Preoperative Electrocardiograms

Patient Factors Predictive of Abnormalities

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Background: Age is often the sole criterion for determining the need for preoperative electrocardiograms. However, screening electrocardiograms have not been shown to add value above clinical information. This study was designed to determine whether it is possible to target electrocardiograms ordering to patients most likely to have an abnormality that would affect management and if age alone is predictive of significant electrocardiograms abnormalities.

Methods: A list was developed of electrocardiograms abnormalities considered significant enough to impact management, as well as a list of patient factors believed to increase cardiovascular risk. electrocardiograms in all patients over 50 yr of age presenting for preoperative evaluation during a 2-month period were reviewed.

Results: A total of 1,149 electrocardiograms were reviewed, with 89 patients (7.8%) having at least one significant abnormality. These patients were compared with a group of 195 patients who had electrocardiograms that did not contain significant abnormalities. Patients at higher risk of having a significantly abnormal electrocardiograms that would potentially affect management were those older than 65 yr of age or who had a history of heart failure, high cholesterol, angina, myocardial infarction, or severe valvular disease. Five patients (0.44%) had an abnormal electrocardiograms in the absence of risk factors. The sensitivity of the model is 87.6%.

Conclusion: Age greater than 65 yr remains an independent predictor for significant preoperative electrocardiograms abnormalities. The specific clinical risk factors that were found have a high sensitivity and identified all but 0.44% of patients with electrocardiograms abnormalities that may affect preoperative management.

ELECTROCARDIOGRAMS are routinely performed preoperatively as a baseline for perioperative changes or as a screening tool to identify significant electrocardiograms abnormalities that may alter perioperative management. Although some studies have shown prognostic value from resting electrocardiograms in terms of all-cause and cardiovascular mortality,[1] most studies have found that resting electrocardiograms are a poor screen for occult coronary artery disease or postoperative outcomes.[2–4] In part, this may be the result of using age as the only criterion for ordering electrocardiograms, even in asymptomatic patients undergoing low-risk ambulatory surgery. Although the prevalence of abnormal electrocardiograms rises exponentially with age such that 25% of the electrocardiograms reveal abnormalities by 60 yr of age,[5] the selection of specific age thresholds for ordering electrocardiograms remains arbitrary, the majority of the abnormalities are not considered clinically significant, and the benefit of detecting abnormalities has not been shown. In addition, the costs and resources used in providing electrocardiograms testing, the additional testing provoked by electrocardiograms abnormalities, and the delay of needed surgical procedures until further consultations or testing are performed are all significant consequences. The American Society of Anesthesiologists task force for preoperative evaluation recognized that electrocardiograms abnormalities may be higher in older people and those with cardiac risk factors, but it could not reach consensus regarding a minimum age to order preoperative electrocardiograms. The task force concluded that age alone may not be an indication for ordering an electrocardiograms in those without risk factors.[6] The most recent American College of Cardiology and American Heart Association perioperative guidelines do not consider electrocardiograms as being indicated in asymptomatic patients undergoing low-risk procedures, regardless of the age. Furthermore, these guidelines consider ordering electrocardiograms in this patient population a class III recommendation where the risk is greater than the benefit because it may be harmful by leading to further workup and testing. It is notable that these guidelines no longer consider minor risk factors such as an abnormal electrocardiograms in their cardiac evaluation stepwise approach for noncardiac surgery regardless of the type and invasiveness of the surgery.[7] However, others have suggested some benefit to using preoperative electrocardiograms as part of cardiac risk stratification in certain populations. Abnormal electrocardiograms have been found to have added prognostic value in intermediate- to high-risk surgery

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patients in terms of predicting risk of cardiovascular death.[8] Also, abnormal electrocardiograms in patients with documented coronary artery disease or at high risk for coronary artery disease and undergoing major noncardiac surgery were shown to predict long-term outcome.[9]

The existing literature gives no guidance on age or risk stratification for minimizing unnecessary preoperative electrocardiogram screening or maximizing its yield and utility. Furthermore, previous studies on the utility of preoperative electrocardiograms have not evaluated the impact on preoperative management as an endpoint. Here, the prevalence of electrocardiograms abnormalities in 1,149 preoperative patients and the correlation between significant abnormalities and a variety of patient risk factors is reported. This study was designed to test the hypothesis that significant abnormalities on preoperative electrocardiograms, *i.e.*, those that would affect preoperative management, do not exist in the absence of specific risk factors. In addition, age in the absence of other risk factors was evaluated as an independent predictor of significant electrocardiograms abnormalities.

Materials and Methods

With approval of the Partners Human Research Committee (Boston, MA), all preoperative electrocardiograms for patients presenting to the Weiner Center for Preoperative Evaluation at Brigham and Women's Hospital (Boston, MA) during the period of October and November 2003 were reviewed. The Weiner Center evaluates more than 85% of all elective surgical patients. All patients over the age of 50 yrs had an electrocardiograms performed per institutional guidelines. All electrocardiograms at Brigham and Women's Hospital are officially interpreted by a staff cardiologist. All electrocardiograms used for the study were downloaded from the hospital's electronic database and coded by two of four possible study investigators using the Minnesota Code classification system[10] (table 1). If any coding discrepancies were noted, all four investigators evaluated the electrocardiogram and a majority decision was used to assign a code.

Q waves and ST or T wave changes were considered minor if the electrocardiograms interpretation graded the abnormality as being nonspecific, and they were considered major if the electrocardiograms interpretation was suggestive of ischemia or infarct per the official cardiology reading. Frequent premature atrial or ventricular complexes were defined as more than one complex in ten beats. Sinus tachycardia was defined as a rate more than 100 beats per minute, and sinus bradycardia was defined as a rate less than 50 beats per minute.

The following electrocardiograms abnormalities, determined ahead of time, were considered to be "significant" in that it was the consensus of our anesthesiology and cardiology group that their presence on a preoperative

Table 1. Coded Electrocardiogram (ECG) Abnormalities

Abnormalities	n (% of Total ECGs)
Q waves	
Minor	33 (2.9)
Major*	15 (1.3)
ST junction/segment depression	
Minor	104 (9.1)
Major*	19 (1.7)
T wave changes	
Minor	186 (16.2)
Major*	57 (5.0)
ST segment elevation*	8 (0.7)
Left axis deviation	65 (5.7)
Right axis deviation	15 (1.3)
Left ventricular hypertrophy	102 (8.9)
First-degree atrioventricular block	48 (4.2)
Mobitz type II or higher blockade*	0 (0)
Short PR interval	6 (0.5)
Pacemaker	13 (1.1)
Left bundle branch block*	20 (1.7)
Right bundle branch block	50 (4.4)
Interventricular conduction delay	65 (5.7)
Frequent premature atrial complexes	10 (0.9)
Frequent premature ventricular complexes	22 (1.9)
Atrial fibrillation*	30 (2.6)
Sinus tachycardia	18 (1.6)
Sinus bradycardia	38 (3.3)

* Significant abnormality requiring further evaluation.

electrocardiograms would result in further assessment or evaluation by the preoperative clinician before the patient could proceed to surgery: major Q waves, major ST junction/segment depression, major T wave changes, ST segment elevation, Mobitz type II or higher blockade, left bundle branch block, and atrial fibrillation. The assessment and evaluation could include the retrieval of a previous electrocardiograms or cardiac testing for comparison, retrieval of information from the patient's primary care physician or cardiologist, the performance of further testing or a change to a patient's medical therapy (*e.g.*, addition of or alteration of a β-blocker dose) as previously described by our group.[11]

Patients with significantly abnormal electrocardiograms were then compared to a control group randomly selected (using an online true random sequence generator) from the remaining patients who had normal or insignificantly abnormal electrocardiograms. The number of patients in this group was chosen to be approximately twice the number of patients who had abnormal electrocardiograms to have increased power given the relative scarcity of cases. The control group was determined to be a representative sampling of the entire possible not significantly abnormal and normal electrocardiograms group because comparisons of age (63.1 ± 9.8 yr for the population) and gender (429 men and 631 women for the population) of the two groups revealed nonsignificant differences of $P = 0.22$ and 0.44, respectively. Patient data collected for these two groups included age, gender, surgical type, and risk, specific items

from the past medical history, and any postoperative complications. The items recorded included a history of myocardial infarction (by patient report), anginal symptoms (by patient report), congestive heart failure (by patient report), severe valvular disease (defined as having at least moderate regurgitation or stenosis of any valve by a documented echocardiogram or having a history of a valve repair), diabetes – insulin-dependant or noninsulin-dependant (by patient report), renal insufficiency (defined as creatinine above the upper limit of normal for age and gender), low functional capacity (metabolic equivalents less than four by patient report), stroke (by patient report), hypertension (by patient report), smoking (current or history by patient report), high cholesterol (by patient report of being on therapy), coronary artery disease (by patient report of bypass surgery or any percutaneous cardiac intervention in the absence of a documented myocardial infarction), and peripheral vascular disease (by patient report or history of vascular surgery). All risk factors for each patient were listed. Postoperative cardiac complications were recorded after a retrospective chart review and included evidence of perioperative ischemia/infarction by cardiac enzymes or new rhythm disturbances on electrocardiograms.

Statistical Analysis

All analyses were performed in SAS 9.1.3 (SAS Institute, Carey, NC). A two-sample t test was used to compare the age differences among groups. A chi-square test was used to test the gender, patient risk factors, and postoperative cardiac complication differences among groups. A univariate sensitivity analysis was done to determine the optimal effect of age, specifically, minimizing the -2 log likelihood. This age cutpoint was then used as an independent risk factor. All categorical data for surgical type, surgical risk, demographics, and items from the medical history were coded as $0 =$ absent and $1 =$ present. A univariate analysis was done to determine which variables were related to having an abnormal electrocardiograms. The variables that were significant to $P < 0.1$ by the univariate analysis were then entered into a regression analysis. A priori decisions were made to remove cardiac and vascular surgery from the regression analysis because these are already represented within the patient factors (e.g., myocardial infarction, coronary artery disease, valve disease, peripheral vascular disease) and thus would have been redundant. In addition, high-risk surgery was removed a priori because most of these surgeries (19 of 25) were within the cardiac and vascular groups. The multivariate logistic regression analysis was carried out by using a manual backwards selection, with a P value (stay criteria) of less than 0.05 being considered significant in the final model. A receiver-operating characteristic curve was constructed by plotting sensitivity against the false-positive rate (1–specificity) over a range of cutpoint values.

Results

A total of 1,149 electrocardiograms were evaluated during the 2-month period. Table 1 lists the incidence of coded abnormalities. A total of 864 separate abnormalities were identified in a total of 540 patients (47.0%). Eighty-nine patients (7.7%) had at least one abnormality that was considered significant. The most common abnormality was minor T wave changes seen in 186 patients (16.2% of the total electrocardiograms). The most common significant abnormality was major T wave changes seen in 57 patients (5.0% of the total electrocardiograms).

Table 2 shows the patient demographics for the patients who had significant electrocardiograms abnormalities and for the control patients. There were significant differences between the groups in terms of age and gender. Examination of various age thresholds revealed that age of 65 yr or older was the most predictive of having an abnormal electrocardiograms. Table 3 lists the patient risk factors for the two groups. The most common risk factor in the significantly abnormal electrocardiograms group was age above 65 yr (69.7%). The most common risk factor in the control group was hypertension (42.6%).

Table 4 lists the odds ratios for the risk factors correlated with having a significantly abnormal electrocardiograms. The patient parameters, listed in order of increasing influence on the predicted probability of having a significantly abnormal electrocardiograms, are as follows: high cholesterol, age over 65 yr, severe valvular disease, myocardial infarction, angina, and congestive heart failure. Each of these factors was independently and significantly associated with an increased probability of the patient having a significantly abnormal electrocardiograms.

Table 5 lists the interventions prompted by finding a significantly abnormal electrocardiograms at the preoperative visit. The 13 patients who were presenting for open heart surgery (coronary artery bypass grafting or valve surgery) are not included because they all would have had cardiac testing at our institution preceding their operation regardless of electrocardiograms findings. In the remaining 76 patients with abnormal electrocardiograms, there were 19 (25%) who required some new intervention before proceeding to the operating

Table 2. Patient Demographics

	Significantly Abnormal ECG (n = 89)	Control ECG (n = 195)	P Value
Age, mean ± SD	69.2 ± 9.1	62.5 ± 10.0	< 0.0001
Gender, n (%)			< 0.02
Male	54 (60.7)	88 (45.1)	
Female	35 (39.3)	107 (54.9)	

ECG = electrocardiogram; SD = standard deviation.

Table 3. Patient Risk Factors

	Significantly Abnormal ECG (n = 89)	Control ECG (n = 195)	P Value
Age >65 yr, n (%)	62 (69.7)	68 (34.9)	< 0.0001
Angina, n (%)	14 (15.7)	3 (1.5)	< 0.0001
Congestive heart failure, n (%)	25 (28.1)	6 (3.1)	< 0.0001
Severe valve disease, n (%)	16 (18.0)	4 (2.1)	< 0.0001
Myocardial infarction, n (%)	24 (27.0)	9 (4.6)	< 0.0001
Diabetes, n (%)	27 (30.3)	21 (10.8)	< 0.0001
Renal insufficiency, n (%)	14 (15.7)	8 (4.1)	0.0007
Low functional capacity, n (%)	32 (36.0)	32 (16.4)	0.0003
Stroke, n (%)	8 (9.0)	3 (1.5)	0.0025
Hypertension, n (%)	56 (63.0)	83 (42.6)	0.0015
Current smoker, n (%)	13 (14.6)	21 (10.8)	0.3554
Former smoker, n (%)	28 (31.5)	64 (32.8)	0.8203
High cholesterol, n (%)	37 (41.6)	35 (17.9)	< 0.0001
Coronary artery disease, n (%)	14 (15.7)	9 (4.6)	0.0014
Peripheral vascular disease, n (%)	13 (14.6)	7 (3.6)	0.0008
Cardiac surgery, n (%)	15 (16.9)	3 (1.5)	< 0.0001
General surgery, n (%)	22 (24.7)	48 (24.6)	0.9849
Gynecologic surgery, n (%)	6 (6.7)	25 (12.8)	0.1275
Neurologic surgery, n (%)	2 (2.2)	9 (4.6)	0.53
Orthopedic surgery, n (%)	12 (13.5)	41 (21.0)	0.1301
Other surgery,* n (%)	0 (0)	4 (2.1)	0.4087
Otorhinolaryngeal surgery, n (%)	3 (3.4)	17 (8.7)	0.1023
Plastic surgery, n (%)	0 (0)	6 (3.1)	0.2195
Thoracic surgery, n (%)	7 (7.9)	22 (11.3)	0.3777
Urologic surgery, n (%)	13 (14.6)	17 (8.7)	0.1342
Vascular surgery, n (%)	9 (10.1)	3 (1.5)	0.0008
High risk surgery, n (%)	25 (28.1)	6 (3.1)	< 0.0001

* Ophthalmology, gastroenterology, radiology, and anesthesiology.

ECG = electrocardiogram.

room. Two patients had β-blockers started; three patients were seen by a cardiologist who felt no further evaluation was needed, and the remaining 14 patients had cardiac testing ordered. The tests were nonimaging or imaging stress tests in 11 patients, and cardiac catheterization in three patients. Three of the patients could not have the test performed before the original surgery date, leading to postponement of the case. Two of the patients had their case cancelled, and the results of the workup are not known. The number of cases postponed or canceled represents 0.4% of the total number of patients who had electrocardiograms over the study period.

There were no statistical differences between the groups in terms of major postoperative cardiac complications, including postoperative atrial fibrillation

Table 4. Predictors of Having a Significantly Abnormal Electrocardiogram (ECG) in the Preoperative Period

Risk Factor	P Value	Odds Ratio	95% CI
Age >65 yr	< 0.0001	4.08	2.13–7.79
Angina	0.0101	7.49	1.62–34.69
Congestive heart failure	0.0001	12.18	3.44–43.11
High cholesterol	0.0195	2.26	1.14–4.48
Myocardial infarction	0.0002	6.16	2.34–16.20
Severe valve disease	0.0259	4.80	1.21–19.10

CI = confidence interval.

Table 5. Preoperative Management Interventions Performed for the Patients with a Significantly Abnormal Electrocardiogram (ECG)*

Intervention	n
Retrieval of old electrocardiograms	25
Retrieval of old cardiac test	32
New cardiac test ordered	14
Cardiology consult obtained	3
β-blocker started	2

* Excluding 13 patients having cardiac surgery.

and ischemia (table 6). The overall number of cardiac complications was extremely small, and the study was not expected to make any conclusions from this endpoint.

The Hosmer and Lemeshow test demonstrates that our model has adequate goodness-of-fit ($P = 0.28$) as indicated by a statistically nonsignificant P value. The discriminative capacity of the model to assign true-positives is also adequate, with a c statistic or area under the receiver-operating characteristic curve of 0.84. The sensitivity of the model, defined as the percentage of patients predicted to have a significantly abnormal electrocardiograms who really have one (true-positive), is 87.6%. The specificity of the model, defined as the percentage of patients predicted to not have a significantly abnormal electrocardiograms who do not have it (truenegative), is 59.5%.

Discussion

This study was designed to better refine the criterion for preoperative electrocardiograms ordering. Patient risk factors of age over 65 yr, history of angina, congestive heart failure, high cholesterol, myocardial infarction, and severe valvular disease were found to be predictive for having a significantly abnormal electrocardiograms, defined as major Q waves, major ST junction/segment depression, major T wave changes, ST segment elevation, Mobitz type II or higher blockade, left bundle branch block, or atrial fibrillation.

This report is unique in defining significant preoperative electrocardiograms abnormalities as those that should prompt further action by the preoperative clinician. Previous studies in this area have defined the impact of preoperative electrocardiograms as the effect on

Table 6. Postoperative Cardiac Complications

	Significantly Abnormal ECG (n = 89)	Control ECG (n = 195)	P Value
Atrial fibrillation, n (%)	2 (2.2)	2 (1)	NS
Ischemia, n (%)	2 (2.2)	0 (0)	NS

ECG = electrocardiogram; NS = not significant.

significant postoperative complications or on the delay or cancellation of surgical procedures.[12] However, in actual clinical practice, the point-of-care decision regarding abnormal electrocardiograms by the preoperative clinician is whether further information or testing is needed before allowing the patient to undergo the planned procedure. Because collection of this information does not necessarily result in a delay or cancellation of surgery, delay or cancellation of a procedure are thus insensitive endpoints on which to measure clinician behavior and resource utilization. This fact is supported by this study in that only five patients had surgery postponed or cancelled. Therefore, we used the decision for further evaluation, which is in actuality the triage point in actual clinical practice, as a metric.

Many surgical institutions use age as the sole criterion for performing preoperative electrocardiograms. The impact of these electrocardiograms, however, is limited by the arbitrary nature of the age selected and the subsequent number of normal or minor abnormalities discovered. Moreover, arbitrary age-based thresholds are associated with the costs and resources used in providing electrocardiograms testing, the additional testing provoked by abnormalities, and the possible delay of surgical procedures. Our hope was that age in the absence of risk factors was not an independent predictor of significant electrocardiograms abnormalities; this would help us reduce the number of preoperative electrocardiograms performed. However, our results indicate that in a population older than 50 yr, an increased odds ratio for independently predicting significant preoperative electrocardiograms abnormalities did occur at age greater than 65 yr (table 4). On the basis of our results, age cannot be eliminated as a screening factor, which sharply differs from the guidelines put forth by the Center for Medicare and Medicaid Services, which has ceased paying for preoperative electrocardiograms based on age.#

The electrocardiograms abnormalities that should prompt the preoperative clinician to request further information, consultation, or testing are controversial. No consensus currently exists in the literature regarding what is considered a significantly abnormal electrocardiograms.[13–18] The abnormalities determined to be significant for the purposes of this study were based on a consensus opinion among our perioperative medicine specialists, a group including anesthesiologists and cardiologists, at the Brigham and Women's Hospital (table 1). Our practice is to require further information, evaluation, or management if the preoperative electrocardiograms exhibits significant Q waves, major ST junction/

segment depression, major T wave changes, ST segment elevation, Mobitz type II or higher blockade, left bundle branch block, or atrial fibrillation. These specific abnormalities are based on the group's evaluation of the existing literature and clinical experience developed over several years. The management can include requesting information from the patient's primary care physician or cardiologist and previous testing results (electrocardiograms, noninvasive and invasive cardiac examinations) or initiating new consultations, cardiac testing, or therapies (e.g., perioperative β-blockade).

Several limitations exist for our study. The first is that the study was performed in a retrospective manner. It is unlikely that this was of significance, however, because a prospective design would not have the ability to change an electrocardiograms or alter the patients' histories. The patient's histories were not known at the time the electrocardiograms were read by the cardiologist, and agreement between investigators regarding the coding was required.

Another limitation is that it is possible that some risk factors could have been further subdivided or sharpened; however the choice of which categories to subdivide was not apparent at the outset of the study. Now that we know the general categories that are significant, it is possible that further research could be done to see if further sharpening would actually lead to a different or more specific list of criteria.

A further limitation is the absence of an analysis of the subsequent impact of the clinician's response to the electrocardiograms on postoperative outcomes. Our study was not intended to evaluate postoperative complications, which were extremely small in incidence (table 5). Many studies that have attempted to correlate preoperative electrocardiograms findings with cardiac events are inconclusive. One study found that a rhythm other than sinus or frequent premature ventricular contractions were the only electrocardiograms findings correlated with postoperative cardiac events.[19] electrocardiograms findings predictive of sudden cardiac death in the population include abnormalities suggestive of myocardial infarction (i.e., Q waves) or an intraventricular conduction defect in people with overt coronary heart disease, left ventricular hypertrophy and tachycardia in people without coronary heart disease, and nonspecific ST-T abnormalities in men without coronary heart disease.[20] In vascular surgery patients, left ventricular hypertrophy or ST depression have been shown to be predictive of postoperative cardiac events.[21]

There are circumstances in which a preoperative electrocardiograms in patients with none of the risk factors defined in our model may be of value. Some clinicians desire baseline electrocardiograms before specific types of surgery, such as cardiac or thoracic, where postoperative electrocardiograms changes frequently occur. Baseline electrocardiograms may also be of value in patients

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Centers for Medicare and Medicaid Services: Medicare National Coverage Determinations Manual, Chapter 1, Part 1 (Sections 10–80.12). Available at: http://www.cms.hhs.gov/manuals/downloads/ncd103c1_Part1.pdf. Accessed May 10, 2008.

who are on pharmacologic agents known to produce adverse effects detected by electrocardiograms changes or correlate with therapeutic responses or disease progression.[22]

It is possible that some clinicians would seek further cardiac information on patients who relate a history of angina, congestive heart failure, myocardial infarction, or severe valvular disease even in the absence of an abnormal electrocardiograms. Thus the findings of this study that history of high cholesterol or age over 65 yr is predictive of abnormal electrocardiograms may be the most valuable addition to our understanding of preoperative assessment.

Although our list of risk factors is capable of identifying patients who are at risk of having significant preoperative electrocardiograms abnormalities, it cannot capture all patients who have abnormal electrocardiograms. Five patients (0.44%) in the significantly abnormal group would not have been identified due to their age being less than 65 yr and the absence of other risk factors defined by the model. Three of these patients were presenting for a general surgical procedure, one for a thoracic surgery and one for an orthopedic surgery; the latter two surgeries were categorized as high-risk. None of these 5 patients had a postoperative cardiac complication. It will need to be determined if it is acceptable to limit electrocardiograms to this high-risk population with the potential to cancel very few cases on the day of surgery if a patient is noted to have an abnormality on the preinduction electrocardiograms.

In conclusion, patient risk factors of age above 65 yr, history of angina, congestive heart failure, high cholesterol, myocardial infarction, or severe valvular disease are predictive for having a significantly abnormal electrocardiograms defined as major Q waves, major ST junction/segment depression, major T wave changes, ST segment elevation, Mobitz type II or higher blockade, left bundle branch block, or atrial fibrillation. Age greater than 65 yr in the absence of other risk factors remains an independent predictor of significant preoperative electrocardiograms abnormalities.

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