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CLINICAL RESEARCH STUDY

Impact of Perioperative Cardiac Assessment Guidelines on Management of Orthopedic Surgery Patients

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ABSTRACT

PURPOSE: The study assessed whether the American College of Cardiology/American Heart Association (ACC/AHA) preoperative cardiac assessment guidelines impact patient management and predict major cardiac events in patients undergoing orthopedic surgery.

SUBJECTS AND METHODS: We conducted a retrospective review of 338 consecutive orthopedic preoperative evaluations performed by internal medicine consultants. Major cardiac events were defined as myocardial infarction, congestive heart failure, and sudden cardiac death.

RESULTS: Major cardiac events occurred in 5.7% of patients. Patients with minor or absent ACC/AHA clinical risk predictors were less likely to have major cardiac events ($P = .007$). More than half (51%) of patients meeting ACC/AHA indications for noninvasive cardiac tests did not receive them. However, most (69%) major cardiac events occurred in patients not meeting criteria for cardiac testing. Abnormal noninvasive cardiac testing results did not alter medication recommendations and only resulted in coronary revascularization in 0.6% of patients. Only 3% of patients with abnormal noninvasive cardiac testing results had major cardiac events. Patients with abnormal cardiac test results were more likely to have recommendations for perioperative beta-blockade ($P < .01$). Patients aged more than 70 years (odds ratio 5.0; 95% confidence interval, 1.32-19.28) and patients undergoing hip surgery (odds ratio 7.5, 95% confidence interval, 1.02-54.55) were more likely to have major cardiac events. Major cardiac events occurred in 12% of urgent and 4% of elective procedures ($P = .009$).

CONCLUSIONS: The ACC/AHA guidelines accurately predict cardiac risk in orthopedic surgery. Abnormal noninvasive cardiac test results rarely affected preoperative recommendations, but improved compliance with beta-blocker therapy. Advanced age, urgent procedures, and hip surgery were associated with increased risk of major cardiac events. © 2007 Elsevier Inc. All rights reserved.

KEYWORDS: Perioperative care; Preoperative care; Risk assessment; Orthopedic surgery; Adrenergic beta-antagonists

Internal medicine preoperative clinics commonly assess and manage cardiac risk before orthopedic surgery. Patients undergoing joint replacement, laminectomy, amputation, and fracture repair are often elderly and have multiple chronic diseases. The 1996 and 2002 American College of Cardiology/American Heart Association (ACC/AHA) peri-

operative cardiac assessment guidelines classify orthopedic surgery as an intermediate-risk surgery.^{1,2} Because many elderly patients have both low functional status and at least intermediate clinical predictors of cardiac morbidity, preoperative noninvasive cardiac tests are performed frequently in accordance with the guidelines. The most commonly described orthopedic surgery in the perioperative literature is hip fracture repair, with cardiac complication rates ranging from 7% to 12%.^{3,4}

Preoperative cardiac testing has been questioned with the widespread use of B-adrenergic blockers in patients with cardiac risk factors but no symptoms of cardiac disease.⁵ Recent evidence in patients undergoing vascular surgery

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found that preoperative percutaneous revascularization, even in those with abnormal noninvasive cardiac testing results, does not reduce perioperative cardiac risk.⁶ There also is evidence that preoperative percutaneous revascularization may increase cardiac events if surgery is performed too soon after revascularization.⁶⁻⁸

Despite numerous studies on risk stratification and reduction in vascular surgery, there are little comparable data for orthopedic procedures.

We wanted to answer 2 major questions with our study: to assess whether ACC/AHA preoperative cardiac assessment guidelines impact noninvasive cardiac testing and patient management and to determine whether any surgical or patient-specific risk factors were associated with major adverse cardiac events, defined as myocardial infarction, congestive heart failure, or sudden cardiac death.

METHODS

Tripler Army Medical Center is a 209-bed tertiary care hospital with orthopedic surgery and internal medicine residencies. Patients are screened before surgery by an anesthesiologist and receive an electrocardiogram. Patients identified as having comorbid conditions associated with an increased risk for perioperative complications are referred to the internal medicine consult service for risk stratification and management. The patients are managed by the orthopedic surgery service postoperatively with additional input provided by the internal medicine consult service at the request of the attending surgeon.

We retrospectively reviewed consecutive preoperative consults between January 1998 and January 2002. We obtained the outpatient prescription history, pertinent laboratory test results, comorbid conditions, perioperative recommendations, and results of any further cardiac testing and consultation. Inpatient admission and discharge summaries, hospital progress notes, and autopsy results were reviewed. In addition, we determined whether beta-blockers were recommended or received during the perioperative period.

Major cardiac complications were categorized as myocardial infarction, symptoms of congestive heart failure with roentgenographic evidence of pulmonary edema, or sudden cardiac death occurring before the patient's hospital discharge. Myocardial infarction was defined as an acute coronary syndrome with elevation of three consecutive troponin-I measurements and an electrocardiogram change from the preoperative baseline. Minor cardiac complications, such as dysrhythmias, were also recorded.

Statistical analyses were performed with STATA 8.0 software (College Station, Tex). Values are reported mean \pm standard deviation. We considered a *P* value of .05 or less to be significant. The chi-square or Fisher exact test was used to compare categorical variables and a Student *t* test (2-tailed) was used to compare continuous variables between groups. One-way analysis of variance with Scheffe post hoc analysis was used to compare cardiac complications between the different subgroups of ACC/AHA clinical predictors and the Revised Cardiac Index Score. Odds ratios estimating the risk of perioperative cardiac complications were calculated using logistic regression in 2 models. One used surgical type, such as hip replacement, knee replacement, extremity surgery, and spine surgery adjusted for age and gender, and the other used individual patient characteristics (disease characteristics and exercise tolerance). We tested for first-degree multiplicative interaction between the independent variables in each of the final models.

CLINICAL SIGNIFICANCE

- The 2005 ACC/AHA guidelines accurately identified low risk orthopedic surgery patients in an internal medicine preoperative clinic.
- Most patients who had perioperative cardiac events did not meet ACC/AHA criteria for non-invasive testing.
- Abnormal non-invasive cardiac testing rarely resulted in preoperative revascularization in asymptomatic patients, but did improve compliance with β -adrenergic blockade.
- Hip surgery, advanced age, and urgent surgery were associated with increased risk of major perioperative cardiac events.

RESULTS

Patient Demographics

A total of 338 consecutive orthopedic preoperative consults to the internal medicine clinic were reviewed with their corresponding operative and hospital records. The patients were elderly, with a mean age of 65.9 years, and had multiple comorbidities (Table 1). The most common of these were coronary artery disease (26%) and diabetes (19%). Most patients (68%) had a specific description of functional status that could be linked to the activity scale of Goldman,⁹ the criteria of Reilly,¹⁰ or the Duke Activity Status Index.¹¹ Many patients (39%) had poor functional status estimated as less than 4 metabolic equivalents (METS). Most patients (92%) with low functional status were limited because of joint pain. Many patients had minor (43%) or no (18%) ACC/AHA predictors of perioperative cardiac risk. However, 38% had intermediate predictors and one patient had a major predictor, symptomatic aortic stenosis (Table 2).

One-third (34%) of preoperative evaluations were done for patients undergoing hip surgery. Of these, nearly half (45%) were for hip fractures, and the remainder were for chronic degenerative joint disease. Knee-replacement surgeries comprised 33%, spine surgery comprised 8%, and other extremity surgery comprised 25%. Extremity surgery included several types of shoulder procedures, ligament and

Table 1 Clinical Characteristics of Patients and Association with Risk for Major Perioperative Cardiac Complications (n = 338)

	All Patients n (%)	Patients without Complications n (%)*	Patients with Complications n (%)†	Univariate Analysis (P value)	Multivariate Model OR (95% CI)*
Mean ± SD age, y	65.9 ± 13.5	65.17 ± 13.3	78.9 ± 8.5	<.001	NA
Male gender, n (%)	211 (62)	201 (66)	10 (53)	.355	0.8 (0.26-2.35)
Age ≥ 70 y, n (%)	157 (71)	141 (44)	16 (84)	.001	5.0 (1.32-19.28)
CCS Class I or II angina pectoris	6 (2)	5 (2)	1 (5)	.237	5.5 (0.45-66.34)
History of myocardial infarction	87 (26)	79 (25)	8 (42)	.095	1.5 (0.43-5.28)
History of congestive heart failure	12 (4)	9 (3)	3 (16)	.003	3.6 (0.75-20.73)
History of diabetes mellitus	64 (19)	59 (18)	5 (26)	.402	0.7 (0.21-2.74)
History of renal insufficiency	11 (3)	9 (3)	2 (10)	.067	4.1 (0.63-32.04)
Abnormal ECG without cardiac history	38 (11)	37 (12)	1 (5)	.394	0.4 (0.04-3.34)
Stage II hypertension (BP ≥180/100 mm Hg)	19 (6)	17 (5.3)	2 (10)	.240	3.3 (0.56-17.78)
Functional capacity <4 METS	132 (39)	122 (38)	10 (53)	.216	1.1 (0.40-3.24)
Perioperative beta-blocker use	125 (37)	115 (36)	10 (53)	.155	1.0 (0.37-2.95)

OR = odds ratio; CI = confidence interval; SD = standard deviation; NA = not available; CCS = Canadian Cardiovascular Society; ECG = electrocardiogram; BP = blood pressure; METS = metabolic equivalents [of oxygen consumption].

*Of 319 patients without major cardiac complications.

†Of 19 patients with major cardiac complications.

tendon repair, amputations, foot and ankle surgery, and open reduction and internal fixation of upper and lower extremity long-bone fractures. Despite the ACC/AHA recommendations classifying all orthopedic surgery as intermediate risk, our consultants classified 75% of the surgeries as intermediate risk and 25% of the surgeries as low risk. All of the surgeries classified as low risk were extremity surgeries. Sixty-five procedures (19%) were considered urgent, such as extremity amputations because of osteomyeli-

tis, hip fractures, and complicated long-bone fractures for which surgery could not be postponed indefinitely.

Perioperative Cardiac Testing

If all orthopedic surgery is considered to be intermediate risk per ACC/AHA guidelines, then noninvasive cardiac testing was indicated in 74 patients who had higher than minor clinical predictors of cardiac risk and poor functional status. However, only 36 patients (49%) received noninvasive cardiac testing. In most patients (92%) in whom cardiac testing was warranted by the guidelines but omitted, the sole indication was poor functional status caused by joint discomfort. Noninvasive cardiac testing was ordered in 11% of the 264 patients when not indicated by the guidelines.

In patients receiving noninvasive cardiac testing, adenosine sestamibi myocardial perfusion imaging was most commonly (85%) ordered. The rest of the tests consisted of transthoracic echocardiography (3%) and graded exercise testing with (10%) and without (2%) sestamibi. One patient receiving transthoracic echocardiography had moderate to severe aortic stenosis. Approximately half (46%) of the myocardial perfusion test results were normal. No graded exercise test results without myocardial perfusion imaging were abnormal. In patients with abnormal myocardial perfusion imaging, 25% had a fixed defect, 67% had reversible defects, and 8% had both fixed and reversible defects. In patients with reversible defects, 53% had abnormalities in the distribution of 1 coronary artery, 40% in 2 vessels, and 7% in 3 vessels. No patients with fixed perfusion defects had further testing. Most abnormal cardiac study results (64%) occurred in patients who met ACC/AHA indications for perioperative noninvasive cardiac testing.

As a result of abnormal test results, 13 patients received cardiology consults. All of these patients had reversible perfusion defects that were multivessel in distribution. Of

Table 2 Perioperative Risk Stratification by Cardiac Indexes

Risk index	Total n (%)	No Major Cardiac Events n (%)*	Major Cardiac Events n (%)†
Revised Cardiac Risk Index, n (%)‡			
0	229 (69)	217 (68)	11 (58)
1	81 (24)	78 (25)	3 (16)
2	20 (6)	15 (5)	5 (26)
3	2 (1)	2 (2)	0 (0)
2002 ACC/AHA clinical predictors, n (%)§			
Major	1 (1)	0 (0)	1 (5)
Intermediate	128 (38)	116 (36)	12 (63)
Minor	146 (43)	140 (44)	6 (32)
None	59 (18)	59 (20)	0 (0)

ACC = American College of Cardiology; AHA = American Heart Association.

*Of 319 patients without major cardiac complications.

†Of 19 patients with major cardiac complications.

‡Patients with a revised cardiac index score ≥ 2 were more likely to experience perioperative cardiac complications than patients with lower risk ($P < .004$).

§Patients with intermediate-risk characteristics were more likely to experience perioperative cardiac complications than patients with lower risk ($P = .007$).

Table 3 Major Cardiac Complications Grouped by Surgery

Surgery	Total n (%)	Myocardial Infarction n (%)	Pulmonary Edema n (%)	Sudden Cardiac Death n (%)	Total Patients with Major Cardiac Events n (%)	Cardiac Mortality n (%)	Noncardiac Mortality n (%)	Total Mortality n (%)
Hip	119 (34)	8 (6.7)	8 (3.2)	1 (0.8)	15* (12.6)†	3 (2.5)	3 (2.5)	6 (5.0)
Knee	108 (33)	1 (0.9)	0 (0.0)	0 (0.0)	1 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)
Spine	29 (8)	1 (3.4)	0 (0.0)	0 (0.0)	1 (3.4)	0 (0.0)	0 (0.0)	0 (0.0)
Extremity	82 (25)	2 (2.4)	1 (4.0)	0 (0.0)	2* (2.4)	0 (0.0)	0 (0.0)	0 (0.0)
Total	338 (100)	12 (3.6)	9 (2.7)	1 (0.3)	19* (5.7)	3 (0.9)	3 (0.9)	6 (1.8)

*Includes patients with both myocardial infarction and pulmonary edema.

† $P = .04$ for increased cardiac events when compared with other surgeries.

these, 5 patients underwent coronary angiography. Two patients received coronary stents and then had surgery after a delay of several months without complications. No patient receiving coronary angiography or stents had symptoms of active ischemic heart disease. Both patients receiving stents had high-grade stenosis of the left anterior descending artery. No new medication recommendations were charted as a result of abnormal cardiac test results.

Perioperative Beta-blockers

Perioperative beta-blockers were recommended in 51% of patients. Patients with low functional status, an abnormal asymptomatic electrocardiogram, a surgery of more than minor risk, poorly controlled hypertension, and age more than 70 years were more likely to receive recommendations for a perioperative beta-blocker ($P < .05$ for all). Of the patients receiving beta-blockers, 74% met the criteria of Mangano and colleagues,¹² 11% did not, and 15% had insufficient information to make this determination.

Follow-up of admission orders revealed that 73% of patients in whom a beta-blocker was recommended received it the day of surgery. When beta-blockers were recommended, patients with abnormal preoperative cardiac test results and patients with a history of hypertension and coronary artery disease were more likely to have a beta-blocker order documented in the hospital record ($P < .001$).

Cardiac Complications

The incidence of major cardiac events was 5.7%, and the total mortality was 1.8% for all surgeries. There were 10 patients with cardiac ischemia, 7 patients with pulmonary edema, 2 patients with both cardiac ischemia and edema, and 1 sudden cardiac death (Table 3). Minor cardiac complications, most commonly supraventricular dysrhythmias, occurred in an additional 1.2% of patients for a total incidence of 6.8% for all cardiac postoperative complications and 0.9% for cardiac-related mortality.

Fourteen patients receiving no preoperative cardiac testing had major cardiac complications. Only one of these patients met ACC/AHA indications for noninvasive testing. The other patients were undergoing intermediate-risk surgeries with intermediate predictors and good functional sta-

tus estimated at more than 4 METS. Half of these patients received beta-blockers.

Five patients with preoperative cardiac testing had major cardiac events. Of these, 3 had a normal test result. In the remaining 2 patients, 1 had moderate to severe aortic stenosis diagnosed by preoperative transthoracic echocardiogram, and 1 had mild reversible ischemia in a single-vessel distribution on a myocardial perfusion study. Beta-blockers were recommended in all 5 patients, only 3 of whom received them perioperatively.

Relationship of Patient and Surgical Characteristics to Complications

With the exception of advanced age, no other comorbid condition was associated with an increased risk of major cardiac events. However, patients with intermediate-risk characteristics were more likely to experience perioperative cardiac events compared with those with minor or no clinical predictors ($P = .007$). Patients with a revised cardiac index score of 2 or more also were more likely to have major cardiac events than patients with a lower score ($P < .004$) (Table 2).

The risk of major cardiac complications was higher in hip surgery than other types of orthopedic surgery when adjusted for age and gender (OR 7.5, 95% CI, 1.02-54.55; $P = .04$) (Table 3). This association also was true when other patient characteristics were added to the regression model. The rate of cardiac events in patients with hip fracture was not significantly higher than that of elective hip replacement. No surgery was determined to be an emergency, but many could be considered urgent, such as hip and other complicated long bone fractures and amputations for diabetic osteomyelitis. Cardiac events occurred in 12% of patients with surgeries deemed urgent and 4% of procedures deemed elective ($P = .009$).

DISCUSSION

Our study demonstrates several important findings. First, the age of the patient and urgency of the surgery were important indicators of increased risk of perioperative cardiac complications. Although most of our patient population was geriatric, the very elderly had a substantially higher risk

of complications with most complications occurring in patients aged more than 70 years. The association of age with increased perioperative risk has been described in studies encompassing multiple types of surgery.¹³ Our finding that urgent surgery had a higher risk than elective surgery has also been reported in previous studies.¹⁴

Next, hip surgery is more likely than other types of orthopedic surgery to result in perioperative cardiac complications. In contrast, cardiac complications occurred in less than 1% of knee replacements. This raises the intriguing question of whether all orthopedic surgeries should be considered intermediate risk, as stated in the 2002 ACC/AHA Perioperative Cardiac Evaluation Guidelines. If many surgeries could be reclassified as minor risk, it would result in substantial cost-savings because patients with poor functional capacity would not require noninvasive cardiac testing. Our data suggest that internists intuitively realize this, because a quarter of the time, they classified many types of orthopedic surgery as minor risk, despite the ACC/AHA guidelines. This happened exclusively with extremity surgeries in our study.

Finally, we found that abnormal noninvasive cardiac testing results rarely changed the consultant's preoperative written recommendations. We also found that most cardiac complications occurred in patients who did not receive noninvasive cardiac testing. Furthermore, only 3% of the patients with abnormal cardiac test results had major cardiac complications.

Major cardiac complications in patients without preoperative cardiac testing mainly occurred in intermediate-risk patients with intermediate clinical predictors and with good functional status. This suggests several possibilities. One is that clinicians may have a difficult time judging whether a patient with subacute joint pain has an exercise tolerance of 4 or greater METS. Patient self-report was accurate in a prior study demonstrating patients who stated they were not able to walk 4 blocks or climb 2 flights of stairs were at higher postoperative risk.¹⁰ Many of our patients had surrogate markers for estimated functional status documented in their preoperative consult based on the Duke Activity Status Index¹¹ and activity scale of Goldman.⁹

Another possibility is that patients with abnormal noninvasive cardiac test results received different postoperative care. Achieving adequate B-adrenergic blockade has proven difficult in other trials.^{15,16} Given that compliance with B-adrenergic blockade was better in patients with abnormal cardiac test results, it is conceivable that perioperative monitoring and beta-blocker titration may have been more closely supervised. Cardiac complications are most common in the first 3 days after surgery and can be detected by findings of ischemia on telemetry.^{17,18}

Would our patients with adverse cardiac outcomes have benefited from preoperative cardiac testing? Or is standardized management in patients with intermediate and higher risk a better strategy to follow? A philosophical shift from preoperative testing to bedside risk stratification and beta-

blockade has been suggested in a recent review as a more rational approach.^{5,19} In contrast with the current ACC/AHA guidelines, older preoperative assessment guidelines published by the American College of Physicians in 1997 do not recommend noninvasive cardiac testing in intermediate-risk patients unless they are undergoing vascular surgery.²⁰ These conflicting guidelines could also explain why internists in our study evaluating intermediate-risk patients did not consistently order noninvasive cardiac tests.

Recent research has demonstrated that medical and orthopedic comanagement may improve outcomes in hip-replacement surgery.²¹ Further studies are needed to see whether a streamlined approach using B-adrenergic blockade in patients of intermediate and higher risk and standardized perioperative cardiac monitoring could reduce the need for preoperative cardiac testing.

There were several limitations to our study. We had insufficient power to determine whether B-adrenergic blockers could reduce perioperative cardiac events. Our retrospective study design made it impossible to determine the effectiveness of beta-blockade in patients who did receive them perioperatively, to document the type of anesthesia used, to assess the estimated blood loss during surgery, and to record the type of ward the patient was placed in postoperatively.

Our study described outcomes in patients who were referred to an internal medicine preoperative consult service in a single tertiary care hospital. Our conclusions may not be generalizable to other types of hospitals and healthier patients undergoing orthopedic surgery who do not receive preoperative internal medicine consults. Further studies should validate our results at other hospitals and include patients who did not receive preoperative consults.

Finally, we grouped many types of orthopedic surgeries that may have subtle differences together. For example, although no surgery was deemed an emergency, 96% of the hip fracture repairs analyzed were performed within 72 hours of injury, whereas an average of 2 weeks elapsed between the preoperative consult and surgical date with elective hip replacement. Grouping elective extremity surgeries, such as repair of a tibia/fibula fracture, and more urgent extremity procedures, such as amputation of a gangrenous foot, proves similarly problematic. The study was not powered to detect differences between different subtypes of orthopedic surgery. However, our study represents an important first step in understanding that perioperative cardiac risk is not equal for different types of orthopedic surgery.

We conclude that in patients undergoing orthopedic surgery who are referred to an internal medicine consult service, older patients, patients undergoing hip surgery, and patients receiving urgent procedures have a higher risk of cardiac events. The ACC/AHA 2002 guidelines for perioperative cardiac evaluation were successful in predicting cardiac risk but did not recommend cardiac testing for most patients having cardiac events. Although few patients had altered treatment recommendations or invasive cardiac test-

ing as a result of abnormal preoperative noninvasive cardiac test results, they were more likely to have recommendations for B-adrenergic blockade. Prospective studies are required to determine whether patients would benefit more from an approach based on B-adrenergic blockade and close postoperative scrutiny versus more widespread preoperative cardiac testing with refined standards for functional status determination, or a combination of both.

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