MARCH 2000
Volume 4, Issue 3

Cardiology Rounds

AS PRESENTED IN THE ROUNDS OF THE CARDIOVASCULAR DIVISION OF BRIGHAM AND WOMEN'S HOSPITAL, BOSTON, MASSACHUSETTS

Assessing and reducing cardiac risk in noncardiac surgery

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The preoperative assessment of patients scheduled for noncardiac surgery is one of the most common clinical challenges facing internists and cardiologists. This task has been complicated in recent years by trends, including an aging population and a lower threshold for performing major procedures on elderly patients and patients with multiple comorbid illnesses. However, advances such as a Revised Cardiac Risk Index and noninvasive tests for ischemia have improved the physician's ability to predict risk. Furthermore, advances in anesthesia, post-operative analgesia, and surgical technique all contribute to a reduced rate of major cardiac complications that is about half that experienced in the 1970s. This review will describe recent advances in clinical risk stratification; perspectives on use of noninvasive tests; recent research on the benefit of perioperative use of beta blockade therapy; and some basic management strategies.

A Case History

E.F. is a 68 year-old-man with a history of stable angina who had several episodes of abdominal pain in the summer of 1999. He was seen by his primary care physician at a community practice in Partners Community HealthCare, Inc., and an abdominal ultrasound revealed multiple gallstones. On a regimen that consisted of atenolol 50 mg po qd and sublingual nitroglycerin as needed, he experienced rare angina, and only with moderate or heavy exertion. As part of his preoperative evaluation,he underwent exercise thallium scintigraphy,which was stopped at 7'30"due to shortness of breath. Electrocardiographic findings and radionuclide imaging were consistent with apical and septal ischemia. Carotid ultrasound was performed to evaluate a carotid bruit and revealed a 75% stenosis. At coronary angiography, he was found to have 75% stenoses in his left anterior descending and left circumflex coronary arteries, and a 60% stenosis in his right coronary artery with preserved left ventricular function. He underwent coronary artery bypass graft (CABG) surgery and carotid endarterectomy in September 1999 without complications. As of February 2000, he has been asymptomatic from his gallstones, and cholecystectomy was deferred.

This real case is presented not because it is extraordinary. In fact, the opposite is true – the issues in this patient's care are truly everyday problems for surgeons, anesthesiologists, primary care physicians, and cardiologists. These issues include:

- What is the risk of major cardiovascular complications for this particular patient?
- Can a test refine risk estimates and thereby change management strategies?
- For high risk patients, what can be done to improve outcomes?

In the past, there was much more art than science in the clinician's efforts to evaluate and reduce cardiac complications with noncardiac surgery and, in truth, most issues in this area have not been explored through experimental investigations. However, recent randomized trials demonstrating the benefit of beta blockade for high risk patients[1,2] undergoing vascular surgery have, for the first time, proven the impact of a risk reduction strategy. These findings require an overall examination of current strategies for risk stratification and reduction.

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The editorial content of *Cardiology Rounds* is determined solely by the Cardiovascular Division of Brigham and Women's Hospital. This publication is made possible by an educational grant.

Table 1: Original Cardiac Risk Index

Risk factor	Points
Age > 70 years	5
MI in previous 6 months	10
S3 gallop or jugular venous distention	11
Important aortic stenosis	3
Rhythm other than sinus or premature atrial contractions on last preoperative electrocardiogram	7
>5 premature ventricular contractions per minute documented at any time before operation	7
PO_2 < 60 or PCO_2 > 50 mm Hg;K<3.0 or HCO_3 <20 mEq/L;BUN > 50 or Cr > 3.0 mg/dL; abnormal AST, signs of chronic liver disease, or bedridden from noncardiac causes	3
Intraperitoneal, intrathoracic or aortic operation	3
Emergency operation	4

Class I = 0-5 points (low risk)
Class II = 6-12 points (intermediate risk)
Class III = 13-25 points (high risk)
Class IV = >25 points (very high risk)

Risk stratification using clinical data

For most of the last two decades, the usual method for stratifying patients according to their risk of cardiovascular complications was Goldman's Cardiac Risk Index,[3] developed in the 1970s by Goldman and his fellow senior residency cohort at Massachusetts General Hospital. These investigators prospectively evaluated and then followed 1001 patients undergoing major noncardiac surgery and identified factors that were independent predictors of increased risk. These factors were used to develop a risk index that was subsequently validated as accurate in other patient populations (Table 1).

However, the Cardiac Risk Index and a modification by other authors[4] have proven less relevant in recent years. First, the experience upon which the Index was based is out of date and does not reflect advances in surgical or anesthetic technique. In addition, some of the most powerful risk factors identified in the original research – such as critical aortic stenosis, recent acute myocardial infarction (MI), and markedly abnormal metabolic status – have become increasingly rare among patients undergoing non-emergent surgery, presumably because clinicians now recognize their importance. As a result, only 5% of 4315 patients undergoing major noncardiac surgery in a cohort in the early 1990s at Brigham and Women's Hospital were in higher risk classes (III or IV) according to the original Cardiac Risk Index.

To address these problems, a group at Brigham and Women's Hospital (including the author and Goldman) developed a Revised Cardiac Risk Index by prospectively studying a cohort of 4315 patients undergoing major noncardiac surgery in the early 1990s.[5] All of the patients in this series underwent nonemergent (ie, elective or urgent) procedures that had an expected length of stay of two or more days. The most common types of procedures were orthopedic (35.5%) and thoracic (12.3%).

Table 2: Major cardiac complications in 4315 patients at Brigham and Women's Hospital undergoing major noncardiac surgery

	N (%)
Any major cardiac complication	92 (2.1%)
• Ventricular fibrillation/cardiac arrest	16 (0.3%)
• Complete heart block	4 (0.1%)
• Acute myocardial infarction	46 (1.1%)
• Pulmonary edema	42 (1.0%)
Cardiac death during admission	12 (0.3%)
Total (cardiac and noncardiac) mortality during admission	43 (1.0%)

Rates of major cardiovascular complications (acute MI, pulmonary edema, ventricular fibrillation, complete heart block) in this population were only 2.1% overall – roughly half that reported in prior decades (Table 2). The most common of these complications were acute MI and pulmonary edema. Only 1% of patients did not survive the hospitalization.

Using data from two-thirds of the population, a new cardiac risk index was developed through multivariate analyses. Six clinical risk factors were identified (Table 3). As was true with the original Cardiac Risk Index, certain types of procedures were associated with a high baseline risk of complications – intraperitoneal, intrathoracic, and suprainguinal vascular procedures. Not surprisingly, a history of ischemic heart disease was also associated with increased risk.

One pleasant surprise was that patients who had previously undergone coronary revascularization had an excellent prognosis, regardless of the length of time since their revascularization. Major cardiac complications occurred in 1 (2%) of 51 patients with a history of prior angioplasty vs 55 (2%) of 2842 patients without prior angioplasty; and 6 (3%) of 217 patients with prior CABG surgery vs 50 (2%) of 2676 patients without prior CABG (p=NS). Therefore, in the Revised Cardiac Risk Index, patients with prior coronary revascularization procedures were categorized as having ischemic heart disease only if they had any of the other criteria for ischemic

Table 3: Revised Cardiac Risk Index

Assign one point to each of the following variables:

1. High risk type of surgery (intraperitoneal, intrathoracic, or suprainguinal vascular procedures)
2. History of ischemic heart disease (history of myocardial infarction, positive exercise test, current complaint of ischemic chest pain or use of nitrate therapy, or EKG with Q waves)
3. History of congestive heart failure
4. History of cerebrovascular disease
5. Insulin therapy for diabetes
6. Preoperative serum creatinine > 2.0 mg/dL

Class I = 0 factors
Class II = 1 factor
Class III = 2 factors
Class IV = >2 factors

Table 4: Major cardiac complication rates and 95% Confidence Intervals in derivation and validation cohorts

	Derivation Cohort (n=2893)		Validation Cohort (n=1422)	
Revised Cardiac Risk Index	Events/ pop.	Rate	Events/ pop.	Rate
Class I	5/1071	0.5 (0.2,1.1)	2/488	0.4 (0.05,1.5)
Class II	14/1106	1.3 (0.7,2.1)	5/567	0.9 (0.3,2.1)
Class III	18/506	3.6 (2.1,5.6)	17/258	6.6 (3.9,10.3)
Class IV	19/210	9.1 (5.5,13.8)	12/109	11.0 (5.8,18.4)

heart disease (eg, a history of prior MI, positive exercise test, current ischemic symptoms, or use of nitrates).

"Congestive heart failure" was defined by the presence of any of the following: history of congestive heart failure, pulmonary edema, or paroxysmal nocturnal dyspnea; physical examination showing bilateral rales or S3 gallop; or chest x-ray showing pulmonary vascular redistribution. All of these variables were correlated with major cardiac complications. "Cerebrovascular disease" was defined as a history of transient ischemic attack or stroke.

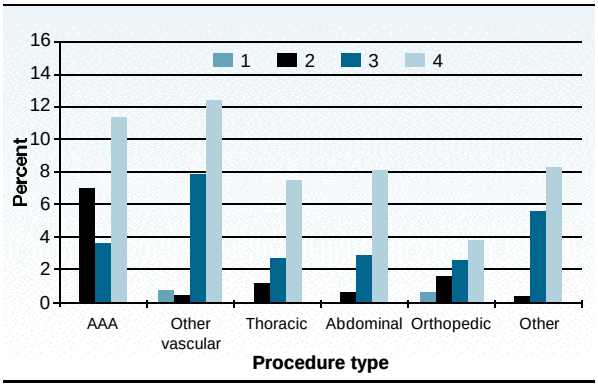
Of interest were factors that did *not* emerge as independent predictors of risk in this population, including age, important aortic stenosis, poor general medical status, or cardiac risk factors such as hypertension or elevated cholesterol. One possibility is that the impact of these factors was not apparent in this generally low risk (ie, non-emergency) surgical population. However, this population is exactly the group for which cardiologists and internists are asked to perform consultations. In emergency surgical cases, the procedure must be undertaken, regardless of the patient's cardiovascular risk.

Since these six factors had approximately the same statistical importance, they were each given the same "weight" in the Revised Cardiac Risk Index. Patients were then assigned to one of four classes based on the number of risk factors that they had (Table 4). The number of major cardiac complications, the rate, and 95% confidence interval are described in Table 4 for both the 2893 patients from whom the index was derived, as well as for the other 1422 patients in the "validation set" in whom the index was tested.

As is apparent from these data, the Revised Cardiac Risk Index stratifies patients (well = accurately, efficiently) according to their risk of major cardiac complications. Not shown are additional analyses that demonstrated that the Revised Cardiac Risk Index is significantly more accurate than the original index, its modification, American Society of Anesthesiologists (ASA) class, and an index developed for vascular surgery patients.[5] One of the more important findings was that about one-quarter of the patients were placed in higher risk classes (III or IV), suggesting that the Revised Index will identify enough patients as being at increased risk to be helpful to clinicians.

As shown in Figure 1, the Index stratified patients well in all subsets except those undergoing abdominal aortic aneurysm repair. In these patients, the baseline risk is presumably sufficiently high that it is difficult to identify a low risk group.

Figure 1: Bars represent the rate of major cardiac complications in the entire patient population (both Derivation and Validation Cohorts combined) for patients in Revised Cardiac Risk Index classes according to the type of procedure performed. AAA = abdominal aortic aneurysm. Note that, by definition, patients undergoing AAA, thoracic, and abdominal procedures were excluded from Class I. In all subsets except patients undergoing AAA, there was a statistically significant trend toward greater risk with higher risk class.



Noninvasive testing

The tests most commonly performed for further risk stratification are noninvasive tests for myocardial ischemia. Exercise stress testing cannot be performed on many patients undergoing major orthopedic or vascular surgery; thus, much of the literature on noninvasive tests has focused on radionuclear scans or echocardiography with dypyridamole, adenosine, or dobutamine to induce ischemia. In summary, this literature shows that patients who have negative tests have a low risk for major cardiac complications.

However, there is clear consensus reflected in available guidelines that these tests should not be used routinely as part of the preoperative evaluation.[6-9] One reason is that these tests are sensitive for detection of any coronary disease, and most stable patients with coronary disease actually have an excellent prognosis with noncardiac surgery. Thus, these tests have a high "false-positive rate" if used to detect patients at high risk for cardiac complications; that is, the vast majority of patients with abnormal test results will not have complications.

Guidelines have also recommended restraint in the use of noninvasive tests because the results are unlikely to change management in patients with either a high or low risk of complications. Assuming that a patient does not warrant coronary angiography and potential revascularization based on usual clinical criteria, it is unlikely that clinicians would want to perform bypass surgery or angioplasty on a relatively asymptomatic patient just because they are scheduled for a low risk noncardiac surgical procedure. At the other end of the risk-spectrum, a patient with unstable angina who is scheduled for abdominal aortic aneurysm surgery is at such high risk for complications that coronary angiography is appropriate regardless of noninvasive test results – thus, there is no need to perform the test.

Table 5. Excerpts from ACC/AHA Guidelines for Management of Cardiac Risk in Noncardiac Surgery (1996)[7]

Issue	Class I	Class II	Class III
Recommendations for preoperative noninvasive evaluation of left ventricular function	Patients with current or poorly controlled CHF.	Patients with prior CHF and patients with dyspnea of unknown etiology.	As a routine test of left ventricular function in patients without prior CHF.
Recommendations for intraoperative nitroglycerin	High-risk patients previously on nitroglycerin who have active signs of myocardial ischemia without hypotension.	As a prophylactic agent for high-risk patients to prevent myocardial ischemia and cardiac morbidity, particularly in those who have required nitrate therapy to control angina.	Patients with signs of hypovolemia or hypotension.
Intraoperative use of pulmonary artery catheters	Patients at risk for major hemodynamic disturbances that are most easily detected by a pulmonary artery catheter who are undergoing a procedure that is likely to cause these hemodynamic changes in a setting with experience in interpreting the results (eg, suprarenal aortic aneurysm repair in a patient with angina).	Either the patient's condition or the surgical procedure (but not both) places the patient at risk for hemodynamic disturbances (eg, total hip replacement in a patient with chronic renal insufficiency).	No risk of hemodynamic disturbances

Therefore, guidelines have recommended using noninvasive tests for ischemia for patients with an intermediate risk for cardiac complications. It is important to note, however, that there are no data that demonstrate this strategy improves outcomes, or that revascularization of patients with abnormal test results will reduce the risk of complications.

There are few data on use of echocardiography to assess left ventricular function for patients undergoing noncardiac surgery. ACC/AHA guidelines consider its use appropriate (Class I) in patients with current or poorly controlled congestive heart failure (Table 5), but do not support its routine use in patients without prior heart failure (Class III).[7]<img src="images/table5.gif">

Risk reduction

The first strong evidence that any intervention – medical or surgical – reduces the risk of short-term cardiac complications with noncardiac surgery was published in 1999. A randomized trial by Poldermans, et al demonstrated the benefit of beta blockade in patients undergoing major vascular surgery.[1] This trial randomized just 112 patients, and followed them for 30 days after surgery; it was actually designed to randomize 266 patients, but was halted early by an independent Safety Committee because the results were so striking that they considered it unethical to continue the trial. This trial focused on an extremely high risk population — patients with abnormal dobutamine stress echocardiography who underwent elective abdominal aortic or infrainguinal arterial reconstruction. These same researchers previously showed that such patients have a 28% rate of perioperative cardiac death or nonfatal MI[10] and in this trial, there was an even higher complication rate among those who did not receive beta blockade — 33.9%. In contrast, patients randomized to perioperative treatment with bisoprolol, a selective beta-1-adrenergic receptor antagonist, had a complication rate of only 3.4% — an extraordinary 91% reduction in risk.

These findings are consistent with other data showing reductions in perioperative ischemia with beta blockade,[11] and also the only prior randomized trial of beta-blockers in patients undergoing major noncardiac surgery.[2] In that trial, atenolol was compared with placebo in a lower risk group of patients undergoing elective noncardiac surgery. There was no short-term difference in outcome, but patients randomized to receive atenolol had a 55% reduction in mortality over two years. Presumably, the impact of beta blockade in the study by Poldermans et al was so much greater and seen so soon because that trial focused on patients with an extremely high baseline risk. The opportunity to improve outcome in such a population with beta blockade was considerable.

As important as the Poldermans trial may be, many questions remain unanswered, including:

- Is beta blockade superior to coronary revascularization for patients with a high risk of complications?
- Can beta blockade reduce risk for patients who do *not* have positive noninvasive tests for ischemia?
- Would this strategy improve outcomes with nonvascular procedures that carry a lower risk of complications?
- Is a one week period of preoperative treatment with a beta-blocker, as used in this study, necessary to achieve full protection?
- Do other beta-blockers offer the same benefits as the $beta_1$-selective (cardioselective) antagonist bisoprolol, which was used in the Poldermans trial?

These questions can and should be addressed in future research. As for other risk-reduction interventions, none have been proven in randomized trials. ACC/AHA guidelines for use of intraoperative nitroglycerin and pulmonary artery catheters are described in Table 5.[7]

Management strategies

Given the research summarized above, there is consensus that clinical data from a careful history and physical examination are the critical initial steps in the management of patients undergoing noncardiac surgery. The Revised Cardiac Risk Index[3] (Table 3) is a reasonable risk stratification aid. Patients with a low clinical risk for complications can generally proceed to surgery without special precautions and with routine postoperative monitoring.

For patients with known cardiovascular disease, the first principle is to evaluate them as if they were *not* scheduled for noncardiac surgery – and ask oneself whether they warrant further cardiovascular work-up as part of their routine long-term care. Patients with unstable coronary artery syndromes are, of course, not candidates for elective noncardiac surgery. For patients with stable angina, exercise testing to detect severe coronary artery disease has been shown to be cost-effective as a routine screening strategy.[12] ACC/AHA guidelines recommend exercise electrocardiography as the routine first-line test for patients (men *and* women) with an adequate functional capacity and an electrocardiogram that lends itself to interpretation during stress testing.[13]

Thus, in the preoperative setting, noninvasive testing for ischemia should be considered for patients with a high probability of coronary disease if such risk stratification has not been performed in the last few years, or if there has been some change in the patient's symptomatic status. Decisions about whether to pursue coronary angiography and revascularization can then be made according to the same criteria as usually used in the outpatient setting. But if such testing has been performed, and the patient is stable, there is no evidence to support repeat testing in order to get a new preoperative assessment. If noninvasive testing for ischemia has been performed previously, or is performed preoperatively, the risk of major cardiac complications is low,and no special precautions should be performed.

The management dilemma for clinicians is in patients with a positive test for ischemia – but one that is not so positive that it is appropriate to perform coronary angiography to exclude severe coronary disease for which the prognosis would be better with revascularization. For such patients, the main management options at this point are the invasive strategy (coronary angiography and possible revascularization) or the noninvasive strategy (optimal medical therapy including beta-blockers).

There are no experimental data to guide this choice at this time. If the remarkably low complication rate seen in the Poldermans study can be confirmed in other settings, the case for medical therapy with full beta-blockade will be compelling. The cumulative complication risk from coronary angiography followed by revascularization, followed by the noncardiac surgery is not likely to be lower than the 3.4% seen in the study by Poldermans et al.[1]

Some patients with coronary disease are not treated with beta-blockers because of side effects such as fatigue or impotence, but these effects can be tolerated for a few weeks before and after surgery. Similarly, many patients are not treated with therapeutic doses of beta-blockers; the benefit from these medications would presumably be greater if greater dosages were given.

If,in the future, beta-blockers are confirmed as being as effective in reducing risk as suggested in the Poldermans study, an intriguing possibility is that the role of noninvasive testing for ischemia may also be reduced. Beta-blockers are generally safe and inexpensive, and offer many long term benefits for patients with coronary artery disease. The obvious question is: Why not just start these agents for patients with an intermediate or higher risk of cardiac complications based upon their clinical data?

A similar approach was suggested in 1996 by Bodenheimer[14] who questioned the value of preoperative risk stratification with noninvasive tests in patients who were clinically stable from a cardiac perspective. Instead, he recommended an increase in efforts to prevent,detect, and reduce postoperative ischemia.

Another common issue is whether to stop or continue aspirin therapy in the week prior to surgery. In the absence of data defining the best strategy, many consultants defer this decision to the surgeon, who is more likely to be affected by the consequences of a prolonged bleeding time.

Implications for case study presented at the start

Although this patient had an excellent outcome from his bypass surgery and carotid endarterectomy, the risk of complications from these procedures is high, and there are no data to prove that these procedures improve long term outcome for asymptomatic individuals such as this patient. There are also no data that prove that this patient's perioperative risk would have been reduced by revascularization, should he subsequently undergo cholecystectomy. It is important to note that most of the literature on the implications of abnormal thallium scintigraphy has been based upon patients undergoing vascular surgery, which carries a higher risk of complications than general abdominal surgery.

A reasonable strategy for a patient with stable coronary disease and an excellent functional capacity would have been to ensure that his level of beta blockade was adequate, and undertake the cholecystectomy with careful postoperative observation for evidence of

ischemia. There is no evidence that a pulmonary artery catheter would improve his prognosis.

Conclusion

In summary, clinicians have new tools for estimating the risk for major cardiac complications in patients scheduled for noncardiac surgery, including a Revised Cardiac Risk Index and noninvasive tests for ischemia. Randomized trial data now convincingly demonstrate dramatic benefit from beta blockade in high risk patients undergoing high risk vascular surgery. It is important that physicians recognize the lack of evidence to directly support many of the strategies commonly used, including risk stratification through noninvasive tests for ischemia and echocardiography; use of coronary revascularization for patients with abnormal test results; and use of pulmonary artery catheters in the perioperative period. Recent research suggests that the future for preoperative care may include fewer tests, fewer coronary revascularizations, more use of beta-blockers, and fewer complications.

References

1. Poldermans D, Boersma E,Bax JJ, et al. The effect of bisoprolol on perioperative cardiac death and myocardial infarction in high-risk patients undergoing vascular surgery. *N Engl J Med* 1999;341:1789-1794.
2. Mangano DT, Layug EL, Wallace A, Tateo I, for the Multicenter Study of Perioperative Ischemia Research Group. Effect of atenolol on mortality and cardiovascular morbidity after noncardiac surgery. *N Engl J Med* 1996:335:1713-1720.
3. Goldman L, Caldera DL,Nussbaum SR,et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. *N Engl J Med* 1977;297:845-50.
4. Detsky AS, Abrams HB,McLaughlin JR,et al. Predicting cardiac complications in patients undergoing noncardiac surgery. *J Gen Intern Med* 1986;1:211-219.
5. Lee TH,Marcantonio EM,Mangione CM,et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation* 1999;100:1043-1049.
6. L'Italien GJ, Paul SD, Hendel RC, et al. Development and validation of a Bayesian model for perioperative cardiac risk assessment in a cohort of 1,081 vascular surgery patients. *J Am Coll Cardiol* 1996;27:779-786.
7. Guidelines for perioperative cardiovascular evaluation for noncardiac surgery: report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation* 1996;93:1278-1317.
8. Mangano DT, Goldman L. Preoperative assessment of patients with known or suspected coronary disease. *N Engl J Med* 1995;333:1750-1756.
9. American College of Physicians. Guidelines for assessing and managing the perioperative risk from coronary artery disease associated with major noncardiac surgery. *Ann Intern Med* 1997;127:309-312.
10. Poldermans D, Arnese M, Fioretti PM, Thomson IR, Boersma E, van Urk H. Improved cardiac risk stratification in major vascular surgery with dobutamine-atropine stress echocardiography. *J Am Coll Cardiol* 1995;26:1197-1202.
11. Stone JG, Foëx P,Sear JW, Johnson LL, Khambatta HJ,Triner L. Myocardial ischemia in untreated hypertensive patients:effect of a single small oral dose of a beta-adrenergic blocking agent. *Anesthesiology* 1988;68:495-500.
12. Lee TH, Fukui T,Weinstein MC,Tosteson ANA, Goldman L. Cost-effectiveness of screening strategies for left main disease in patients with stable angina. *Med Decis Making* 1988;8:268-278.
13. Gibbons RJ, Balady GJ, Beasley JW, et al. ACC/AHA guidelines for exercise testing:a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). *J Am Coll Cardiol* 1997;30:260-315.
14. Bodenheimer M. Noncardiac surgery in the cardiac patient: what is the question? Ann Intern Med. 1996;124:763-6. vascular surgery patients. *J Am Coll Cardiol* 1996;27:779-786.

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