Prospective Evaluation of Cardiac Risk Indices for Patients Undergoing Noncardiac Surgery

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Background: **Prediction of perioperative cardiac complications is important in the medical management of patients undergoing noncardiac surgery. Several indices have been developed to aid prediction, but their performance has not been systematically compared.**

Objective: **To compare four existing methods for predicting perioperative cardiac risk.**

Design: **Prospective cohort study.**

Setting: **Two teaching hospitals in London, Ontario, Canada.**

Patients: **2035 patients referred for medical consultation before elective or urgent noncardiac surgery.**

Measurements: **Myocardial infarction, unstable angina, acute pulmonary edema, or death. The indices were compared by examining the areas under their respective receiver-operating characteristic (ROC) curves.**

Results: **Cardiac complications occurred in 6.4% of patients. The area under the ROC curve was 0.625 (95% CI, 0.575 to 0.676) for the American Society of Anesthesiologists index, 0.642 (CI, 0.588 to 0.695) for the Goldman index, 0.601 (CI, 0.544 to 0.657) for the modified Detsky index, and 0.654 (0.601 to 0.708) for the Canadian Cardiovascular Society index. These values did not significantly differ.**

Conclusions: **Existing indices for prediction of cardiac complications perform better than chance, but no index is significantly superior. There is room for improvement in our ability to predict such complications.**

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See editorial comment on pp 384-386.

Published guidelines for assessment of perioperative cardiac risk have stressed the need for accurate clinical evaluation, including the use of cardiac risk indices (1). Such evaluation is particularly important because additional testing has been shown to have no substantial effect on perioperative cardiac morbidity and is recommended only for selected patients (1, 2). Because most surgical patients (>90%) do not benefit from additional testing, it is important to evaluate existing indices critically to ensure their optimal use.

Before the existence of multivariate clinical prediction rules, the American Society of Anesthesiologists (ASA) score (3) was considered a good predictor of perioperative death. However, it does not perform as well as other indicators when specifically predicting cardiac events (4). The original cardiac risk index, described by Goldman and colleagues (5) in 1977, was the first widely used multivariate predictive model. In 1986, Detsky and coworkers (6) added angina severity and a history of remote myocardial infarction to the model. The index was further modified in 1997, when the American College of Physicians (ACP) suggested stratifying patients into three risk groups (1). The performance of this method has not been tested.

Other clinical prediction rules for perioperative cardiac complications have been described (7–9), but they are not widely used. All cardiac risk indices are based on information obtained from the history and physical examination of the patient and from preoperative laboratory testing, including electrocardiography.

Several investigators have attempted to validate existing cardiac risk indices in various surgical populations (7, 10), but none have directly compared existing methods in a single, large, prospective study. The purpose of our investigation was to compare existing methods of cardiac risk prediction in a large cohort of patients undergoing noncardiac surgery.

Methods

Patients scheduled for urgent or elective surgical procedures who were referred for an internal medicine consultation at one of two hospitals were enrolled between January 1995 and April 1997. The two hospitals (St. Joseph's Health Centre and the Victoria Campus of the London Health Sciences Centre) are teaching institutions affiliated with the University of Western Ontario, London, Ontario, Canada. Data from the history, physical examination, and electrocardiography were recorded at the initial assessment.

Table 1. **Patient Characteristics at Baseline***

Characteristic	Patients, *n (%)*
Age > 70 years	1205 (59)
Myocardial infarction in the past 6 months	23 (1.1)
Myocardial infarction more than 6 months ago	407 (20)
Unstable angina in the past 6 months	43 (2.1)
Third heart sound or jugular venous distention on examination	41 (2.0)
Pulmonary edema last week	15 (0.7)
Pulmonary edema ever	138 (6.8)
Suspected aortic stenosis	11 (0.5)
Rhythm other than sinus	202 (9.9)
Frequent premature ventricular contractions	55 (2.7)
Poor general medical status†	180 (8.8)
Emergency surgery	99 (4.9)
Type of operation	
Vascular—aorta	64 (3.1)
Vascular—carotid	17 (0.8)
Vascular—peripheral	112 (5.5)
Orthopedic	638 (31)
Thoracic/abdominal	435 (21)
Head and neck	149 (7.3)
Minor/other	620 (30)

* 2035 patients participated.
† Defined as one or more of the following: Pa_{O_2} < 60 mm Hg, Pa_{CO_2} > 50 mm Hg, potassium level < 3.0 mmol/L, HCO_3 level < 20 mmol/L, urea nitrogen level > 18 mmol/L (50 mg/dL), creatinine concentration > 265 μmol/L (3.0 mg/dL), elevated aminotransferase levels, signs of chronic liver disease, or bedridden status due to noncardiac causes.

The consulting internist monitored patients until discharge, and major cardiac events (unstable angina, myocardial infarction, acute pulmonary edema, and death) were recorded.

Cardiac events were defined clinically, but the study internists relied on generally accepted diagnostic criteria for ascertainment of events. For example, myocardial infarction was diagnosed only in the presence of acute electrocardiographic changes and an elevation of the MB fraction of creatinine kinase to at least 5.0 U/L, with a MB index of at least 0.04. Unstable angina was diagnosed if typical symptoms were present in a patient with new electrocardiographic changes compatible with ischemia. Acute pulmonary edema was diagnosed if patients exhibited compatible clinical or radiographic findings. Death was defined as all-cause mortality.

Patients were categorized according to the ASA index (3), the Goldman index (5), the modified Detsky index (1), and the preoperative Canadian Cardiovascular Society (CCS) index for angina level (11). To determine the accuracy of the stratification systems within each index, we calculated the areas under the receiver-operating characteristic (ROC) curves with SPSS software, version 9.0 (SPSS, Inc., Chicago, Illinois), using a nonparametric method. The areas were compared by using the technique of Hanley and McNeil (12) (expected sensitivity, 60% to 75%). Analyses of differences in event frequencies between the sites were performed by using the chi-square test. A *P* value less than or equal to 0.05 was considered statistically significant.

Results

A total of 2035 patients enrolled in the study (1465 at site 1 and 570 at site 2). Patient characteristics at baseline are shown in **Table 1**. Overall, 130 patients (6.4%) had a cardiac event: 5.5% of patients at site 1 and 8.6% of patients at site 2 ($P = 0.015$). This difference was caused by a greater incidence of pulmonary edema at site 2 (5.3%) than at site 1 (2.5%) ($P = 0.002$). The overall event rate did not differ between the sites after we adjusted for cardiac risk (using the CCS index [11] or the Goldman index [5]). There were 36 myocardial infarctions (1.8%), 67 episodes of acute pulmonary edema (3.3%), 27 cases of unstable angina (1.3%), and 48 deaths (2.4%). Individual patients may have had more than one event, but each case (defined as any event or combination of events) was counted only once.

All of the cardiac risk indices provided a statistically

Table 2. **Frequency of Major Perioperative Cardiac Events Stratified according to Risk Indices***

Methods (Reference)	Stratum	Patients	Cardiac Events
		n	*n (%)*
American Society of Anesthesiologists index (3)	1	179	5 (2.8)
	2	1032	47 (4.6)
	3	764	65 (8.5)
	4	50	12 (24)
	5	2	1 (50)
Canadian Cardiovascular Society index (11)	0	1418	57 (4.0)
	1	215	21 (9.8)
	2	293	28 (9.6)
	3	75	17 (23)
	4	17	6 (35)
Goldman index (5)	1	1433	60 (4.2)
	2	478	46 (9.6)
	3	113	20 (18)
	4	11	4 (36)
Modified Detsky index (1)	1	1875	96 (5.1)
	2	125	17 (14)
	3	35	17 (49)

* Major perioperative events were defined as myocardial infarction, acute pulmonary edema, unstable angina, and death.

significant degree of stratification (**Table 2**) ($P < 0.001$ for all comparisons). The areas under the ROC curves were 0.625 (95% CI, 0.575 to 0.676) for the ASA index (3), 0.642 (CI, 0.588 to 0.695) for the Goldman index (5), 0.601 (CI, 0.544 to 0.657) for the modified Detsky index (1), and 0.654 (CI, 0.601 to 0.708) for the CCS index (11). Differences among the areas under the ROC curves were not statistically significant ($P > 0.05$). The results did not change when analysis was limited to patients undergoing major surgical procedures or when deaths that were considered possibly noncardiac (25 of 48) were excluded. Each model was evaluated for its prediction of specific cardiac complications. All of the models were significantly better than chance at predicting myocardial infarction and death. However, only the CCS index (11) was useful for predicting the development of unstable angina, and the Goldman index (5) did not seem able to accurately predict the development of pulmonary edema.

Discussion

The most striking finding of our study was the generally poor degree of accuracy of existing cardiac risk prediction methods. The greatest area under the ROC curve (0.654) was obtained by using only the CCS rating of angina severity (11). The four methods did not differ significantly, and the confidence intervals around the areas under the ROC curves overlapped. Although the estimated power for these comparisons is at best 75%, the relatively narrow 95% confidence intervals indicate that a significant difference among them was not likely to have been missed.

In our study, the modified Detsky index stratified patients into three groups on the basis of their point scores alone, as suggested in the ACP guidelines (1). It is possible that the predictability of this index would have been improved if we had used the likelihood ratio method described in the original article (6). In the article, Detsky and coworkers (6) reported an area under the ROC curve of 0.75 for their model, compared with 0.69 for the Goldman index (5). However, for the method described in their report to be used, the pretest probability of cardiac complications must be available for each type of surgical procedure at a given health center. Because these data are not readily available in most clinical settings, we did not use this method.

The difference in complication rates between the two centers seems to be due primarily to a difference in the incidence of acute pulmonary edema. Complication rates did not statistically significantly differ after adjustment for cardiac risk, which indicates that the difference in frequency of cardiac complications between the sites may have been caused by a disparity in the pretest probability of cardiac events. The four indices performed similarly at both sites.

One potential limitation of our study is the lack of postoperative surveillance for cardiac complications (besides that done clinically). Nevertheless, our results are probably similar to the application of these cardiac risk indices in clinical practice and therefore reflect the effectiveness of the models evaluated rather than their efficacy.

Another potential limitation of our study is that patients were selected for enrollment only if they were referred for a medical consultation. Although this may have introduced some selection bias, we felt that the event rate in unreferred patients would be too low to derive meaningful results without obtaining a much larger sample. Our results are therefore most applicable to a medical consultation setting and to patients whose pretest likelihood of cardiac complications is somewhat higher than that of patients in general practice.

The reasons for the relatively poor performance of these cardiac risk indices are probably complex. Our patients may have differed substantially from those who participated in the development of the original models. Nevertheless, if the models are meant to be generalizable, their predictive utility in somewhat dissimilar samples of patients should remain high. Another possible explanation of our results is that several cardiac events may have been missed because of the observational nature of our study. However, if the models are meant to be used clinically, they should be sensitive to clinically relevant events. The observed cardiac event rate in our study was similar to that reported in other investigations of perioperative cardiac risk; therefore, it is unlikely that a substantial number of events was missed.

In conclusion, our results indicate that existing cardiac risk indices provide useful clinical information about risk but have limited overall accuracy. Therefore, there remains room for improvement in our ability to determine which patients scheduled for noncardiac surgery are at greatest risk for cardiac complications. We anticipate further research in this area.

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