Postoperative Myocardial Infarction and Cardiac Death

Predictive Value of Dipyridamole-Thallium Imaging and Five Clinical Scoring Systems Based on Multifactorial Analysis

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Sixty-six patients unable to complete a standard preoperative exercise test because of physical limitations were studied to determine the predictive value of individual clinical parameters, of clinical scoring systems based on multifactorial analysis, and of dipyridamole-thallium imaging before major general and vascular surgery. Study endpoints were limited to postoperative myocardial infarction or cardiac death before hospital discharge. There were nine postoperative cardiac events (seven deaths and two nonfatal infarctions). There was no statistical correlation between cardiac events and preoperative clinical descriptors, including individual clinical parameters, the Dripps-American Surgical Association score, the Goldman Cardiac Risk Index score, the Detsky Modified Cardiac Risk Index score, Eagle's clinical markers of low surgical risk, and the probability of postoperative events as determined by Cooperman's equation. There were no cardiac events in 30 patients with normal dipyridamole-thallium scans or in nine patients with fixed myocardial perfusion defects. Of 21 patients with reversible perfusion defects who underwent surgery, nine had a postoperative cardiac event (sensitivity, 100%; specificity, 43%). In the six other patients with reversible defects, preoperative angiography showed severe coronary disease or cardiomyopathy. Thus in patients unable to complete a standard exercise stress test, postoperative outcome cannot be predicted clinically before major general and vascular surgery, whereas dipyridamole-thallium imaging successfully identified all patients who sustained a postoperative cardiac event.

CARDIAC COMPLICATIONS are a major cause of postoperative morbidity and death after vascular and major general surgery when there is coexisting coronary artery disease.[1-3] Available methods used to identify high-risk coronary patients include clinical history and physical examination, resting electrocardiography, clinical scoring systems, exercise testing, dipyridamole-thallium imaging, and systematic coronary angiography. The latter is not practical as a screening procedure. Most authors agree that if the exercise stress test is clinically and electrically negative at 85% of the maximal predicted heart rate, a patient can safely undergo surgery.[4-6] Unfortunately many patients cannot achieve an adequate exercise level because of peripheral vascular disease, advanced age, neurologic or locomotor problems, or beta blocker use. The present study was undertaken to assess the predictive value of individual clinical parameters, of five clinical scoring systems, and of dipyridamole-thallium imaging for postoperative cardiac events in patients with suspected or known coronary artery disease unable to achieve an adequate level of exercise on the treadmill.

Material and Methods

Patient Population

The study population consisted of 66 consecutive patients referred for dipyridamole-thallium imaging before major general or vascular surgery. Reasons for referral for cardiac risk assessment included multiple risk factors, a history of atypical chest pain, resting electrocardiographic abnormalities, or suspected or known coronary artery disease. An adequate level of stress on the standard treadmill test could not be achieved either because of physical limitations or because of beta blocker use.

Clinical Evaluation

Medical charts were reviewed and Dripps-American Surgical Association score,[7] Goldman Cardiac Risk Index score and class,[8] Detsky Modified Risk Index score and class,[9] Eagle's criteria,[10] and Cooperman event

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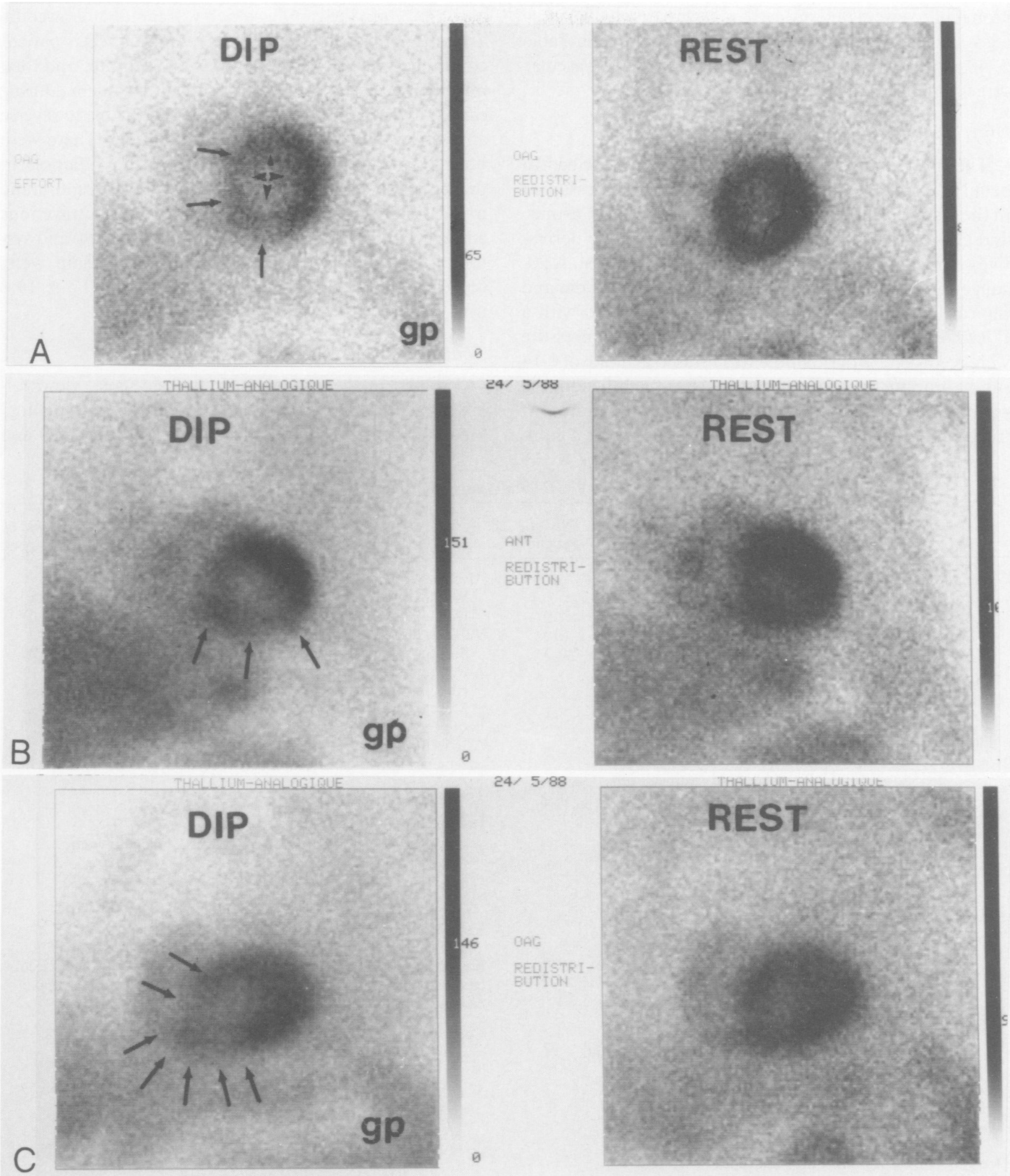

FIGS. 1A–C. Fifty-seven-year-old man admitted for surgery of the right superficial femoral and popliteal arteries. He had had a remote myocardial infarction, but denied any angina. Immediate postdipyridamole (left) and redistribution (right) thallium myocardial perfusion images in the best septal (A), left anterior 70 degree (B), and anterior (C) views show severe, completely reversible perfusion defects of the septal, inferoapical (A), anterior, apical, and inferior (B and C) myocardial segments. Peri- and postoperative outcome was uneventful until he died suddenly six days after surgery.

probability[11] were determined for each patient. The scoring systems are described in Table 1. As described in Table 2, 48 patients underwent major reconstructive vascular surgery and 18 underwent major general surgery.

Dipyridamole Infusion Protocol

The dipyridamole infusion protocol was described in detail in a previous report.[12] Briefly, patients were studied in the fasting state, having avoided coffee, tea, soft drinks, and chocolate for 24 hours, and all theophylline derivatives were discontinued for 48 hours before the test. A 20-gauge canula was installed in a large antecubital vein and the cardiac rhythm was continuously monitored with a II lead. Baseline and q 1 mn heart rate and blood pressure were recorded. Dipyridamole was infused at a rate of 0.14 mg/kg/minute over four minutes. After the infusion, the patient stood up and walked in place for two minutes. At that point, 3 mCi of thallium-201 was injected as a compact bolus into the canula, which was rapidly followed by a 10-mL bolus of normal saline solution. The patient continued walking on the spot for two minutes and then imaging was begun under the scintillation camera. During each study aminophylline 125 mg was available to reverse any serious adverse effects of dipyridamole. There were no major irreversible side effects from dipyridamole in the 66 patients. Patients who developed symptomatic myocardial ischemia responded quickly to intravenous aminophylline. The mean variation in heart rate and systolic blood pressure after dipyridamole infusion were, respectively, 9.1 ± 8 beats per minute and 17 ± 19.8 mm Hg.

Thallium-201 Myocardial Imaging

The first image was taken in the best septal view, followed by the left anterior oblique 70-degree (with manual breast support by the technician in female patients) and

TABLE 1. *Clinical Scoring Systems*

Test	No. of Patients
Goldman Cardiac Operative Risk Index[8]	
History	
Age > 70	5
Myocardial infarction < 6 months	10
Aortic stenosis	3
Physical exam (third heart sound, S3 gallop, or signs of congestive heart failure)	11
Electrocardiogram	
Any rhythm other than sinus	7
> 5 premature ventricular contractions/mn	7
Poor general medical condition	3
$PO_2 < 60$	
$P\ CO_2 > 50$	
$K^+ < 3$	
BUN > 50	
Creatinine > 3 (>260 mmol/L)	
Bedridden	
Operation	
Emergency	4
Intrathoracic or intra-abdominal or aortic	3
Total points = 0 to 53	

Goldman Classification	Total points
1	0–5
2	6–12
3	13–25
4	>25

Test	No. of Patients
Detsky Modified Multifactorial Risk Index[9]	
Coronary artery disease	
Myocardial infarction within 6 months	10
Myocardial infarction more than 6 months	5
Canadian Cardiovascular Society angina	
Class III	10
Class IV	20
Unstable angina within 6 months	10
Alveolar pulmonary edema	
Within 1 week	10
Ever	5
Valvular disease	
Suspected critical aortic stenosis	20
Arrhythmias	
Rhythm other than sinus (may have APB's)	5
More than 5 PVC's prior to surgery	5
Poor general medical status	5
Age over 70 years	5
Emergency operation	10
Total score: 0 to 120	

Detsky Classification

Detsky class	Total points
1	0–15
2	16–30
3	>30

Eagle Vascular Surgery Low Risk Clinical Markers[10]

The patient is considered to be at low risk for surgery if the following 5 clinical markers are absent: history of angina, clinical or electrocardiographic evidence of prior myocardial infarction, diabetes and congestive heart failure.

Cooperman equation[11]

$$P = \text{antilog}_2[(C_1 * X_1) + (C_2 * X_2) + \cdots + C]$$

X_1 = angina ($C_1 = 0.46$)
X_2 = congestive heart failure ($C_2 = 1.02$)
X_3 = arrhythmia ($C_3 = 0.62$)
X_4 = previous myocardial infarction ($C_4 = 0.64$)
X_5 = cerebrovascular accident ($C_5 = 1.15$)
X_6 = abnormal electrocardiogram ($C_6 = 1.25$)

Dripps-American Surgical Association Physical Status Score[7]

1 = normal healthy patient for elective operation
2 = mild systemic disease
3 = severe systemic disease with limited activity but not incapacitated
4 = incapacitating systemic disease which is a constant threat to life
5 = moribund patient not expected to survive 24 hours with or without operation

TABLE 2. *Surgical Procedures*

Procedure	No. of Patients
Vascular surgery (n = 48)	
Limb vascular procedures	12
Aortomesenteric bypass	1
Aortorenal bypass	4
Elective aortic replacement for aortoiliac arteriosclerotic disease	16
Elective resection of abdominal aortic aneurysms	11
Carotid endarterectomy	4
Major general surgery (n = 18)	
Hysterectomy	4
Hemicolectomy for colonic cancer	2
Renal transplant	1
Marshall-Marchetti	1
Radical cystectomy	1
Radical thyroidectomy	2
Total hip prosthesis	3
Excision of infected prosthesis	1
Ankle reconstruction	1
Gastrectomy	2

anterior views. Delayed images were obtained four hours after thallium injection and the patient was instructed to eat lightly during that time interval. Preset time eight-minute images were taken in each of the three views (initial and delayed images) with a photopeak set at 80 kev with a 20% window. Care was taken to position the patients identically for the initial and redistribution studies. For each scintigraphic study, the following images were displayed: analog images, interpolated background subtracted images, circumferential profiles, and washout rate analysis. All myocardial scintigraphic images were interpreted by two experienced observers without prior knowledge of patient history, coronary anatomy, or postoperative outcome. The myocardium was divided into three segments in each view for a total of nine segments. Scans were interpreted either as normal, as showing a fixed defect, or as displaying a reversible defect in at least one myocardial segment.

A fixed defect was defined as an initial perfusion defect with no redistribution on delayed images, plus electrocardiographic evidence of a necrosis in the corresponding segment with a clinical history of myocardial infarction and documented elevation of cardiac enzymes (when available) proportional to the size of the observed perfusion defect. Otherwise, because of the high reported incidence of viable but stunned myocardium in fixed defects,[13] we took either delayed 24-hour resting thallium images or a radionuclide gated equilibrium ventriculogram (MUGA scan) under continuous intravenous nitroglycerin infusion to confirm the presence of scar tissue. Infrequent differences in interpretation were resolved by consensus.

Study Endpoints

Only cardiac death (acute myocardial infarction or sudden unexpected death) and acute myocardial infarction before hospital discharge were accepted as endpoints. Acute myocardial infarction was diagnosed when at least two of the following three criteria were met: (1) a recent episode of characteristic chest pain that lasted more than 30 minutes; (2) a transient increase above the upper limit of normal of total serum creatinine kinase (CK) and its myocardial isoenzyme subfraction (MB CK), related temporally to the episode of chest pain; and (3) Minnesota code criteria for definite or probable myocardial infarction accompanied by evolving ST- and T-wave changes.[14,15] The results of thallium studies were made available to referring physicians who decided to refer the patient either for coronary angiography or directly to surgery. Sixty patients went to surgery, with antianginal drug therapy when there was thallium redistribution. The choice of drug therapy was not standardized and depended on the preferences of the referring physician. Patients with redistribution were usually monitored with a Swan-Ganz catheter during surgery, transferred to the intensive care unit after operation, and followed by the consulting cardiologist after operation.

Statistical Analysis

Correlation between clinical parameters, scoring systems, results of dipyridamole-thallium imaging, and cardiac events was done using chi square and ANOVA analysis. All values are mean ± standard deviation.

Results

Clinical Features and Postoperative Outcome

The clinical features of the 66 patients are listed in Table 3. No patient had preoperative clinical evidence of heart failure. Among the 60 patients who underwent surgery, 51 had an uneventful outcome, and 9 had cardiac events: 7 cardiac deaths (6 due to myocardial infarctions and 1 sudden death) (Fig. 1) and 2 nonfatal myocardial infarctions. The latter two infarctions included one transmural anterior infarct, and one non-Q wave infarct. Cardiac events appeared two to six days after operation (mean, 3.9 days). Surgery was cancelled in six of the patients who had thallium redistribution; all underwent preoperative coronary angiography and either had significant coronary artery disease (five) or cardiomyopathy (one), as illustrated in Table 4.

Predictive Value of Clinical Parameters

There was no statistical correlation between either individual clinical parameters (Table 3) or the scoring sys-

TABLE 3. *Clinical Predictors*

Clinical Parameter n = 66	No Event 51 pts. (%)	Event 9 pts (%)	Surgery Cancelled 6 pts (%)
Age	58.3 ± 10.7	63.1 ± 6.7	57.5 ± 9.32
Number of men	26 (51)	6 (66)	2 (33)
Surgery			
Vascular	42 (82)	6 (66)	3 (50)
Abdominal procedure	34 (66)	5 (55)	4 (66)
Cerebrovascular disease	10 (19)	3 (33)	2 (33)
COPD	11 (21)	3 (33)	1 (16)
Cr > 260 mmol/L	4 (7)	0	1 (16)
Risk factors			
Mean number	1.63 ± 0.91	1.89 ± 0.99	2 ± 1
Smoking	42 (82)	7 (77)	5 (83)
Hypertension	21 (41)	4 (44)	3 (50)
Diabetes	10 (19)	4 (44)	2 (33)
Family history	8 (15)	0	1 (16)
Angina grade			
0	24 (48)	7 (77)	5 (83)
1	1 (2)	0	0
2	12 (23)	1 (11)	1 (26)
3	1 (2)	0	0
Atypical chest pain	12 (23)	1 (11)	0
Previous MI	13 (25)	5 (55)	0
Electrocardiogram			
LVH	7 (13)	4 (44)	1 (16)
ST-T	16 (31)	4 (44)	4 (66)
Arrhythmia	5 (9)	4 (44)	0

COPD, chronic obstructive pulmonary disease.
Cr, creatinine.
Angina grade, Canadian Classification.
Previous MI, previous myocardial infarction.
Electrocardiogram, LVH: left ventricular hypertrophy.
ST-T, ST-T segment anomalies.
Arrhythmia, any rhythm other than sinus or more than five premature ventricular contractions per minute.
Abdominal procedure, intra-abdominal procedure.

tems (Table 5), and postoperative outcome, with one exception. The relation between the Cooperman probability of a cardiac event and postoperative outcome attained borderline statistical significance ($p = 0.05$), but there is a wide dispersion of individual probability values in each group. For example, although all patients who sustained a postoperative cardiac event had a Cooperman probability greater than 15%, so did 60% (30 of 51) of patients with an uneventful outcome.

Predictive Value of Dipyridamole-Thallium Imaging

No events occurred in the 30 patients with normal scans or in the nine patients with fixed defects as defined in this study. One patient had a fixed anterior wall defect and a history of infarction, but only inverted T waves in the anterior leads on the electrocardiogram. A MUGA scan during continuous nitroglycerin infusion showed normal anterior wall motion. Therefore the anterior wall defect was considered to be completely reversible and the patient was not classified in the fixed defect category. He died three days after operation of an acute myocardial infarction. Twenty-one patients displayed a reversible defect, including the nine patients who sustained a postoperative cardiac event (sensitivity, 100%; specificity, 43%).

Discussion

Failure of Clinical Scoring Systems

No clinical descriptor, including individual clinical parameters and the five scoring systems, could predict postoperative outcome. The absence of a preoperative history of angina in most (78%) patients who sustained a cardiac event underscores the difficulty of evaluating patients who spontaneously restrict their activities in response to peripheral vascular or other limiting diseases.[16]

The poor predictive value of chest pain has been previously reported in a series of 12,654 patients.[1] The Dripps-American Surgical Association classification, although involving the study of 33,224 patients,[7] is more a physical fitness scale than an assessment of peri- and postoperative risk. This probably accounts for its lack of predictive value. The Goldman Cardiac Risk Index,[8] based on the preoperative assessment of 1001 consecutive patients, is straightforward and readily adopted by clinicians but was not separately verified on a hypothesis-testing group of patients in the original study. It later yielded less encouraging results in a validating set of patients.[9] Detsky developed a modified version of the Goldman multifactorial scoring system that was validated on a group of 455 patients.[9] In our study all patients who developed postoperative cardiac events were classified at relative low risk (class 1 or 2) according to Detsky's scale.

In a series of 111 patients, Eagle observed that there were no cardiac events in patients with no angina, congestive heart failure, diabetes, previous myocardial infarction, or electrocardiographic Q waves.[10] In our study one third of patients with a cardiac event would have been classified as low risk according to Eagle's criteria. Determination of event probability from Cooperman's equation,[11] developed by multivariate analysis in 566 patients, showed

TABLE 4. *Angiographic Data of Patients Whose Surgery Was Cancelled*

Patient	LM	RCA	LAD	Cx	Procedure Cancelled
1	75	0	0	0	Elective aortic replacement
2	50	50	100	100	Elective resection of AAA*
3	0	100	80	75	Thyroidectomy
4	0	100	70	0	Ankle reconstruction
5	0	50	85	50	Aorto-renal bypass
6 cardiomyopathy: EF = 34%					Renal transplantation

* AAA, abdominal aortic aneurysm.
EF, ejection fraction.
LM, RCA, LAD, and Cx, Left main, right, left anterior descending and circumflex coronary arteries.
All patients had thallium redistribution.

TABLE 5. *Failure of Clinical Scoring Systems to Predict Postoperative Events*

Scoring System (n = 66)	No Event 51 pts (%)	Event 9 pts (%)	Surgery Cancelled 6 pts (%)	p
Dripps-ASA				
Total score	2.14 ± 0.99	2.22 ± 0.42	2 ± 0	NS*
Goldman				
Total score	4.36 ± 3.36	3.67 ± 4.42	3.33 ± 2.92	NS
Number of patients in low risk class 1 or 2	50 (98)	8 (89)	6 (100)	NS
Detsky				
Total score	4.51 ± 5.71	5 ± 3.33	4.67 ± 2.98	NS
Eagle criteria				
Number of pts. classified at low risk	14 (27)	3 (33)	2 (17)	NS
Cooperman equation				
Probability (%)	21 ± 17	37 ± 24	31 ± 27	0.05

See Table 1 for description of scoring systems.

* Not significant.

a weak statistical correlation ($p = 0.05$) with postoperative outcome. Furthermore the range of probabilities in both groups is so wide that prediction of postoperative outcome is not feasible in individual patients. Cooperman realized this problem and urges that caution must be used in applying the risk equation to individual patients.[11]

Clinical Significance of Silent Myocardial Ischemia

Silent myocardial ischemia is now well recognized as being as important as symptomatic ischemia in the evaluation of whether a coronary patient is at risk for myocardial infarction or sudden death.[17-21] For example data on 424 patients from the Coronary Artery Surgery Study (CASS) Registry shows that patients with exercise-induced angina or silent ischemia have a similar risk of developing an acute myocardial infarction or sudden coronary death, except in patients with three-vessel coronary artery disease in which the risk is greater in asymptomatic patients.[17]

With respect to preoperative cardiac assessment, this may explain the failure of all clinical modalities that rely on symptomatic ischemia as a risk indicator, such as a history of angina, the Eagle clinical markers, the Detsky Modified Cardiac Risk Index, and Cooperman's equation. Thallium imaging has the advantage of being a very sensitive tool to detect both symptomatic and silent ischemia,[22] and has been shown to be more sensitive than the exercise electrocardiogram.[23]

Dipyridamole-Thallium Myocardial Perfusion Imaging

The poor predictive value of clinical descriptors leaves only exercise testing and dipyridamole-thallium imaging as practical noninvasive means of identifying high risk patients. Exercise testing is frequently nondiagnostic in patients with peripheral vascular disease, advânced age, neurologic or locomotor problems, or beta blocker use,[24] and should probably be avoided in patients with a large abdominal aortic aneurysm because of the low risk of rupture.[25] Thallium imaging after dipyridamole-induced coronary vasodilation produces myocardial perfusion images similar to those obtained after exercise and have been shown to be as sensitive and specific as thallium exercise testing for the diagnosis of coronary artery disease.[26,27]

In our study, all 39 patients with normal dipyridamole-thallium scans or fixed perfusion defects (scar tissue from a previous myocardial infarction) underwent surgery uneventfully, whereas 43% of patients (9 of 21) with thallium redistribution sustained a postoperative cardiac event. Surgery was cancelled in six patients with extensive thallium redistribution on myocardial perfusion images and all had either severe coronary artery disease or cardiomyopathy on coronary angiography. Data compiled from six previous studies[10,28-32] yields results similar to ours: a 1.1% (3 of 272 patients) overall event rate in patients without redistribution and a 29.4% (47 of 160 patients; range, 19% to 43%) event rate in patients with reversible defects.

Management of Patients with Reversible Defects

The management of patients with reversible defects is still controversial. Current recommendations include preoperative coronary angiography with revascularization of high-risk lesions, surgery with antianginal medication, and cancellation or modification of surgery when feasible.[4,5,10,28-33] At the present time, we believe that cases must be managed on an individual basis in the absence of data on the combined morbidity and mortality risks associated with coronary angiography and myocardial revascularization followed by peripheral vascular reconstruction in a population of patients with multi-level vascular disease. Surgeons frequently resort to less aggressive extra-abdominal vascular procedures in high-risk patients in the hope of reducing cardiac risk, whereas there appears to be little or no decrease in cardiac risk by resorting to extra-abdominal vascular reconstruction.[33,34]

Limitations of the Study

The poor predictive value of the multifactorial scoring systems may be related to our choice of study endpoints: only cardiac death and infarction were accepted as postoperative events because these events are irreversible and severe enough to justify preoperative coronary angiography and revascularization. Event rates in our study would have been different had we also chosen unstable angina, pulmonary edema, cardiac arrhythmia, and peripheral emboli as study endpoints. The high ratio of cardiac deaths and transmural infarctions to non-Q wave infarctions in our study may be due either to statistical sampling in a small group of patients who sustained a cardiac event or to the cardioprotective effect of antianginal medication given to patients with thallium redistribution.

Postoperative outcome cannot be predicted by either individual clinical parameters or the five clinical scoring systems studied. However dipyridamole-thallium imaging successfully identified all patients who sustained a postoperative cardiac event.

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References

1. Knorring J. Postoperative myocardial infarction: a prospective study in a risk group of surgical patients. Surgery 1981; 90:55–60.
2. Deron SJ, Kotler MN. Noncardiac surgery in the cardiac patient. Am Heart J 1988; 116:831–838.
3. Hertzer NR, Beven EG, Young JR, et al. Fatal myocardial infarction following peripheral vascular operations. A study of 951 patients followed 6 to 11 years postoperatively. Clev Clin Q 1982; 49:1–11.
4. Gage AA, Bhayana JN, Balu V, et al. Assessment of cardiac risk in surgical patients. Arch Surg 1977; 112:1488–1492.
5. Arous EJ, Baum PL, Cutler BS. The ischemic exercise test in patients with peripheral vascular disease. Implications for management. Arch Surg 1984; 119:780–783.
6. McCabe CJ, Reidy NC, Abbott WM, et al. The value of electrocardiogram monitoring during treadmill testing for peripheral vascular disease. Surgery 1981; 89:183–186.
7. Dripps RD, Lamont A, Eckenhoff JE. The role of anaesthesia in surgical mortality. JAMA 1961; 178:261–266.
8. Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. N Engl J Med 1977; 297:845–850.
9. Detsky AS, Abrams HB, McLaughlin JR. Predicting cardiac complications in patients undergoing noncardiac surgery. J Gen Intern Med 1986; 1:211–219.
10. Eagle KA, Singer DE, Brewster DC, et al. Dipyridamole-thallium scanning in patients undergoing vascular surgery. JAMA 1987; 257:2185–2189.
11. Cooperman M, Pflug B, Martin EW, Evans WE. Cardiovascular risk factors in patients with peripheral vascular disease. Surgery 1978; 84:505–509.
12. Taillefer R, Lette J, Phaneuf DC, et al. Thallium-201 myocardial imaging during pharmacologic coronary vasodilation: comparison of oral and intravenous administration of dipyridamole. J Am Coll Cardiol 1986; 8:76–83.
13. Braunwald E, Kloner RA. The stunned myocardium: prolonged, postischemic ventricular dysfunction. Circulation 1982; 66:1146–1149.
14. Blackburn H, Keys A, Simonson E, et al. The electrocardiogram in population studies: a classification system. Circulation 1960; 21: 1160–1175.
15. Rose GA, Blackburn H. Cardiovascular Survey Methods. Geneva: World Health Organization Monograph, 1968. p.56.
16. Goldman L, Cook F, Mitchell N, et al. Pitfalls in the serial assessment of cardiac functional status: how a reduction in "ordinary" activity may reduce the apparent degree of cardiac compromise and give a misleading impression of improvement. J Chron Dis 1982; 35: 763–771.
17. Weiner DA, Ryan TJ, McCabe CH, et al. Risk of developing an acute myocardial infarction or sudden coronary death in patients with exercise-induced silent myocardial ischemia. A report from the Coronary Artery Surgery Study (CASS) Registry. Am J Cardiol 1988; 62:1155–1158.
18. Rocco MB, Nabel EG, Campbell S, et al. Prognostic importance of myocardial ischemia detected by ambulatory monitoring in patients with stable coronary artery disease. Circulation 1988; 78: 877–884.
19. Falcone C, de Servi S, Poma E, et al. Clinical significance of exercise-induced silent myocardial ischemia in patients with coronary artery disease. J Am Coll Cardiol 1987; 9:295–299.
20. Gottlieb SO, Weisfeldt ML, Ouyang P, et al. Silent ischemia predicts infarction and death during 2 year follow-up of unstable angina. J Am Coll Cardiol 1987; 10:756–760.
21. Gottlieb SO, Gottlieb SH, Achuff SC, et al. Silent ischemia on Holter monitoring predicts mortality in high-risk postinfarction patients. JAMA 1988; 259:1030–1035.
22. Berman DA, Rozanski A, Knoebel S. The detection of silent ischemia: Cautions and precautions. Circulation 1987; 75:101–105.
23. Beller GA. Myocardial perfusion imaging for detection of silent myocardial ischemia. Am J Cardiol 1988; 61:22F–26F.
24. Cutler BS, Wheeler HB, Paraskos JA, Cardullo PA. Applicability and interpretation of electrocardiographic stress tests in patients with peripheral vascular disease. Am J Surg 1981; 141:501–506.
25. Puls A, Thadani U. Rupture of abdominal aortic aneurysm during exercise. Am J Med 1986; 81:887–889.
26. Leppo J, Boucher CA, Okada RD, et al. Serial thallium-201 myocardial imaging after dipyridamole infusion: diagnostic utility in detecting coronary stenoses and relationship to regional wall motion. Circulation 1982; 3:649–657.
27. Eagle KA, Strauss HW, Boucher CA. Dipyridamole myocardial perfusion imaging for coronary heart disease. Am J Noninvas Cardiol 1988; 2:292–303.
28. Leppo J, Plaja J, Gionet M, et al. Noninvasive evaluation of cardiac risk before elective vascular surgery. J Am Coll Cardiol 1987; 9: 269–276.
29. Brewster DC, Okada RD, Strauss W, et al. Selection of patients for pre-operative coronary angiography: use of dipyridamole-stress-thallium myocardial imaging. J Vasc Surg 1985; 2:504–510.
30. Boucher CA, Brewster DC, Darling RC, et al. Determination of cardiac risk by dipyridamole-thallium imaging before peripheral vascular disease. N Engl J Med 1985; 312:389–394.
31. Sachs RN, Tellier P, Larmignat P, et al. Assessment by dipyridamole-thallium-201 myocardial scintigraphy of coronary risk before peripheral vascular surgery. Surgery 1988; 5:584–587.
32. Cutler BS, Leppo JA. Dipyridamole thallium-201 scintigraphy to detect coronary artery disease before abdominal aortic surgery. J Vasc Surg 1987; 5:91–100.
33. Cutler BS. Prevention of cardiac complications in peripheral vascular surgery. Surg Clin NA 1986; 66:281–292.
34. Mohr R, Smolinsky A, Morag B, et al. Cardiac complications in vascular procedures: comparison of percutaneous angioplasty and surgery. Cathet Cardiovasc Diagn 1983; 9:339–343.