunction	Need to assess LV or valvular function

On the other hand, because dipyridamole can induce bronchospasm and can lower blood pressure, dobutamine echocardiography is preferred in patients with known bronchospastic lung disease and perhaps significant carotid stenosis. Dobutamine echocardiography is also preferable when information about left ventricular function or valvular heart disease is also needed.

If either test is positive, then the patient is obviously at a high risk. This should lead to a careful consideration of several factors:

1) Is the medical regimen optimal? If it is not, then the medical regimen should be optimized and the test repeated. If still positive, the next consideration should be: Is the surgery necessary? Use of other approaches such as angioplasty or modification of the surgical procedure may be the best course in some patients.

2) If the patient is a candidate for myocardial revascularization, then coronary angiography should be undertaken and, if appropriate, coronary artery bypass surgery performed. This approach may not only minimize the post-operative risk but may also improve the long-term prognosis.

3) If the surgery is necessary, and the patient is not a candidate for MR, then aggressive perioperative management including intraoperative hemodynamic monitoring, intravenous nitroglycerine, beta blockers, special anesthesiological techniques and continuous postoperative EKG monitoring should be given due consideration.

<u>The High Risk Patient</u>

The patient with 15 or more points on the Detsky index or with more than 3 Eagle criteria is also at high risk. If the results of Poldermans et al are confirmed by other investigators, then further risk stratification in patients with >3 Eagle criteria may be achieved by DSE. If it is negative, the patient's risk is low. If DSE is positive, especially at a low ischemic threshold, then the patient is at a very high risk. Such patients should have coronary angiography and myocardial revascularization, if appropriate. If the patient is not a suitable candidate for MR, the medical regimen is optimal and the surgical procedure is essential, then careful perioperative management as discussed above is recommended.

To summarize, patients with cardiac disease are at high risk for postoperative cardiac complications, especially those older than 70-75 years of age, with a recent MI, decompensated CHF or poor general medical status or those having emergency surgery. Despite absence of specific data, individuals with unstable angina and critical aortic stenosis should be treated as high risk patients. The type of surgery profoundly affects the outcome. Patients having vascular surgery are at the highest risk. Severe CAD can be present despite absence of clinical markers. This not only leads to increased perioperative risk but also to a shortened life span. Several strategies such as ETT, DTS and DSE are available for risk stratification. Myocardial revascularization should be considered after evaluating the overall risk of coronary angiography, morbidity and mortality resulting from CABG or PTCA and from delaying the vascular procedure. Benefits include a decrease in perioperative morbidity and mortality relating to the vascular surgery procedure and a prolonged survival. An algorithm for management of these patients is presented.

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