CARDIAC EVENTS SUCH AS MYOCARDIAL INFARCTION OR CARDIAC DEATH ARE COMMON COMPLICATIONS OF SURGERY, OCCURRING IN 1% TO 5% OF UNSELECTED PATIENTS UNDERGOING NONCARDIAC SURGERY.1,6 THESE EVENTS ARE ASSOCIATED WITH MARKEDLY INCREASED MORTALITY7,8 AND RESULT IN HIGHER COSTS,5,9 MAKING THEM THE MOST COMMON REASONS FOR PREOPERATIVE EVALUATIONS.10-12

The prevalence of these events and their high mortality have made the prevention of perioperative cardiac events the subject of practice guidelines,13 position papers,14 and numerous prediction rules seeking to identify patients at high risk for cardiac complications.5,7,15-20 Until recently, attempts to reduce the incidence of these complications depended on preoperative assessments of risk followed by clinical recommendations, including the option of postponing or canceling the surgical procedure.11,14

The evidence behind guidelines for testing or interventions, whether preoperative, intraoperative, or postoperative, was remarkably weak even as consensus approaches were developed for using treatments up to and including prophylactic coronary artery bypass surgery. Concern exists that preoperative intervention might prove detrimental because it remains unclear whether the benefit in reduced perioperative cardiac events is offset by the risks of revascularization itself.13,14,21,22

Strategies including percutaneous transluminal angioplasty as the revascularization of choice and the use of beta-blockers in selected patients deserves consideration.18,19

Context Recent studies suggest that perioperatively administered beta-blockers may reduce the risk of adverse cardiac events in patients undergoing major noncardiac surgery.

Objective To review the efficacy of perioperative beta-blockade in reducing myocardial ischemia, myocardial infarction, and cardiac or all-cause mortality from randomized trials.

Data Sources A MEDLINE and conventional search of English-language articles published since 1980 was performed to gather information related to perioperative cardiac complications and beta-blockade. Reference lists from all relevant articles and published recommendations for perioperative cardiac risk management were reviewed to identify additional studies.

Study Selection and Data Extraction Prospective randomized studies (6) were included in the analysis if they discussed the impact of beta-blockade on perioperative cardiac ischemia, myocardial infarction, and mortality for patients undergoing major noncardiac surgery. Articles were examined for elements of trial design, treatment protocols, important biases, and major findings. These elements were then qualitatively compared.

Data Synthesis We identified 5 randomized controlled trials: 4 assessed myocardial ischemia and 3 reported myocardial infarction, cardiac, or all-cause mortality. All studies sought to achieve beta-blockade before the induction of anesthesia by titrating doses to a target heart rate. Of studies reporting myocardial ischemia, numbers needed to treat were modest (2.5-6.7). Similarly modest numbers needed to treat were observed in studies reporting a significant impact on cardiac or all-cause mortality (3.2-8.3). The most marked effects were seen in patients at high risk; the sole study reporting a nonsignificant result enrolled patients with low baseline risk. As a group, studies of perioperative beta-blockade have enrolled relatively few carefully selected patients. In addition, differences in treatment protocols leave questions unanswered regarding optimal duration of therapy.

Conclusions Despite heterogeneity of trials, a growing literature suggests a benefit of beta-blockade in preventing perioperative cardiac morbidity. Evidence from these trials can be used to formulate an effective clinical approach while definitive trials are awaited.

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peroperative cardiac risk. One study found that postoperative ischemia increased the odds of postoperative myocardial events 21-fold. As a result, medical strategies to reduce perioperative ischemia have been proposed. Studies using intravenous calcium channel blockers or intravenous nitroglycerin provided mixed results. In contrast, small observational studies of β-blockers have examined the effects of perioperative cardiac complications and adrenergic blockade and combined the results of these searches with MeSH terms. Reference lists from all relevant articles and published recommendations for perioperative cardiac risk management were reviewed to identify additional studies.

To account for advances in perioperative medical, surgical, and anesthetic technique, we limited our search to investigations published since 1980. To focus on efficacy, we further limited our search to prospective randomized trials reporting the impact of β-blockade on perioperative cardiac ischemia, myocardial infarction, and mortality.

Because of the recognized difficulties in quality scoring of randomized trials, we did not score the quality of trials meeting our inclusion criteria. However, the abstraction forms for each trial did include key elements pertaining to trial design, such as blinding, comparability of the intervention and control groups, completeness of follow-up, and important confounders or biases.

Our search strategy yielded 7 randomized trials of perioperative β-blockade. A randomized trial by Harwood et al was excluded because both groups received β-blockers (ie, there was no control group). Although data from a study by Wallace et al were derived from the study by Mangano et al, the study reported effects of β-blockade on different outcomes (ie, myocardial ischemia) and was included as a subset of the same study in our review.

Thus, this review included 6 publications representing 5 trials studying

<table>
<thead>
<tr>
<th>Table. Randomized Controlled Trials of the Effectiveness of Perioperative β-Blockade*</th>
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<tbody>
<tr>
<td>Source, y</td>
</tr>
<tr>
<td>Mangan et al,42 1996; Wallace et al,27 1998</td>
</tr>
<tr>
<td>Poldermans et al,46 1999</td>
</tr>
<tr>
<td>Raby et al,37 1999</td>
</tr>
<tr>
<td>Stone et al,44 1988</td>
</tr>
<tr>
<td>Urban et al,45 2000</td>
</tr>
</tbody>
</table>

*MI indicates myocardial infarction; NS, not significant.

All comparisons are presented as β-blocker vs control.
the effectiveness of perioperative β-blockade in reducing perioperative myocardial ischemia and cardiac or all-cause mortality (Table).

**Study Interventions and Outcomes**

Although studies used different agents, doses, and dosing schedules, the general approach in each study was similar: administration of a β-blocker before induction of anesthesia, followed by β-blockade throughout the operation and postoperative period. In all but one study, the dose was titrated to a target heart rate, generally 70/min or lower (Table).

The identified studies reported a range of clinical outcomes: 4 included assessment of myocardial ischemia,26,36,43,44 and 3 reported myocardial infarction, pulmonary edema, cardiomyopathy, and 3 reported myocardial ischemia.26,36,43,44 and 3 reported myocardial ischemia.42,44,45

**Evidence for Effectiveness of β-Blockade in Reducing Perioperative Cardiac Events**

Of 4 studies reporting the effect of β-blockers on perioperative ischemia, all but 1 found a statistically significant reduction in ischemia among treated patients. Wallace et al,29 in a subset analysis of data from Mangano et al,46 reported less frequent perioperative myocardial ischemia in atenolol-treated patients. Stone et al13 suggested a similar effect of β-blockade on Holter monitor–documented myocardial ischemia. However, the authors did not report the types of procedures included in their sample, nor did they statistically compare baseline patient characteristics, leaving their conclusions open to debate. Raby et al36 also found a significant beneficial effect of β-blockade by using a continuous infusion of esmolol in high-risk patients undergoing vascular surgery. Although Urban et al44 also found a reduction in perioperative ischemia, this difference failed to reach statistical significance. These findings may be explained in part by differences in the cardiac risk of this cohort, who were undergoing elective total knee replacement. In studies finding a statistical difference, rates of ischemia were between 28% and 73% in controls compared with the 15% rate of ischemia observed in this control group. In addition, the target heart rate of 80/min used in this study was substantially higher than that in other studies, suggesting that inadequate adrenergic blockade may have played a role in their findings.

Of studies reporting cardiac events and cardiac mortality, 2 reported significant improvement in patient outcomes because of β-blockade. In a study of male veterans at risk for coronary disease (Box 1) and undergoing major noncardiac surgery, Mangano et al46 observed no difference in in-hospital mortality caused by β-blockade. However, they observed a relative reduction in all-cause mortality of nearly 55% at 2 years. This difference, which appeared within the first 8 months of follow-up, was ascribed to a marked reduction in cardiac events in the first year of therapy (67% reduction at year 1, 48% at year 2). Patients in the β-blocker group had less coronary disease at study entry, were receiving angiotensin-converting enzyme inhibitors more frequently, and were less likely to have...
β-blockers in noncardiac surgery

Box 1. Eligibility Criteria for Use of Perioperative β-Blockers

Minor Clinical Criteria (Adapted From Mangano et al48)
Use β-blockers in patients meeting any 2 of the following criteria:
- Aged 65 years or older
- Hypertension
- Current smoker
- Serum cholesterol concentration at least 240 mg/dL (6.2 mmol/L)
- Diabetes mellitus not requiring insulin therapy

Revised Cardiac Risk Index Criteria50
Use β-blockers in patients meeting any of the following criteria:
- High-risk surgical procedure, defined as intraperitoneal, intrathoracic, or suprainguinal vascular procedure
- Ischemic heart disease, defined as the following:
  - History of myocardial infarction
  - History of or current angina
  - Use of sublingual nitroglycerine
  - Positive exercise test results
  - Q waves on electrocardiogram
- Patients who have undergone percutaneous transluminal coronary angioplasty or coronary artery bypass graft surgery and who have chest pain presumed to be of ischemic origin
- Cerebrovascular disease, defined as the following:
  - History of transient ischemic attack
  - History of cerebrovascular accident
- Diabetes mellitus requiring insulin therapy
- Chronic renal insufficiency, defined as a baseline creatinine level of at least 2.0 mg/dL (177 μmol/L)

*Suggested by Boersma et al.60 Congestive heart failure is also an element in the Revised Cardiac Risk Index but is not an indication for perioperative β-blockade.

β-blocker use discontinued postoperatively, perhaps biasing results in favor of the treatment group.47,48 However, adjustment for these differences in multivariable models did not alter their findings.46 Although acknowledging the limitations of their results in terms of generalizability to other patient populations and sites, the authors favored broader use of β-blockade in clinical trials.

Poldermans et al15 found an even greater benefit of β-blockade among high-risk patients. These investigators enrolled patients who were to undergo vascular surgery and had myocardial ischemia documented by dobutamine echocardiography, with an estimated rate of major perioperative cardiac events of 28%. The entire patient cohort had experienced a 90% reduction in cardiac death or nonfatal myocardial infarction by 30 days. Follow-up care did not include additional therapy (ie, cardiac catheterization or revascularization), raising concerns that the research algorithm did not realistically reflect clinical practice.49,50 However, if the true rate of events in β-blocker–treated patients is low (the point estimate from this small study was 3.4%), the risks associated with revascularization51 may outweigh any incremental benefit.

In contrast to the previous 2 studies, the study by Urban et al44 found no significant difference in rates of inhospital myocardial infarction. It is likely that these investigators’ ability to detect a difference was limited in part by the relatively small sample size and shorter length of follow-up. This study also included a large proportion of patients (30% in each group) who had been receiving β-blockers preoperatively; such patients were variably excluded from other trials. Patients who are β-blocker naive may have a different response to perioperative β-blockers, or long-term use of these agents may represent a confounding factor incompletely accounted for in other studies of perioperative β-blockade.

Differences in absolute magnitude of benefit can be ascribed in part to the cardiac risks of the patients enrolled (reflected in event rates in the control groups), with the greatest absolute benefits seen in patients at highest risk. That is, assuming a fixed relative benefit of β-blockade, the absolute differences in rates of adverse events will vary according to the baseline risk of the patients treated. For patients at extremely high risk, such as those enrolled by Poldermans et al,49 the absolute reduction in risk was 30%, resulting in a number needed to treat of slightly more than 3. In contrast, Mangano et al50 observed an 8% absolute risk reduction, suggesting that 9 patients would require therapy to reduce mortality at 2 years. Although not statistically significant, the 4% absolute reduction in risk (2% in treated patients vs 6% in control patients) observed by Urban et al would result in a much larger number needed to treat, despite an approximately 33% reduction in risk.

Adverse Effects of Perioperative β-Blockade

Stone et al13 reported high rates of bradycardia (21 of 89 patients) in β-blocker–treated patients, half of whom required atropine therapy. Adverse events related to the use of β-blockers in other reviewed studies were similarly infrequent. For example, 38% of β-blocker–treated subjects, compared with 15% of control subjects, had bradycardia intraoperatively, but other postoperative adverse events were rare and did not require discontinuation of the medication.52 Similar rates of adverse effects have been noted in studies examining β-blockade in patients undergoing cardiac surgery.41,52,53 One study examining the use of propranolol in patients undergoing thoracotomy for pneumonectomy suggested that patients receiving this nonselective β-blocker had...
more frequent postoperative bradycardia (25% vs 4%; \( P = .018 \)) and hypotension (49% vs 20%; \( P = .003 \)); higher incidence of pulmonary edema (16% vs 8%; \( P = .45 \)) was not statistically significant.\(^54\)

The use of perioperative \( \beta \)-blockade in patients who had not been receiving \( \beta \)-blockers long-term may also pose an additional risk in that withdrawal of \( \beta \)-blockers may lead to adrenergic hypersensitivity and possibly worsened outcomes. A recent prospective observational study noted that patients who were not receiving \( \beta \)-blockers long-term but who discontinued perioperative use immediately after surgery had a markedly increased risk for postoperative myocardial infarction.\(^53\) This effect was not observed in randomized trials of \( \beta \)-blockade that used shorter treatment regimens\(^36,45\) and needs to be confirmed by larger studies. Alternatively, confusion about the use of \( \beta \)-blockade or discontinuity in postoperative care may lead to \( \beta \)-blockers’ being inappropriately discontinued during hospitalization or afterward. Discontinuing \( \beta \)-blocker use in patients who have a longstanding indication for adrenergic blockade may lead to adverse outcomes perioperatively\(^56\) or worsened patient survival.\(^37-39\)

**Clinical Questions**

**Which Patients Should Receive \( \beta \)-Blockers Perioperatively?** Studies of perioperative \( \beta \)-blockade have been performed largely in selected patient populations with a risk of perioperative cardiac events that is higher, on average, than that of the general population of surgical patients. Thus, physicians must seek data from studies that included patients most akin to those they treat in practice. Although it has significant limitations, the study by Mangano et al\(^46\) is the only one to enroll a reasonably broad spectrum of surgical patients. Thus, its criteria may represent a reasonable means of identifying patients who would benefit from \( \beta \)-blockade (Box 1), largely by excluding low-risk patients. This approach has been incorporated into the American College of Physicians guidelines.\(^14\)

A recent observational study of patients undergoing vascular surgery suggested a clinical approach to the use of \( \beta \)-blockade. In this study, adjusted relative risk of postoperative cardiac events among patients receiving \( \beta \)-blockers was 0.3 (95% confidence interval [CI], 0.1-0.7) across strata of the Revised Cardiac Risk Index (Box 1),\(^63,64\) an effect size similar to that seen in randomized trials. However, lowest-risk patients who had no Revised Cardiac Risk Index criteria received little benefit in absolute terms from \( \beta \)-blockers, while those at highest risk (3 or more criteria) remained at substantial risk even if treated with \( \beta \)-blockers. As an observational trial, these findings may be subject to confounding factors not accounted for in multivariable analyses and may not be generalizable to other groups.

The effectiveness of \( \beta \)-blockade in patients at high risk because of aortic stenosis or unstable or severe cardiovascular symptoms is unknown. It is likely that patients with severe cardiac symptoms caused by angina pectoris would benefit from \( \beta \)-blockade, but these patients have not been studied directly. The safety and effectiveness of new preoperative \( \beta \)-blockade in patients with a depressed ejection fraction is also unknown, since these patients were not included in randomized trials. \( \beta \)-Blockade has not been studied in patients undergoing regional anesthesia or conscious sedation. In addition, no study to date has directly examined the use of \( \beta \)-blockade in patients who have poor functional status and might otherwise be referred for additional noninvasive testing.\(^53,54,56\) Patients who are at risk because of high-grade conduction system disease have an absolute contraindication to \( \beta \)-blockade and require different management strategies.

The effectiveness of \( \beta \)-blockade in terms of costs or outcomes in patients at low risk is unclear. Results from Boersma et al\(^18\) suggest that \( \beta \)-blockade provides little additional benefit in patients with no clinical risk factors. Thus, it seems likely that patients who are undergoing low-risk procedures (eg, those undergoing same-day or outpatient surgery or ophthalmic surgery) and have no or minimal cardiac risk factors may be as likely to experience adverse effects from \( \beta \)-blockers as to experience a cardioprotective benefit.

\( \beta \)-Blockade may have additional beneficial effects for elderly patients. In one study, patients who received \( \beta \)-blockers were extubated more quickly, required less medication for pain, and were more alert sooner after surgery.\(^62\) Although the unblinded nature of this study leaves its findings open to debate, the possibility of additional benefits is tantalizing and worthy of further investigation.

**Which \( \beta \)-Blocking Agent Should Be Used?** All studies showing benefit of \( \beta \)-blockade on mortality and myocardial ischemia have used \( \beta _1 \)-selective agents. Nonselective agents such as propranolol, although likely to have a similar impact on myocardial oxygen demand if titrated appropriately, are more likely to produce adverse pulmonary effects\(^50,54\) and in fact caused more bronchospasm in one study of perioperative propranolol.\(^54\)

No evidence suggests an advantage of any particular \( \beta _1 \)-selective \( \beta \)-blocker. Studies to date have used several agents, suggesting that the efficacy of \( \beta \)-blockade is class rather than drug dependent. Blocking or blunting adrenergic responses is the key pathophysiologic step connecting \( \beta \)-blockers to improved outcomes, and evidence suggests that physicians may choose any medication that meets this physiologic goal.

Patients who are receiving long-term \( \beta \)-blocker therapy need not begin taking one of the drugs used in published studies instead. Evidence from Mangano et al\(^62\) and Urban et al\(^14\) support using additional intravenous agents, whether an additional dose of the patient’s long-term medication or another \( \beta \)-blocker, immediately perioperatively, but no evidence supports exchanging one agent for another.

**Are Other Adrenergic Blocking Agents Effective?** Selective sympatholytics (\( \alpha _2 \)) may also improve patient outcomes. Clonidine has been suggested to
lower blood pressure, heart rate, and nor-
epinephrine levels in patients undergo-
going vascular surgery suggested that cloni-
fact, one study of 297 patients under-
ving vascular surgery suggested that clon-
dine-treated patients had fewer epis-
odes of ischemia.67 In a recent study, mivazer-
el, an α1-agonist that reduces postganglionic noradrenaline avail-
ability and spinal efferent sympathetic out-
put, reduced the incidence of perioper-
ative ischemia.68 A subsequent large ran-
domized trial of 1897 patients un-
dergoing noncardiac surgery produced mixed results, however.69 In the whole 
cohort, mivazerol had no statistically sig-
nificant effect on all-cause mortality or 
myocardial infarction, but cardiac mor-
tality was reduced by half (relative risk of 
events among treated patients, 0.50; 95% CI, 0.25-0.96). In planned sub-
group analyses, a more marked impact 
was observed among patients under-
going vascular surgery, where the relative 
risk of postoperative myocardial infar-
tion and death among treated patients 
was 0.67 (95% CI, 0.45-0.98), and the relative risk for cardiac death was 0.32 
(95% CI, 0.12-0.76).69 Although mivazer-
el is not available in the United States, 
findings from this study support the cen-
tral role of adrenergic blockade in pre-
venting cardiac events.

No data to date suggest that α1-
selective blocking agents provide any 
benefit to patients perioperatively, and 
use of these agents alone is not sup-
ported by current evidence. Patients re-
ceiving α1 blockers long-term would 
likely benefit from the addition of 
β-blocking agents perioperatively.

When Should β-Blocker Use Be 
Started Preoperatively and When 
Should It Be Discontinued? Although 
questions remain regarding the opti-
mal dosing schedule for perioperative 
β-blocker therapy, investigations show-
ing a positive effect sought to achieve 
sympatholysis before induction of an-
esthesia. Thus, physicians should try to 
begin therapy early enough so that 
doses can be titrated appropriately. 
The time required to meet this goal may 
very, depending on the agent, the route 
of administration, or patient factors, but 
it is clear that a physiologic dose of 
β-blocker must be administered for any 
potential impact to be appreciated. For 
example, intravenous atenolol, as used 
by Mangano et al,42 may be adminis-
tered and titrated to a physiologic dose in 
the preanesthesia holding area or 
even the operating room. Physicians 
who choose to begin β-blocker therapy 
ally may require additional lead time 
for patients to reach the target heart rate. 
In fact, patients in Poldermans’ study45 
began oral therapy 1 month before sur-
gery, on average, with titration of the 
dose performed at a visit 1 week after 
initialization of bisoprolol.

Postoperatively, most protocols ex-
tended beyond the first postoperative day 
and even up to 1 month after surgery. 
Nonrandomized data from Shammash et 
al and previous case reports suggest the 
hazards of discontinuation of β-block-
ers immediately postoperatively. A re-
cent study suggested that, among vas-
cular surgery patients who had not been 
receiving β-blockers long-term, continu-
ing β-blockade up to 3 years after sur-
gery reduced cardiac mortality.70 Al-
though tantalizing, these results are based 
on a small number of patients (n = 112) 
with a high burden of cardiovascular ill-
ness and need to be reproduced in larger, 
less selected cohorts.

The safest conclusion to be drawn 
from current studies is that β-blocker use 
should begin before surgery, even up to 
a month before the procedure, with ti-
tration of the dose taking place as an out-
patient procedure and up to the induc-
tion of anesthesia. Therapy should be 
continued at least through hospitaliza-
tion, and longer if adequate medical fol-
low-up can be arranged postopera-
tively. Close follow-up is particularly 
important in the care of patients who 
were not receiving β-blockers long-
term before surgery so that the drug dose 
can be tapered if long-term use is not 
indicated. Follow-up is also imperative for 
patients receiving β-blockers for med-
ical reasons so that continuity in their 
medication is maintained.

Ample evidence suggests that long-
term β-blocker therapy is underused 
in patients with definitive indica-
tions.71-73 Thus, the perioperative pe-
riod may represent an opportunity to 
begin β-blocker therapy in appropriate 
patients, such as those with a his-
tory of myocardial infarction.

Long-term use of β-blockade for pa-
tients with heart failure has been clearly 
shown to improve patient mortality,76 
and these patients might also be iden-
tified perioperatively. However, guide-
lines for administration of these agents 
in patients with heart failure require 
close monitoring,79 and the doses ad-
ministered are usually far lower and not 
titrated to heart rate. β-Blockade in 
these patients, therefore, should not be 
routinely started for prophylaxis peri-
operatively.

In Which Patients Should Addi-
tional Cardiac Risk Stratification Be 
Pursued? Data describing the effective-
ness of β-blockade, especially the re-
sults of the study by Poldermans et al,45 
have made some authors wonder 
whether risk stratification is still neces-
sary.69 However, β-blockers alone may 
not reduce the risk of postoperative car-
diac events below thresholds sug-
gested in the American College of Phy-
sicians44 or American Heart Association/
American College of Cardiology risk stra-
fication guidelines.13 In the study by 
Boersma et al,60 patients who were in 
the highest risk strata (5 or more points 
according to the Revised Cardiac Risk 
Index of Lee et al)5 and received β-block-
ers continued to have an estimated car-
diac event rate of 14%; these authors sug-
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Perioperative β-Blockade: 
A Suggested Algorithm 
Although the literature to date has gaps 
and areas of uncertainty, there is ample 
evidence to suggest a clinical ap-
proach to the patient undergoing elec-
tive surgery. We have synthesized the results of our literature review into a clinical algorithm (FIGURE), a set of patient selection criteria (Box 1), and a list of suggested medications, routes, and dosages (Box 2). As in the era before β-blockers, the initial approach to the patient should include risk stratification according to

**Figure.** Perioperative β-Blockers: Patient Selection and Preoperative Risk Stratification

<table>
<thead>
<tr>
<th>Identify Eligible Patients</th>
<th>Risk Stratification</th>
</tr>
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<tbody>
<tr>
<td>≥3 Revised Cardiac Risk Index Criteria</td>
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<tr>
<td>Cardiac Event Rate Without β-Blockade</td>
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<td>≥5 Criteria: 32%5,60</td>
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**Additional Risk Stratification With Noninvasive Tests**

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<tr>
<th>Cardiac Event Rate With β-Blockade</th>
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<td>6.5% to 16%60</td>
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**Assess Functional Status:** Both (1) History of Angina or Peripheral Vascular Disease and (2) Poor (<4 METS) or Indeterminate Functional Status?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
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**Good Functional Status**

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**Positive Noninvasive Test Results**

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**Negative Noninvasive Test Results**

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<th>Consider Additional Therapies to Reduce Risk, eg, Coronary Revascularization</th>
<th>Begin β-Blockade Proceed With Surgery</th>
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Revised Cardiac Risk Index criteria and minor clinical criteria adapted from Mangano et al42 are listed in Table 2. Revised Cardiac Risk Index criteria exclude patients with congestive heart failure because the safety and efficacy of perioperative β-blockers has not been proven in these patients. Cardiac event rates with and without β-blockade are ranges based on rates from Lee et al5 for cardiovascular complications observed in the validation set (those in the derivation set were somewhat lower) and on estimates from Boersma et al.60 Options for noninvasive testing for further risk stratification include dipyramidole thallium scintigraphy, stress echocardiography, exercise electrocardiography, or cardiac catheterization in appropriate patients. Examples of activities that expend about 4 METS (metabolic equivalent tasks) include climbing 1 flight of stairs, being able to walk on level ground at 4 mph, or being able to climb a short hill without difficulty.
clinical criteria. As described, there are numerous risk stratification strategies available to physicians, many of which have published information regarding test characteristics and accuracy. There is little reason to suspect that other risk indices could not be used similarly, but only 1 study has explicitly reported the use of any risk-stratification method in the context of β-blocker use.\(^{60}\) This study used the Revised Cardiac Risk Index of Lee et al\(^{30}\) to identify high-, intermediate-, and low-risk groups and suggested a strategy for further testing or use of β-blockers. The criteria of Mangano et al\(^{42}\) provide an alternative approach to choosing patients, largely by excluding patients at lowest risk, but do not identify patients who require further risk stratification alone.

The first step in risk stratification is to identify patients who are at lowest risk (those whose estimated risk is lower than 10%). Using β-blockers in patients at low risk (0 Revised Cardiac Risk Index criteria and none of the cardiac risk factors in Mangano et al\(^{42}\); Box 1) imparts little absolute benefit, and surgery can proceed without addition of this medication. In contrast, patients at highest risk (those whose estimated risk is higher than 10%). Using β-blockers perioperatively every day (1-2 Revised Cardiac Risk Index criteria) require additional risk stratification using noninvasive or invasive testing. Although the study by Boersma et al\(^{60}\) used dobutamine echocardiography to identify highest-risk patients, other noninvasive testing and even coronary angiography may be substituted according to published guidelines.\(^{13}\) As described, the utility of preoperative revascularization remains unclear, except in patients with an indication for these procedures in the absence of the planned surgical procedure. We recommend noninvasive testing only in higher-risk patients and in moderate-risk patients whose exercise capacity cannot be determined by history, a much narrower use of testing than recommended by some\(^{60}\) but consistent with the recommendations of others.\(^{13,14}\)

Patients who are at high risk and have negative noninvasive testing results and those at intermediate risk (1-2 Revised Cardiac Risk Index criteria) should begin taking a β-blocker if not taking one long-term (Box 2). Optimally, medications should be started before hospitalization and, if possible, as long as 30 days before surgery. This period, used in the study by Poldermans et al,\(^{49}\) will allow for adequate titration of the medication to the target heart rate. Patients receiving β-blockers long-term should have their dose evaluated and adjusted appropriately as outpatients. Dose titration up to induction of anesthesia may be performed with intravenous atenolol\(^{42}\) in all patients.

Postoperatively, oral β-blocker use should be restarted as soon as possible, with intravenous atenolol\(^{42}\) used for stable patients who are unable to take medications orally. Patients who are unstable should receive a short-acting intravenous β-blocker such as esmolol until they are able to tolerate longer-acting oral medications. The transition to oral medications should overlap with intravenous medications to maintain a target heart rate. Oral β-blocker use should be continued at least through hospitalization and up to 1 month postoperatively, when a gradual reduction in the dose can be initiated in patients without an indication for long-term therapy. As mentioned, the postoperative visit may also represent an opportunity to begin long-term β-blocker therapy in appropriate patients.

**Conclusions**

Results from several well-designed clinical trials suggest that use of β-blockers perioperatively is associated with significant reductions in cardiac morbidity and mortality. However, as a group, studies that support their use are
relatively small, with a total enrollment of fewer than 700 patients. In addition, these studies often included patients who were selected and not consecutively recruited, making generalizability of their results difficult. No randomized study to date has compared the impact of β-blockade in an unselected population of patients undergoing surgery, so there is little direct evidence describing the impact of β-blockers in average patients, such as those who have stable coronary disease and are undergoing elective surgery. β-Blocker therapy may reduce the need for additional tests and revascularization procedures, further reducing costs of care, but wider use of this therapy will be better supported if findings from existing studies are replicated in large randomized trials. Studies are also required to answer questions regarding optimal duration of therapy, identify populations of patients in which β-blocker use is cost-effective, and allow for development of new perioperative risk-management algorithms that reflect the impact of β-blockers on patient outcomes.

REFERENCES

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