Preoperative Evaluation for Major Noncardiac Surgery

Focusing on Heart Failure

Adrian F. Hernandez, MD; L. Kristin Newby, MD, MHS; Christopher M. O'Connor, MD

The number of patients undergoing major noncardiac surgery has steadily increased over the last decade. Cardiovascular complications are important and often feared by patients, surgeons, and anesthesiologists. Although preoperative risk assessment has improved since Goldman and colleagues published their landmark article that introduced the Multifactorial Index of Cardiac Risk 25 years ago, it continues to require modification, especially with the increasing prevalence of heart failure and the increase in procedures performed in the elderly. This review will summarize preoperative assessment and perioperative management with an emphasis on heart failure.

Arch Intern Med. 2004;164:1729-1736

Over the last 25 years, there has been steady improvement in the care of patients undergoing major noncardiac surgery. In the past, attention was focused on coronary artery disease (CAD) and the detection of ischemia. For the future, changes in the epidemiologic characteristics of patients undergoing surgery may require improved strategies and care, especially for those with heart failure (HF). This review will summarize preoperative risk evaluation and perioperative care focusing on HF.

EXPANDING SURGICAL VOLUME AND COSTLY COMPLICATIONS

The increasing volume of noncardiac surgical procedures and changes in the epidemiology of cardiovascular disease may collide to create an epidemic of postoperative complications despite improved care in both fields (**Figure 1**). In 2000, there were almost 40 million procedures performed in the United States, with over 10 million major noncardiac surgical procedures compared with only 519 000 cardiac surgical procedures.[2] The elderly pose a special problem since they are the largest population to undergo surgery, yet are at high risk for perioperative complications and major cardiac complications.[3,4] Individuals 65 years and older account for over 10 million noncardiac procedures and at least 4 million major noncardiac surgical procedures each year, which has increased over the last decade.[2]

Based on information from the late 1980s, at least 1 million perioperative cardiac complications occur per year, with an estimated $20 billion in annual costs for in-hospital and long-term care.[1] Although studies show clinical pathways can reduce length of stay, there may be vulnerable groups, such as the older, poorer, or sicker populations, which may be more susceptible to adverse outcomes with subsequent costs occurring after the initial discharge.[5-7] Currently, no accurate estimates are available owing to improvements in anesthesia techniques, β-blocker use, and risk assessment vs an increased prevalence of HF, an aging population, and more survivors of sudden death and myocardial infarction (MI) (**Figure 2**).

EVOLVING EPIDEMIOLOGY OF CARDIOLOGY

The incidence and prevalence of HF is soaring at a staggering rate. Based on the

From the Divisions of Cardiology (Drs Hernandez, Newby, and O'Connor) and Clinical Pharmacology (Dr O'Connor), Department of Medicine, Duke University Medical Center and Duke Clinical Research Institute, Durham, NC. Dr Newby has received research grant support from Roche Diagnostics Corporation and Dade-Behring Inc, participates in a speaker's bureau sponsored by Biosite, and serves as a consultant for Ortho Clinical Diagnostics.

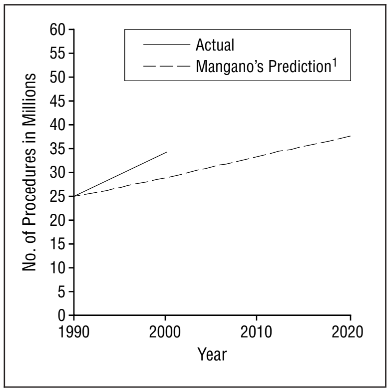

Figure 1. The noncardiac surgical volume is increasing beyond previous predictions by Mangano[1] in 1990.

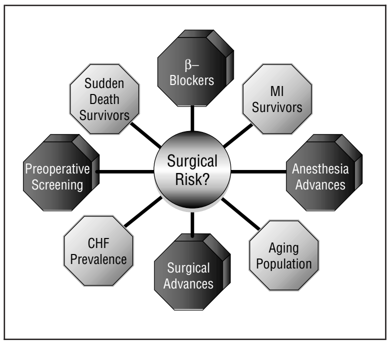

Figure 2. Despite advances in care, the changing complexity of patients undergoing major noncardiac surgery may make prediction of cardiovascular risk more difficult in the future. CHF indicates congestive heart failure; MI, myocardial infarction.

Framingham Heart Study, there are an estimated 550 000 new cases of HF each year, with an estimated prevalence of 5 million patients.[8]

Several factors may contribute to the increasing incidence and prevalence of HF. Advances in medical care, in particular strategies for management of acute ischemic heart disease and sudden death, have resulted in improved survival with chronic diseases such as atherosclerosis, hypertension, and diabetes.[9,10] Recently, the Framingham Heart Study also showed an improvement in survival of patients diagnosed with HF, which, coupled with a rapidly growing elderly population, could also contribute to a higher long-term prevalence.[11,12]

These changes in the epidemiology of cardiovascular disease along with an aging population will change substantially the landscape of preoperative risk stratification and raise concerns whether our current strategies are adequate.

PREOPERATIVE RISK STRATIFICATION

Goldman and colleagues[13] established a multivariable model of cardiac risk for noncardiac surgery, later named the original Cardiac Risk Index, which dramatically improved the prior American Society of Anesthesiologists (ASA) classification.[14] There have been other models developed to assess risk for perioperative complications emphasizing different aspects. All use clinical assessment, medical history, and a few basic laboratory assessments and now serve as a routine component of preoperative screening.

Original Cardiac Risk Index

In their original study, Goldman and colleagues[13] enrolled 1001 patients 40 years or older undergoing major noncardiac surgery. They derived a multivariable model using 9 clinical signs and standard laboratory measurements to generate a weighted cardiac index with 4 classifications predicting cardiac risk independent of surgery.[13] This served as the basis for many years for most physicians assessing preoperative risk. However, limitations such as lack of model validation, unknown interobserver variability, and expectation bias due to event classification by investigators led to the development of other risk indices.

Modified Cardiac Risk Index

The next major development arose from a study of 455 consecutive patients referred to a general medical consultation service.[15] Detsky and colleagues[15] found an area under the receiver operator characteristic (ROC) curve of 0.69 for the original Cardiac Risk Index, which was lower than that in the original study by Goldman and colleagues.[13] They simplified the point system, added angina severity, and modified the criteria for HF, providing an improved c-index of 0.76. While the efforts of Detsky and colleagues[15] were a substantial improvement, there were concerns of referral bias given that surgeons or anesthesiologists had to ask for a medical consultation. Overall, the main limitations were the single institution design, lack of end point adjudication, and the limits of generalizability of the risk index to "real-world" consultation.

Revised Cardiac Risk Index

In an effort to further improve available risk stratification tests, Lee and colleagues[16] proposed an even easier risk stratification tool composed of 6 simple factors derived from the largest study cohort to date—4315 patients 50 years or older identified through the hospital's Preadmission Test Center or in the hospital (**Table 1** and **Table 2**). Through this mass screening process, approximately 80% of patients undergoing major noncardiac surgery were approached for enrollment into the study. Major cardiac complications were seen in 2% of patients in the derivation cohort and 2.5% in the validation cohort. Independent predictors of risk in this cohort were high-risk type of surgery (intraperitoneal, intrathoracic, or suprainguinal vascular), history of ischemic heart disease, history of HF, history of cerebrovascular disease, preoperative treatment with insulin, and preoperative serum creatinine level greater than 2.0 mg/dL (>176.8 μmol/L). The area under the ROC curve for this model was 0.806 in the validation cohort, compared with 0.582 for the Modified Cardiac Risk Index, 0.701 for the original Cardiac Risk Index, and 0.706 for ASA class.

Overall, this simplified approach effectively grouped patients into 3 groups. What to do for low-risk patients is straightforward, but those classified as intermediate or high risk still require clinical judgment for the best approach. The investigators used an improved study design by having study personnel who did not participate in subjects' care perform daily medical review to collect data, and a reviewer blinded to preoperative clinical data classified all postoperative outcomes. Of note, possibly related to the smaller size of the validation cohort, was that insulin therapy and preoperative serum creatinine level did not prove to be as important in the validation phase. Another limitation is that the model cannot take into account changes in a patient's clinical status over time. For example, if a patient has decompensated HF today, the physician delays surgery for 1 month, and the patient clinically improves, the patient's calculated risk remains the same, which may or may not reflect reality. The same applies to a patient with a recent acute coronary syndrome who has surgery delayed for months after coronary revascularization.

HF AND NONCARDIAC SURGERY

Role of HF in Risk Indices

In the original Cardiac Risk Index by Goldman and colleagues,[13] clinical signs of HF including an S3 gallop or jugular venous distention (JVD) were the most significant predictors of postoperative life-threatening or fatal cardiac complications. In the final analysis, signs of HF carried the highest weight in the original Cardiac Risk Index. In addition, 36 of the 39 patients manifesting 1 or more life-threatening cardiac complications had pulmonary edema (**Table 3**).

Owing to the diverse group of clinicians evaluating numerous patients, in actual practice, the prior assessment for HF soon was recognized to be impractical. In the study by Detsky and colleagues,[15] the interobserver agreement for S3 and JVD was poor (κ statistic, 0.42 and 0.50, respectively). Therefore, to make the diagnosis of HF more objective and reproducible preoperatively, Detsky and colleagues grouped HF into 2 categories as the presence of alveolar pulmonary edema within 1 week or ever. Although the definition was stricter, HF still had a major role in predicting events as well as being a major outcome. Of the 43 serious events, there were 10 new or worsened episodes of HF without alveolar pulmonary edema, and 5 episodes of alveolar pulmonary edema.[15]

In the Revised Cardiac Risk Index study population, HF was both an important predictor and a key complication. The outcome required a formal reading of pulmonary edema on the chest radiograph by a radiologist with a plausible clinical setting. In the validation set, it provided the highest odds ratio (4.3) for major cardiac complications. In addition, it was an important outcome similar to MIs.[16] Other models have shown HF as an important predictor of perioperative events and the degree of HF appears to correlate with complications.[17]

Table 1. Revised Cardiac Risk Index[16]

Risk Factor	Definition	Points
Ischemic heart disease	Any of	1
	History of MI	
	History of positive exercise test result	
	Current chest pain	
	Nitrate use	
	ECG with Q wave	
Congestive heart failure	Any of	1
	History of HF	
	Pulmonary edema	
	PND	
	Bilateral rales	
	S3 gallop	
	CXR with pulmonary vascular redistribution	
Type of surgery	High risk (intraperitoneal, intrathoracic, or suprainguinal vascular)	1
Cerebrovascular disease	TIA or stroke	1
Diabetes mellitus	Preoperative treatment with insulin	1
Renal function	Creatinine level >2.0 mg/dL (>177 μmol/L)	1

Abbreviations: CXR, chest radiograph; ECG, electrocardiogram; HF, heart failure; MI, myocardial infarction; PND, paraxsymal nocturnal dyspnea; TIA, transient ischemic attack.

Table 2. Major Cardiac Complication Rates Using the Revised Cardiac Risk Index[16]

	Rate (95% Confidence Interval), %	
Points	Derivation Cohort	Validation Cohort
0	0.5 (0.2-1.1)	0.4 (0.05-1.5)
1	1.3 (0.7-2.1)	0.9 (0.3-2.1)
2	3.6 (2.1-5.6)	6.6 (3.9-10.3)
≥3	9.1 (5.5-13.8)	11.0 (5.8-18.4)
ROC	0.759	0.806

Abbreviation: ROC, receiver operating characteristic (area under the ROC curve).

Table 3. Event Comparison of Different Cardiac Risk Indices*

Event	Original[13] (N = 1001)	Modified[15] (N = 455)	Revised[16] (N = 315)
Total No. of cardiac complications	39 (3.9)	47 (10.3)	92 (2.1)
Heart failure	36 (3.6)	16 (3.5)	42 (1.0)
Myocardial infarction	18 (1.8)	14 (3.1)	46 (1.1)
Ventricular tachycardia/cardiac arrest	12 (1.2)	NA	16 (0.4)
Cardiac death	19 (1.9)	11 (2.4)	12 (0.3)

Abbreviation: NA, not applicable.
*Data are given as number (percentage).

Diagnosis of HF in Risk Indices

Despite use of the standard Framingham criteria for HF in a number of large epidemiological studies, investigators have not clearly applied these same standard definitions in preoperative risk studies.[18,19] **Table 4** summarizes the definitions of HF that have been used in the major preoperative risk studies.

Table 4. Heart Failure (HF) Evaluation Definitions of the Different Cardiac Risk Indices

	Original[13]	Modified[15]	Revised[16]
Preoperative history	Not indicated	Respiratory distress relieved by diuretics	History of HF, pulmonary edema, or PND
Preoperative physical signs	S3 gallop JVD: elevation >12 cm above the fourth intercostal space in midaxillary line	S3 gallop JVD: >3-cm vertical distance above the sternal angle with patient at 45° angle	S3 gallop Bilateral rales
Preoperative studies	CXR with pulmonary venous congestion	CXR with pulmonary edema	CXR with pulmonary vascular redistribution
Postoperative diagnosis of HF	Pulmonary edema with classic CXR changes or respiratory distress and rales at least three fourths of the way up the lung fields that improved promptly with diuretic therapy	New or worsened HF, new respiratory distress, S3 gallop, JVD, and CXR with pulmonary edema or vascular redistribution	Pulmonary edema on CXR in a plausible clinical setting

Abbreviations: CXR, chest radiograph; JVD, jugular venous distention; PND, paroxysmal nocturnal dyspnea.

Preoperative assessment of HF has shifted from emphasizing physical examination signs to simply having a history of HF. In doing so, problems of interobserver variability and reproducibility in general application were reduced. In the Revised Cardiac Risk Index, the investigators defined HF by a combination of symptoms and signs that incorporated some of the Framingham criteria, but important elements were still missing such as orthopnea and dyspnea on exertion that are now recommended by the American College of Cardiology/American Heart Association (ACC/AHA) guidelines for the definition of HF.[16,18,20]

The studies required a postoperative chest radiograph for confirmation of HF, which helped standardize the diagnosis.[13,15,16] However, all of the studies depended on the primary provider to order chest radiographs since it was not done routinely in the postoperative period, causing end points to be missed. For most of the studies, a single reviewer classified events rather than a central events classification committee.[13,15-17,21,22]

Over the last several years, numerous studies have highlighted the importance of natriuretic peptides as diagnostic and prognostic markers in HF.[23-26] With the recent approval of commercial assays for B-type natriuretic peptide and N-terminal pro–B-type natriuretic peptide, it may be possible to improve both preoperative classification of HF and diagnosis of HF as a postoperative complication by incorporating the markers in routine assessment. Further studies will be needed to assess the utility of such a strategy.

Echocardiography

Although echocardiography appears to be very accessible and potentially useful test for preoperative evaluation, it has limited prognostic value as a routine test. To help determine the value of routine echocardiography in preoperative screening, Halm et al[27] evaluated 339 of 474 consecutive men in a Veterans Affairs medical center with known or suspected CAD. In this study, 8% of patients had HF and 3% had ischemic events postoperatively. Although an ejection fraction less than 40% and wall motion score were associated with some outcomes, both had poor predictor characteristics.

In a more recent study, Rohde and colleauges[28] evaluated 570 patients enrolled in the Revised Cardiac Risk Index cohort who underwent transthoracic echocardiography at the discretion of their physician within 3 months of surgery. Overall, models including the reported echocardiographic data predicted major cardiac complications better than models with only clinical variables (c-statistic, 0.73 vs 0.68; $P<.05$). An abnormal echocardiogram with any degree of systolic dysfunction, moderate to severe left ventricle (LV) hypertrophy, moderate to severe mitral regurgitation, or aortic gradient of 20 mm Hg or greater provided a sensitivity of 80%, specificity of 52%, positive predictive value of 12%, and negative predictive value of 97%. However, severe LV dysfunction compared with mild to moderate LV dysfunction did not have as strong an association with cardiogenic pulmonary edema and MI. The heterogeneity of these findings likely points out that HF and ischemic heart disease comprise a combination of factors that change every day, while we usually only measure a few at 1 point in time. Therefore, in the end, adding echocardiography added little to risk models.

Preoperative Stress Imaging and HF

A number of studies have evaluated stress imaging in preoperative risk assessment; the largest experience using dipyridamole thallium-201 imaging.[29] Eagle and colleagues[21] used a combination of clinical and thallium data for preoperative assessment in patients with vascular disease. The latest study from his group used a model incorporating the clinical variables of advanced age (>70 years), angina, history of MI, diabetes mellitus, history of HF, and prior coronary revascularization.[22] Importantly, even in that study that emphasized ischemic heart disease, HF was an important predictor of the primary outcome (nonfatal MI, fatal MI, or cardiac death) in the training set and validation set with odds ratios of 2.7 and 3.2, respectively. Although thallium scoring correlated with events, the results showed that only the intermediate-risk group based on clinical assessment benefited from further testing to stratify patients into low- and high-risk categories.

As observed by Eagle and colleagues,[21] HF played a major role as a clinical predictor in other studies evaluating perfusion imaging. In a meta-analysis combining 5 studies using thallium imaging for preoperative risk assessment in 1188 patients, HF was the second most important predictor of cardiac events behind reversible thallium defect (odds ratio, 3.6; $P<.001$).[29]

Table 5. Tests and Strategies for Managing Patients With Heart Failure (HF) in the Perioperative Setting

Perioperative β-Blockade: Patients with HF should normally be taking β-blockers for long-term benefits. If not, try to start β-blocker therapy early enough to ensure it is well tolerated before surgery.
Stress Testing: It should be done in high-risk patients with ≥3 points on the Revised Cardiac Risk Index or in patients considered at intermediate risk who are unable to receive perioperative β-blockers or if testing would be done as normal clinical care for long-term goals.
Degree of HF Compensation: Currently, requires clinical judgment. No objective testing strategies have been evaluated in the perioperative setting.
Echocardiography: Routine use of echocardiography does not add information for risk stratification or potential changes in management. It should be reserved for evaluation of clinical changes as done for routine management of HF.
Right Heart Catheterization and Monitoring: Current evidence does not support its routine use. If needed, measurement of central venous pressure is adequate for perioperative management of volume status.

Risk Factors for Postoperative HF

With today's current approach to preoperative care, it is unclear what the risk factors for postoperative HF are. In a 1990 study by Mangano and colleagues,[30] a history of dysrhythmia, diabetes, duration of anesthesia, vascular surgery, and narcotic anesthesia were all associated with postoperative HF while postoperative ischemia was not. They speculated that vascular surgery placed patients at higher risk because of the length of the procedure and volume of intravenous fluids. In another study, Charlson and colleagues[31] found that the risk for postoperative HF was limited to patients with preoperative symptomatic cardiac disease, especially in patients with diabetes. Another possible factor in postoperative HF may be the inability to administer some HF medications because of the inability to use an oral route postoperatively. Finally, it appears that surgery leads to activation of the renin-angiotensin system and postoperative elevations in cortisol as well as epinephrine levels.[32]

Timing of HF Perioperatively

Manifestations of perioperative HF usually develop during the day of surgery or the second to third postoperative day, although this is not well studied.[31] Theoretically, there are 2 potential periods when HF may worsen: (1) immediately after surgery because of the length of surgery, myocardial ischemia, and rapid fluid shifts and (2) a few days later, when HF may occur because of reabsorption of third-spaced fluid.[33] In the study by Mangano and colleagues,[30] 48% of HF occurred after the third postoperative day.

Perioperative Care

The exact approach to patients with HF in the perioperative period is uncertain, but understanding the degree and cause may be helpful. The ACC/AHA guidelines state, "Every effort must be made to detect unsuspected HF by a careful history and physical examination."[34]

The mainstay of perioperative care is to identify patients with intermediate to high risk features and either perform preoperative evaluation with noninvasive testing followed by revascularization or use perioperative β-blockers (**Table 5**). There are no randomized controlled trials indicating the effect of revascularization preoperatively, and previous observational studies provide a mixed picture.[35-40] Until a large randomized trial is done, the benefit of revascularization remains to be definitively proven for prevention of perioperative cardiac events.

Randomized controlled trials support β-blocker therapy perioperatively, but there have only been 30 patients with HF in these trials.[41-45] The first major trial using atenolol in 200 patients with CAD or at risk for CAD showed a reduction in deaths and combined cardiovascular outcomes.[45] However, the benefit was not apparent until after discharge and was largely seen during the first 6 to 8 months after surgery, although the protocol only stipulated therapy during hospitalization.

The Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography (DECREASE) study also supports the merits of perioperative β-blocker therapy.[44] Of the 846 patients screened with dobutamine echocardiography, 112 with positive test results were ultimately randomized to perioperative treatment with bisoprolol or standard care. The primary end point of death from cardiac causes or nonfatal MI was significantly different between the randomized groups; 2 patients (3.4%) in the bisoprolol group compared with 18 patients (34%) in the standard care group ($P<.001$) experienced the primary end point. Of note, 8 patients with extensive wall-motion abnormalities either at rest or during stress testing were excluded. If the Revised Clinical Risk Index is considered, dobutamine stress echocardiography only adds significant prognostic information for patients with 3 or more risk factors.[46] Thus, in most patients who have fewer than 3 risk factors, use of perioperative β-blockade without having to undergo substantial testing appears reasonable.[47] However, the study was limited in describing an approach for patients with HF since it only had 14 patients with HF and HF was not an outcome.

One issue that arises in surgical patients that may be particularly important for patients with HF is how to administer their medications appropriately if patients are not able to take anything orally. Clinicians use intravenous medications such as β-blockers in the perioperative period, but timing or duration is uncertain in patients with worsening HF, given the small number of patients in clinical trials. More-over, the pharmacodynamics of intravenous medications may not be as well appreciated by clinicians compared with the more routinely used oral agents.

Intraoperative Monitoring

For patients with HF, some investigators recommend right heart catheterization (RHC) in the perioperative period depending on the clinical situation.[48,49] Intraoperative hemodynamic changes are associated with increased complication rates, so logically most would assume invasive monitoring would reduce perioperative complications.[50]

In an observational cohort study of 4059 patients who underwent major noncardiac surgery (excluding abdominal aortic aneurysm repair), the value of RHC was underwhelming. Over 200 patients had an RHC, with an overall 3-fold increase in the incidence of major postoperative cardiac events and an adjusted odds ratio of 2.0 for postoperative major cardiac events.[51]

In the most recent study evaluating RHC, investigators showed no benefit for perioperative RHC in a randomized controlled trial of elderly patients undergoing major noncardiac surgery.[52] Almost 2000 patients 60 years or older with ASA's class III-IV scheduled for major surgery followed by a stay in an intensive care unit were randomized to RHC or usual care. There was no benefit to RHC-directed therapy over standard care, and there was a higher rate of pulmonary embolism in the catheter group. One limitation of this study is that New York Heart Association (NYHA) class III-IV HF patients only composed 13% of the study population. Thus, it is unknown whether RHC helps in this group, but the trend favored standard care in the subgroup analysis. The study provided hemodynamic goals for the RHC group resulting in higher use of inotropic agents (48.9% vs 32.8% in the standard care group), which may be a reason for the lack of benefit. Thus, we see another area in which clinical logic does not correlate with clinical outcome.

Transesophageal echocardiography (TEE) and continuous electrocardiogram evaluation have also been evaluated to determine if routine use in patients at high risk for CAD adds to the identification of perioperative outcomes beyond clinical assessment. However, sensitivity and positive predictive value were low for TEE prediction of ischemic outcomes. In a multivariable analysis, the odds ratio for the association of TEE findings with outcomes was 2.6 and was most predictive of ventricular tachycardia. In evaluating ischemic outcomes alone, TEE was not predictive beyond routine clinical data.[53]

LIMITATIONS OF PREVIOUS STUDIES

Preoperative evaluation has progressed substantially, but several limitations could be addressed in the future. Most of the prior studies were done in a single center, and only recently have studies incorporated multiple centers.[54,55] However, these ongoing studies may be limited owing to the unique population within the Veterans Affairs system or because of the difficulty in generalizing from academic centers to community practice. Future studies must also address prior study limitations such as end point adjudication with a multiple reviewer system and standardized evaluation of HF outcomes. Finally, assessing early events after discharge and readmissions that may be related to perioperative cardiovascular events should be captured.

FUTURE DIRECTIONS

Now it is time to turn to evaluation of other medications and other preoperative risk stratification strategies, especially in patients with HF. Physicians do not routinely follow evidenced-based guidelines for risk stratification and testing strategies, while at the same time their estimates of cardiac risk compared with validated indices are poor.[56] Thus, the future will require a diverse group of clinicians to efficiently and accurately evaluate a large number of patients possibly at higher risk.

Medications, such as statins, which were shown in a recent case-control study and another observational study to lower risk of perioperative cardiac complications, should be validated prospectively.[57,58] In patients with HF or at risk for HF when undergoing noncardiac surgery, studies should evaluate the role of digoxin and angiotensin-converting enzyme inhibitors as well as other new therapies.

Measurement of multiple biomarkers such as natriuretic peptides or C-reactive peptide may provide a simple and efficient method of risk stratification compared with undergoing expensive noninvasive studies or even cardiac catheterization. In patients with NYHA class III-IV HF, the role of RHC or other noninvasive tests such as bioimpedance before surgery may be useful in addition to new therapies that may be available without as many adverse effects as currently used inotropic agents.

Finally, because of the pressure to reduce length of stay and prevent readmission, studies should evaluate new strategies, such as measurements of B-type natriuretic peptide levels, to aid decision making for discharge of patients with HF. Thus, there are many potential areas of investigation needed to reduce the morbidity or mortality of patients with HF undergoing major noncardiac surgery.

CONCLUSIONS

Patients with HF have as significant a risk of perioperative complications as patients with ischemic heart disease, and they should be evaluated thoroughly to ensure that they are well compensated prior to undergoing surgery and that standard perioperative β-blockade is used. Excessive testing with echocardiography or RHC does not necessarily assist in determining safety for surgery. Stress testing for high-risk patients may help in deciding proper therapies or revascularization strategies, while those at intermediate risk may only need β-blocker therapy. In most well-planned elective surgical procedures, the issues of stability while receiving β-blockers should already be settled. Postoperative monitoring for decompensation, appropriate medication use, and early follow-up by a primary care provider should help further reduce perioperative complications.

There remain a number of unresolved issues, and perioperative care may need to be improved in patients with complex cardiovascular disease such as HF. Last minute cardiac consultations are already a part of daily care in the preoperative setting.[59] Therefore, pathways for risk assessment and intervention should be simplified. Prior studies have emphasized ischemic heart disease, but with emerging techniques such as the measurement of biomarkers, more accurate determination of HF in the perioperative setting may lead to further refinements in prognosis or diagnosis in patients undergoing noncardiac surgery.

Accepted for publication October 10, 2003.

Dr Hernandez is supported in part by an American College Cardiology Foundation/Merck grant.

Correspondence: Christopher M. O'Connor, MD, DUMC Box 3356, Duke University Medical Center, Durham, NC 27710 (oconn002@mc.duke.edu).

REFERENCES

1. Mangano DT. Perioperative cardiac morbidity. *Anesthesiology.* 1990;72:153-184.
2. National Center for Health Statistics. Inpatient surgery. May 1, 2003. Available at: http://www.cdc.gov/nchs/fastats/insurg.htm. Accessed December 2003.
3. Polanczyk CA, Marcantonio E, Goldman L, et al. Impact of age on perioperative complications and length of stay in patients undergoing noncardiac surgery. *Ann Intern Med.* 2001;134:637-643.
4. Gerson MC, Hurst JM, Hertzberg VS, Baughman R, Rouan GW, Ellis K. Prediction of cardiac and pulmonary complications related to elective abdominal and noncardiac thoracic surgery in geriatric patients. *Am J Med.* 1990;88:101-107.
5. Pollard JB, Garnerin P, Dalman RL. Use of outpatient preoperative evaluation to decrease length of stay for vascular surgery. *Anesth Analg.* 1997;85:1307-1311.
6. Macario A, Horne M, Goodman S, et al. The effect of a perioperative clinical pathway for knee replacement surgery on hospital costs. *Anesth Analg.* 1998;86:978-984.
7. Hellinger FJ. The effect of managed care on quality: a review of recent evidence. *Arch Intern Med.* 1998;158:833-841.
8. American Heart Association. *2003 Heart and Stroke Statistical Update.* Dallas, Tex: American Heart Association; 2003.
9. Massie BM, Shah NB. Evolving trends in the epidemiologic factors of heart failure: rationale for preventive strategies and comprehensive disease management. *Am Heart J.* 1997;133:703-712.
10. Moss AJ, Zareba W, Hall WJ, et al. Prophylactic implantation of a defibrillator in patients with myocardial infarction and reduced ejection fraction. *N Engl J Med.* 2002;346:877-883.
11. Levy D, Kenchaiah S, Larson MG, et al. Long-term trends in the incidence of and survival with heart failure. *N Engl J Med.* 2002;347:1397-1402.
12. Population Division of the United States Bureau of the Census. Population menu. December 31, 2002. Available at: http://www.census.gov/population. Accessed December 2003.
13. 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.
14. American Society of Anesthesiologists. New classification of physical status. *Anesthesiology.* 1963;24:111.
15. Detsky AS, Abrams HB, McLaughlin JR, et al. Predicting cardiac complications in patients undergoing non-cardiac surgery. *J Gen Intern Med.* 1986;1:211-219.
16. Lee TH, Marcantonio ER, 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.
17. Larsen SF, Olesen KH, Jacobsen E, et al. Prediction of cardiac risk in non-cardiac surgery. *Eur Heart J.* 1987;8:179-185.
18. McKee PA, Castelli WP, McNamara PM, Kannel WB. The natural history of congestive heart failure: the Framingham study. *N Engl J Med.* 1971;285:1441-1446.
19. Senni M, Tribouilloy CM, Rodeheffer RJ, et al. Congestive heart failure in the community: trends in incidence and survival in a 10-year period. *Arch Intern Med.* 1999;159:29-34.
20. Hunt SA, Baker DW, Chin MH, et al. ACC/AHA Guidelines for the Evaluation and Management of Chronic Heart Failure in the Adult: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Revise the 1995 Guidelines for the Evaluation and Management of Heart Failure): developed in collaboration with the International Society for Heart and Lung Transplantation; Endorsed by the Heart Failure Society of America. *Circulation.* 2001;104:2996-3007.
21. Eagle KA, Coley CM, Newell JB, et al. Combining clinical and thallium data optimizes preoperative assessment of cardiac risk before major vascular surgery. *Ann Intern Med.* 1989;110:859-866.
22. 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 surgical candidates. *J Am Coll Cardiol.* 1996;27:779-786.
23. Cowie MR, Struthers AD, Wood DA, et al. Value of natriuretic peptides in assessment of patients with possible new heart failure in primary care. *Lancet.* 1997;350:1349-1353.
24. Levin ER, Gardner DG, Samson WK. Natriuretic peptides. *N Engl J Med.* 1998;339:321-328.
25. Maisel AS, Krishnaswamy P, Nowak RM, et al. Rapid measurement of B-type natriuretic peptide in the emergency diagnosis of heart failure. *N Engl J Med.* 2002;347:161-167.
26. Tsutamoto T, Wada A, Maeda K, et al. Plasma brain natriuretic peptide level as a biochemical marker of morbidity and mortality in patients with asymptomatic or minimally symptomatic left ventricular dysfunction: comparison with plasma angiotensin II and endothelin-1. *Eur Heart J.* 1999;20:1799-1807.
27. Halm EA, Browner WS, Tubau JF, Tateo IM, Mangano DT; Study of Perioperative Ischemia Research Group. Echocardiography for assessing cardiac risk in patients having noncardiac surgery. *Ann Intern Med.* 1996;125:433-441.
28. Rohde LE, Polanczyk CA, Goldman L, Cook EF, Lee RT, Lee TH. Usefulness of transthoracic echocardiography as a tool for risk stratification of patients undergoing major noncardiac surgery. *Am J Cardiol.* 2001;87:505-509.
29. Shaw LJ, Eagle KA, Gersh BJ, Miller DD. Meta-analysis of intravenous dipyridamole-thallium-201 imaging (1985 to 1994) and dobutamine echocardiography (1991 to 1994) for risk stratification before vascular surgery. *J Am Coll Cardiol.* 1996;27:787-798.
30. Mangano DT, Browner WS, Hollenberg M, London MJ, Tubau JF, Tateo IM; The Study of Perioperative Ischemia Research Group. Association of perioperative myocardial ischemia with cardiac morbidity and mortality in men undergoing noncardiac surgery. *N Engl J Med.* 1990;323:1781-1788.
31. Charlson ME, MacKenzie CR, Gold JP, Ales KL, Topkins M, Shires GT. Risk for postoperative congestive heart failure. *Surg Gynecol Obstet.* 1991;172:95-104.
32. Udelsman R, Norton JA, Jelenich SE, et al. Responses of the hypothalamic-pituitary-adrenal and renin-angiotensin axes and the sympathetic system during controlled surgical and anesthetic stress. *J Clin Endocrinol Metab.* 1987;64:986-994.
33. Shires GT III, Barber A, Shires GT. Fluid and electrolyte management of the surgical patient. In: Schwartz SI, Shires GT, eds. *Principles of Surgery.* New York, NY: McGraw-Hill Co; 1999:53-75.
34. Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update for perioperative cardiovascular evaluation for noncardiac surgery—executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1996 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery). 2002. Available at: http://www.acc.org/clinical/guidelines/perio/exec_summ/periop_index.htm. Accessed December 2003.
35. Fleisher LA, Eagle KA. Clinical practice: lowering cardiac risk in noncardiac surgery. *N Engl J Med.* 2001;345:1677-1682.
36. Posner KL, Van Norman GA, Chan V. Adverse cardiac outcomes after noncardiac surgery in patients with prior percutaneous transluminal coronary angioplasty. *Anesth Analg.* 1999;89:553-560.
37. Kaluza GL, Joseph J, Lee JR, Raizner ME, Raizner AE. Catastrophic outcomes of noncardiac surgery soon after coronary stenting. *J Am Coll Cardiol.* 2000;35:1288-1294.
38. Eagle KA, Rihal CS, Mickel MC, Holmes DR, Foster ED, Gersh BJ. Cardiac risk of noncardiac surgery: influence of coronary disease and type of surgery in 3368 operations: CASS Investigators and University of Michigan Heart Care Program: Coronary Artery Surgery Study. *Circulation.* 1997;96:1882-1887.
39. Hassan SA, Hlatky MA, Boothroyd DB, et al. Outcomes of noncardiac surgery after coronary bypass surgery or coronary angioplasty in the By-

pass Angioplasty Revascularization Investigation (BARI). *Am J Med.* 2001;110:260-266.
40. Fleisher LA, Eagle KA, Shaffer T, Anderson GF. Perioperative- and long-term mortality rates after major vascular surgery: the relationship to preoperative testing in the medicare population. *Anesth Analg.* 1999;89:849-855.
41. Raby KE, Brull SJ, Timimi F, et al. The effect of heart rate control on myocardial ischemia among high-risk patients after vascular surgery. *Anesth Analg.* 1999;88:477-482.
42. Stone JG, Foex 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.
43. Pasternack PF, Grossi EA, Baumann FG, et al. Beta blockade to decrease silent myocardial ischemia during peripheral vascular surgery. *Am J Surg.* 1989;158:113-116.
44. Poldermans D, Boersma E, Bax JJ, et al; Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography Study Group. The effect of bisoprolol on perioperative mortality and myocardial infarction in high-risk patients undergoing vascular surgery. *N Engl J Med.* 1999;341:1789-1794.
45. Mangano DT, Layug EL, Wallace A, Tateo I; 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.
46. Boersma E, Poldermans D, Bax JJ, et al. Predictors of cardiac events after major vascular surgery: role of clinical characteristics, dobutamine echocardiography, and beta-blocker therapy. *JAMA.* 2001;285:1865-1873.
47. Grayburn PA, Hillis LD. Cardiac events in patients undergoing noncardiac surgery: shifting the paradigm from noninvasive risk stratification to therapy. *Ann Intern Med.* 2003;138:506-511.
48. Weitz HH. Perioperative cardiac complications. *Med Clin North Am.* 2001;85:1151-1169.
49. Practice guidelines for pulmonary artery catheterization: a report by the American Society of Anesthesiologists Task Force on Pulmonary Artery Catheterization. *Anesthesiology.* 1993;78:380-394.
50. Charlson ME, MacKenzie CR, Gold JP, et al. The preoperative and intraoperative hemodynamic predictors of postoperative myocardial infarction or ischemia in patients undergoing noncardiac surgery. *Ann Surg.* 1989;210:637-648.
51. Polanczyk CA, Rohde LE, Goldman L, et al. Right heart catheterization and cardiac complications in patients undergoing noncardiac surgery: an observational study. *JAMA.* 2001;286:309-314.
52. Sandham J, Hull R, Brant FB, et al. A randomized, controlled trial of the use of pulmonary-artery catheters in high-risk surgical patients. *N Engl J Med.* 2003;348:5-14.
53. Eisenberg MJ, London MJ, Leung JM, et al; The Study of Perioperative Ischemia Research Group. Monitoring for myocardial ischemia during noncardiac surgery: a technology assessment of transesophageal echocardiography and 12-lead electrocardiography. *JAMA.* 1992;268:210-216.
54. Fink AS, Campbell DA Jr, Mentzer RM, et al. The National Surgical Quality Improvement Program in non-veterans administration hospitals: initial demonstration of feasibility. *Ann Surg.* 2002;236:344-353.
55. Khuri SF, Daley J, Henderson W, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care: National VA Surgical Quality Improvement Program. *Ann Surg.* 1998;228:491-507.
56. Devereaux PJ, Ghali WA, Gibson NE, et al. Physician estimates of perioperative cardiac risk in patients undergoing noncardiac surgery. *Arch Intern Med.* 1999;159:713-717.
57. Poldermans D, Bax JJ, Kertai MD, et al. Statins are associated with a reduced incidence of perioperative mortality in patients undergoing major noncardiac vascular surgery. *Circulation.* 2003;107:1848-1851.
58. Lindenauer PK, Pekow P, Wang K, Gutierrez B, Benjamin EM. Lipid-lowering therapy and in-hospital mortality following major noncardiac surgery. *JAMA.* 2004;291:2092-1099.
59. Dudley JC, Brandenburg JA, Hartley LH, Harris S, Lee TH. Last-minute preoperative cardiology consultations: epidemiology and impact. *Am Heart J.* 1996;131:245-249.