Self-reported Exercise Tolerance and the Risk of Serious Perioperative Complications

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Background: Impaired exercise tolerance during formal testing is predictive of perioperative complications. However, for most patients, formal exercise testing is not indicated, and exercise tolerance is assessed by history.

Objective: To determine the relationship between self-reported exercise tolerance and serious perioperative complications.

Methods: Our study group consisted of 600 consecutive outpatients referred to a medical consultation clinic at a tertiary care medical center for preoperative evaluation before undergoing 612 major noncardiac procedures. Patients were asked to estimate the number of blocks they could walk and flights of stairs they could climb without experiencing symptomatic limitation. Patients who could not walk 4 blocks and climb 2 flights of stairs were considered to have poor exercise tolerance. All patients were evaluated for the development of 26 serious complications that occurred during hospitalization.

Results: Patients reporting poor exercise tolerance had more perioperative complications (20.4% vs 10.4%; $P<.001$). Specifically, they had more myocardial ischemia ($P=.02$) and more cardiovascular ($P=.04$) and neurologic ($P=.03$) events. Poor exercise tolerance predicted risk for serious complications independent of all other patient characteristics, including age (adjusted odds ratio, 1.94; 95% confidence interval, 1.19-3.17). The likelihood of a serious complication occurring was inversely related to the number blocks that could be walked ($P=.006$) or flights of stairs that could be climbed ($P=.01$). Other patient characteristics predicting serious complications in multivariable regression analysis included history of congestive heart failure, dementia, Parkinson disease, and smoking greater than or equal to 20 pack-years.

Conclusion: Self-reported exercise tolerance can be used to predict in-hospital perioperative risk, even when using relatively simple and familiar measures.

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RISK ASSESSMENT is an important component of the preoperative evaluation. It is used in planning perioperative treatment[1] and to help shape decisions about the advisability and extent of surgery.[2] Factors considered in assessing an individual's risk for surgery include the nature of the procedure to be performed and the severity of comorbid medical problems. Prolonged procedures[3-5] and those with significant physiologic stress[3,6,7] (eg, thoracic surgery) are associated with increased risk. The presence and severity of medical illness correlate with an increased risk for perioperative complications,[6-11] especially in the setting of emergent surgery.[7]

Exercise tolerance may be another important factor to consider when assessing a patient's surgical risk.[1,2] Patients with poor exercise tolerance on formal testing have been shown to have more perioperative complications.[12-17] McPhail et al[13] showed that among patients undergoing vascular surgery, those with a good performance during treadmill testing or arm ergometry had fewer postoperative cardiovascular complications. In addition, Gerson et al[12,17] showed that geriatric patients who were unable to exercise for 2 minutes with supine bicycle ergometry had more cardiovascular and pulmonary complications. Other studies, in highly selected populations, have also shown that patients who perform poorly on standardized testing have a worse prognosis after surgery.[14-16]

Unfortunately, formal exercise testing is expensive, time-consuming, and not specifically indicated for most patients. As a result, clinicians usually determine a patient's exercise tolerance from the patient's history. Patients are asked to describe the nature and frequency of their physical activities. This is then considered

PATIENTS AND METHODS

The study was conducted at the University of Washington Medical Center, Seattle, a 450-bed academic medical center providing tertiary surgical and medical care to the residents of the northwestern United States. All outpatients aged 18 years and older referred to the medical consulting service clinic for preoperative consultation prior to noncardiac surgery from October 17,1995, through June 9,1997, were eligible to participate. All participants provided written informed consent. The study was approved by our institutional review committee.

PATIENTS

Patients were referred to the clinic by the surgical team or by anesthetists when they had concerns about the patient's medical problems. Approximately 15% of patients undergoing surgery at the University of Washington are referred to the clinic for preoperative evaluation. Of the 951 consecutive patients referred to the clinic during the study period, 896 (94%) consented to participate. Of these, 229 (26%) were undergoing a minor procedure and were excluded. Minor procedures, defined as those with minimum risk for serious complications,[6] included biopsy, central venous catheter placement, lumpectomy without node dissection, transurethral resection of the prostate or bladder tumor, inguinal hernia repairs, and all ophthalmologic procedures except enucleation.

Of the 667 patients having major procedures, 67 (10%) had their procedures canceled, leaving 600 patients to form our study group. Procedures were considered to be canceled if not scheduled at the University of Washington Medical Center within 90 days of the evaluation. Twelve patients underwent 2 procedures, each with a distinct admission and discharge. To be as inclusive as possible, all analyses were based on 612 procedures. Reanalysis using only 1 procedure per patient (n = 600) while randomly excluding 12 procedures resulted in no appreciable change in the results.

DATA COLLECTION

Each patient provided an extensive history and underwent a thorough physical examination. These evaluations were conducted by an attending internist or a senior medical resident. Outside records were sought and preoperative testing was ordered as clinically indicated. No additional testing was specifically performed as part of the study.

We asked each patient to estimate the number of blocks they could walk (0-4) on level ground and the number of flights of stairs (0-4) they could climb without experiencing symptomatic limitation. We chose these measures for their simplicity and familiarity to the average clinician (they are similar to the Canadian classification system used for quantifying the severity of angina[6]). Limiting symptoms were recorded when available. Complete exercise tolerance information was unavailable for 4 patients. These patients were conservatively classified as having poor exercise tolerance for the purposes of analysis. There was a higher rate of complications in the group with poor exercise tolerance when these 4 patients were excluded from analysis.

A atient was considered to have a medical problem if 2 or more of the following criteria were satisfied: history consistent with the diagnosis, supportive physical findings, positive diagnostic test results, or treatment for the illness. Patients were classified as having ventricular arrhythmias when they had more than 5 premature ventricular contractions per minute.[7] The diagnosis of obstructive lung disease included patients with either emphysema or asthma. A patient's age was calculated as of the day of surgery. Goldman[7] and Detsky[6] scores were calculated for all patients, using previously published definitions (**Appendix 1** and **Appendix 2**).

If a patient's surgical procedure was directly related to the treatment or diagnosis of a possible malignant neoplasm, it was considered to be oncology related. The American Society of Anesthesiologists (ASA) classification[11,19] was assigned by the attending anesthesiologist on the day of surgery (**Table 1**). Anesthesia data were obtained from the Department of Anesthesia's existing quality improvement database or the anesthesia record. The length of stay was calculated from the date of surgery until discharge. Length of stay data for 3 patients admitted to the physiatry ward directly after surgery were excluded. Their long hospital stays (25, 88, and 99 days) were planned in advance and reflected, in large part, their need for other services.

PERIOPERATIVE COMPLICATIONS

A list of perioperative complications and their definitions was composed before the study was started (**Table 2**). Five major categories of complications were established: cardiovascular, pulmonary, neurologic, infectious, and miscellaneous. We also recorded deaths, unexpected transfers to the intensive care unit (ICU) or cardiac telemetry ward, and activation of the medical center's emergency response system (code blue). Other complications could be noted by the attending physicians if they

with the other available information to assess the patient's ability to safely undergo surgery. The use of self-reported exercise tolerance in perioperative risk assessment has certain advantages. The information is readily available and requires no additional testing. One recently published algorithm for perioperative cardiac testing suggests that self-reported exercise tolerance should be considered in the decision-making process.[1] However, there are few data available demonstrating the reliability of self-reported exercise tolerance in predicting perioperative complications.[1,2,18] We sought to explore this issue in a group of patients undergoing major noncardiac surgery.

RESULTS

PATIENT CHARACTERISTICS

Six hundred patients underwent 612 major procedures. The majority of patients were women (Table 1). The mean ± SD age was 63.0 ± 14.8 years. Seventy percent of patients in the study population had a history of hypertension, coronary artery disease, prior myocardial infarction, or other cardiovascular illness. About one half of the procedures were oncologic. The average duration resulted in additional therapy, placed the patient at increased risk, or prolonged the length of stay. All complications were included from the time the patient entered the preanesthesia holding area until the time of hospital discharge. All perioperative complications were considered serious, with the exception of surgical site infection (superficial) and unexpected transfer to the ICU or cardiac telemetry ward.

Perioperative complications were reviewed and confirmed by 2 internal medicine attending physicians blinded to the study design and the results of the preoperative evaluation. In instances when the 2 physicians disagreed, a third physician adjudicated the case. Follow-up was available for all patients. Diagnostic billing codes were obtained from the medical center's information systems department and were used to further review medical records to ensure that all initially defined complications had been recorded.

STATISTICAL ANALYSIS

Statistical analysis was performed with SAS, version 6.12, statistical software (SAS Institute Inc, Cary, NC). Values are reported as mean ± SD. We considered $P \leq .05$ to be significant. The χ^2 test, including test for trend for ordinal data, or the Fisher exact test[20] was used to compare categorical variables between groups. All *P* values shown are for χ^2 tests, unless otherwise specified. The *t* test (2-tailed) was used to compare continuous variables between groups. Sensitivity, specificity, and likelihood ratios were calculated for the various definitions of poor exercise tolerance.[21] Age-adjusted odds ratios estimating the risk of any perioperative complication were calculated using logistic regression for each variable found to be significant on bivariate analysis. In order to determine if these variables predicted perioperative complications independent of one another, we also added them to an age-adjusted multivariable logistic regression model in a stepwise manner. Two multivariable logistic regression models were constructed. One used independent variables describing patient characteristics (eg, disease history and exercise tolerance), and the other used surgical characteristics (eg, surgery type and anesthesia duration). We tested for first-degree multiplicative interaction between the independent variables in each of the final models.

of anesthesia was approximately 5½ hours. The mean length of stay was 6.0 ± 6.0 days, with a median stay of 5 days. The minimum stay was 0 days (n = 17) and the maximum was 70 days.

SELF-REPORTED EXERCISE TOLERANCE

We used the exercise tolerance ordinal data (0-4 blocks walked or 0-4 flights of stairs climbed) to explore potential cut points for differentiating patients with good vs poor exercise tolerance. The sensitivity, specificity, and likelihood ratios for predicting perioperative complications were calculated using various combinations of blocks walked and stairs climbed. We felt that a definition of poor exercise tolerance with the highest sensitivity for predicting perioperative complications would have the greatest clinical utility. Defining poor exercise tolerance as the inability to walk at least 3 blocks or climb 2 flights of stairs (n = 207) yielded the greatest likelihood ratio (1.6), with a specificity of 0.69 but a sensitivity of

Table 1. Comparison of Patient and Surgical Characteristics Between Patients With Good and Poor Exercise Tolerance*

	No. (%) of Patients†		
	Good Exercise Tolerance (n = 269)	Poor Exercise Tolerance‡ (n = 343)	*P*§
Patient Characteristics			
Age, y	61.2 ± 15.1	64.4 ± 14.4	.008
Male	131 (48.7)	114 (33.2)	.001
White	255 (94.8)	320 (93.3)	.44
Coronary disease	53 (19.7)	89 (25.9)	.07
Myocardial infarction	27 (10.0)	45 (13.1)	.24
Congestive heart failure	14 (5.2)	38 (11.1)	.01
Ventricular arrhythmia	20 (7.4)	24 (7.0)	.84
Atrial arrhythmia	34 (12.6)	55 (16.0)	.24
Peripheral vascular disease	26 (9.7)	50 (14.6)	.07
Cerebrovascular disease	21 (7.8)	40 (11.7)	.11
Hypertension	120 (44.6)	186 (54.2)	.02
Diabetes	35 (13.0)	71 (20.7)	.01
Obstructive lung disease	49 (18.2)	105 (30.6)	.001
Smoking ≥20 pack-years	126 (46.8)	154 (44.9)	.63
Parkinson disease	0 (0)	8 (2.3)	.01‖
Dementia	3 (1.1)	7 (2.0)	.53‖
ASA classification¶			
1	11 (4.1)	2 (0.6)	.001#
2	150 (55.8)	101 (29.4)	.001#
3	108 (40.2)	231 (67.4)	.001#
4	0 (0)	9 (2.6)	.001#
Goldman score**	3.9 ± 4.1	4.3 ± 4.3	.19
Detsky score††	3.6 ± 4.3	4.7 ± 5.4	.003
Surgical Characteristics			
Oncology related	146 (54.3)	156 (45.5)	.03
Peritoneal	84 (31.2)	103 (30.0)	.75
Vascular	14 (5.2)	22 (6.4)	.53
Thoracic	8 (3.0)	10 (2.9)	.97
Orthopedic	89 (33.1)	121 (35.3)	.57
Gynecology	56 (20.8)	82 (23.9)	.36
Otolaryngology	49 (18.2)	44 (12.8)	.07
Urology	14 (5.2)	13 (3.8)	.40
Neurosurgery	10 (3.7)	13 (3.8)	.96
Duration of anesthesia, min	322.6 ± 197.4	330.6 ± 183.2	.61

*ASA indicates American Society of Anesthesiologists.
†Continuous data are reported as mean ± SD.
‡Includes patients who cannot walk 4 blocks and climb 2 flights of stairs without symptomatic limitation.
§The *t* test for continuous variables and χ^2 test for categorical variables were used when comparing patients with good vs poor exercise tolerance unless otherwise specified.
‖The Fisher exact test was used.
¶A score of 1 indicates a normally healthy patient; 2, a patient with mild systemic disease; 3, a patient with severe systemic disease that is not incapacitating; and 4, a patient with an incapacitating systemic disease that is a constant threat to life.[11,19]
#The χ^2 test for trend was used.
**From Goldman et al.[7] See Appendix 1.
††From Detsky et al.[6] See Appendix 2.

Table 2. Definitions of Perioperative Complications

Sentinel Events

Unexpected transfer: transferred to the intensive care unit (ICU) or cardiac telemetry ward for any reason

Code blue: activation of the medical center's emergency response system for any reason

Death: prior to discharge

Cardiovascular Complications

Myocardial ischemia: (1) typical symptoms or ST segment changes of 1 mm or more in 2 or more contiguous leads and (2) initiation of a rule out myocardial ischemia protocol or antianginal therapy (eg, nitrate therapy)

Myocardial infarction: (1) new Q waves (≥0.03 s in duration) in 2 or more contiguous leads; (2) diagnosis of myocardial ischemia with elevated total creatine kinase (CK) level (>130 U/L), with CK-MB fraction >7 ng/mL and a quotient (CK-MB/total CK) >0.04; or (3) evidence of acute or subacute infarction on autopsy

Arrhythmia: any new arrhythmia (1) requiring both observation in a monitored setting and pharmacologic therapy for rate control or antiarrhythmic therapy or (2) causing hypotension or death

Hypotension: systolic blood pressure ≤90 mm Hg or initiation of pressor therapy (eg, dopamine therapy) or fluid boluses to maintain blood pressure, lasting for ≥4 h

Congestive heart failure: (1) new S_3 gallop or jugular venous pressure ≥10 cm H_2O, (2) rales halfway or more up the chest or chest roentgenogram changes consistent with pulmonary edema, and (3) initiation of therapy (eg, diuretic therapy)

Pulmonary Complications

Pneumonia: (1) temperature ≥38.0°C, positive sputum culture results or focal infiltrate on chest roentgenography films, and initiation or change in antimicrobial therapy or (2) evidence of pneumonia based on biopsy specimen or autopsy findings

Ventilator ≥24 h: new ventilator support for ≥24 h

Adult respiratory distress syndrome: (1) fraction of inspired oxygen ≥0.50 or ventilator support for ≥48 h, chest roentgenography films showing bilateral interstitial infiltrates, and no simultaneous diagnosis of congestive heart failure or pneumonia or (2) established by biopsy specimen or autopsy findings

Hypoxia: (1) fraction of inspired oxygen ≥0.50 for ≥48 h or (2) new requirement for supplemental oxygen for ≥7 d

Bronchospasm: (1) wheezing on examination for ≥24 h and (2) frequent nebulizer therapy, new steroid therapy, or transfer to ICU for respiratory treatment

Pulmonary embolism: (1) high probability on nuclear medicine perfusion scan or pulmonary angiogram results, (2) high clinical suspicion with initiation of therapy (anticoagulant or vena cava filter), or (3) evidence of pulmonary embolism on biopsy specimen or autopsy findings

Other pulmonary: included 2 patients with postintubation airway edema

Neurologic Complications

Delirium: confusion for ≥24 h and specific intervention (medication, physical restraints, or sitter)

Stroke: (1) focal neurologic deficit consistent with cerebral ischemia lasting ≥24 h, (2) new acute or subacute defect on cerebral imaging films consistent with ischemic or hemorrhagic cerebral event, or (3) evidence of acute or subacute cerebral ischemia based on biopsy specimen or autopsy findings

Transient ischemic attack: focal neurologic deficit consistent with cerebral ischemia lasting <24 h

Infection (neurologic): (1) positive bacterial, fungal, or viral culture/study results from brain or cerebrospinal fluid or radiographic imaging consistent with intracerebral infection *and* initiation of antibiotic or antifungal therapy or (2) autopsy findings or biopsy specimen consistent with intracerebral infection

Other neurologic: included 2 patients each with peripheral neuropathy or seizures

Table 2. Definitions of Perioperative Complications (cont)

Infectious Complications

Surgical site infection (superficial): (1) purulent drainage or positive pathologic culture from wound and (2) incision and drainage of the wound or initiation of new antibiotic therapy

Surgical site infection (deep): (1) purulent drainage or positive pathologic culture from wound and (2) wound dehiscence or wound opened by the surgeon

Abscess: (1) purulent drainage or positive pathologic culture results; (2) abscess identified by examination, exploration, or radiological films; and (3) requires drainage or prolonged antimicrobial therapy

Bacteremia: positive blood culture results requiring therapy or intervention

Sepsis: (1) diagnosis of hypotension; (2) culture results, biopsy specimen, radiographic films, or autopsy findings consistent with infection; and (3) initiation of specific therapy

Other infectious: included 1 patient each with anastomotic leak, fungemia, oral-cutaneous fistula, colitis, or peritonitis

Miscellaneous Complications

Deep venous thrombosis: (1) new occlusive deep vein thrombosis at any location (diagnosed radiographically or with ultrasonography) or (2) findings of thrombosis on biopsy specimen or autopsy

Gastrointestinal bleeding: (1) heme-positive emesis or stool test results, (2) transfusion or >10-point change in hematocrit, and (3) no other reasonable cause of hematocrit change

Alcohol withdrawal: (1) history of alcohol abuse, (2) diagnosis of delirium, and (3) requiring specific therapy (eg, benzodiazepine therapy)

Renal insufficiency: rise in creatinine level ≥177 μmol/L (2.0 mg/dL) from baseline

Fall: documented during hospitalization

Other miscellaneous: included 1 patient each with malignant hyperthermia, intraoperative arterial occlusion, compartment syndrome, wound hematoma (requiring reoperation), hemothorax, and spontaneous cecal perforation

only 0.49, for predicting perioperative events. However, we defined poor exercise tolerance as the inability to walk 4 blocks and climb 2 flights of stairs because it provided the highest sensitivity (0.71), albeit with a lower specificity (0.47) and likelihood ratio (1.3), for predicting all serious perioperative complications.

Three hundred forty-three patients (56.0%) reported poor exercise tolerance. They were, on average, older and more often women. They had higher incidences of diabetes, hypertension, obstructive lung disease, congestive heart failure, and Parkinson disease and had higher ASA scores assigned (Table 1). The 2 groups did not differ significantly with respect to surgical characteristics, except that patients with good exercise tolerance were more likely to have surgical oncology procedures.

PERIOPERATIVE COMPLICATIONS

Serious perioperative complications occurred with 98 procedures (**Table 3**). They included 65 cardiovascular, 74 pulmonary, 27 neurologic, and 23 miscellaneous events and 22 serious infections. Forty-six patients had more than a single event. Fifty-three patients (8.7%) were unexpectedly transferred to the ICU or cardiac telemetry ward. The emergency response system was used for 2 patients. Three patients died, 2 from cardiac causes and 1 from hepatic and renal failure. Three patients (1.3%) who underwent minor procedures had serious perioperative complications (data not shown).

Poor exercise tolerance was associated with an increased risk for serious perioperative complications independent of age and all other patient characteristics (**Table 4**). Patients with poor self-reported exercise tolerance had more myocardial ischemia and more cardiovascular and neurologic events (Table 3). After adjustment for age, patients with poor exercise tolerance had more myocardial ischemia (adjusted odds ratio [OR], 4.68; 95% confidence interval [CI], 1.04-21.03) and neurologic events (adjusted OR, 2.53; 95% CI, 1.00-6.43). There was a trend toward more cardiovascular events (adjusted OR, 1.81; 95% CI, 0.94-3.46), but this was not statistically significant. The likelihood of a serious complication was inversely related to the number of blocks that could be walked ($P = .006$) or the number of flights of stairs that could be climbed ($P = .01$). Patients whose exercise tolerance was limited by cardiac symptoms were more likely to have complications ($P < .001$). Unlimited exercise tolerance was associated with fewer serious events ($P = .002$).

Other patient characteristics that predicted serious complications in bivariate analyses included a history of coronary artery disease, myocardial infarction, peripheral vascular disease, congestive heart failure, ventricular arrhythmia, dementia, Parkinson disease, and smoking greater than or equal to 20 pack-years (Table 4). When these variables were included in an age-adjusted multiple logistic regression model, only poor exercise tolerance, a history of congestive heart failure, dementia, Parkinson disease, and smoking greater than or equal to 20 pack-years were found to be significant independent predictors of serious complications. There were no significant first-degree multiplicative interactions. Age was not a statistically significant factor in the bivariate or multivariable analysis, although patients with perioperative complications were significantly older (65.6 ± 10.4 vs 62.5 ± 15.4 years; *t* test, $P = .01$). The age-adjusted ORs were almost identical to unadjusted ORs for all logistic models evaluating serious complications. Three patients who had a recent myocardial infarction (<6 months) underwent surgery and 1 had an ischemic event. There were too few patients in this subgroup for meaningful statistical analysis.

Of the surgical characteristics, the risk associated with longer duration of anesthesia was particularly striking. Patients with complications had longer procedures compared with other patients (477.5 ± 253.1 vs 298.4 ± 159.6 minutes; *t* test, $P < .001$). The risk of complications increased with the duration of the surgery, particularly when anesthesia time was 8 hours or longer. Other surgical characteristics associated with an increased risk for serious complications in bivariate analyses included surgical oncology and thoracic, peritoneal, or otolaryngology procedures (**Table 5**). When these variables were included in an age-adjusted multiple logistic regression model, only thoracic or peritoneal procedures and anesthesia time of 8 hours or longer were independently associated with serious complications. There were no significant first-degree multiplicative interactions.

Table 3. Perioperative Complications Among Patients With Good or Poor Exercise Tolerance

	No. (%) of Patients		
Perioperative Complications†	Good Exercise Tolerance (n = 269)	Poor Exercise Tolerance (n = 343)	*P**
Cardiovascular (total)	14 (5.2)	33 (9.6)	.04
Arrhythmia	10 (3.7)	18 (5.3)	.37
Myocardial ischemia	2 (0.7)	13 (3.8)	.02
Myocardial infarction	1 (0.4)	2 (0.6)	>.99‡
Hypotension	4 (1.5)	6 (1.8)	>.99‡
Congestive failure	3 (1.1)	6 (1.8)	.74‡
Pulmonary (total)	17 (6.3)	31 (9.0)	.21
Hypoxia	8 (3.0)	19 (5.5)	.13
Ventilator ≥24 h	8 (3.0)	9 (2.6)	.79
Pneumonia	4 (1.5)	10 (2.9)	.24
Adult respiratory distress syndrome	2 (0.7)	4 (1.2)	.70‡
Bronchospasm	3 (1.1)	3 (0.9)	>.99‡
Pulmonary embolism	1 (0.4)	1 (0.3)	>.99‡
Other	2 (0.7)	0 (0.0)	.19‡
Neurologic (total)	6 (2.2)	20 (5.8)	.03
Delirium	6 (2.2)	17 (5.0)	.08
Other	0 (0.0)	4 (1.2)	.14‡
Infections (total serious)§	6 (2.2)	10 (2.9)	.60
Surgical site			
Superficial	5 (1.9)	11 (3.2)	.30
Deep	5 (1.9)	6 (1.8)	>.99‡
Bacteremia	1 (0.4)	3 (0.9)	.64‡
Abscess	0 (0.0)	1 (0.3)	>.99‡
Sepsis	0 (0.0)	1 (0.3)	>.99‡
Other	1 (0.4)	4 (1.2)	.39‡
Miscellaneous (total)	6 (2.2)	15 (4.4)	.15
Deep vein thrombosis	2 (0.7)	3 (0.9)	>.99‡
Renal insufficiency	2 (0.7)	3 (0.9)	>.99‡
Alcohol withdrawal	2 (0.7)	3 (0.9)	>.99‡
Fall	0 (0.0)	2 (0.6)	.51‡
Other	1 (0.4)	5 (1.5)	.24‡
Unexpected transfer	15 (5.6)	38 (11.1)	.02
Code blue	2 (0.7)	0 (0.0)	.19‡
Death	2 (0.7)	1 (0.3)	.59‡
Total serious complications∥	28 (10.4)	70 (20.4)	.001

**The χ^2 test was used to compare patients with good vs poor exercise tolerance unless otherwise indicated.*
†Defined in Table 2.
‡The Fisher exact test was used.
§Includes all infections listed with the exception of superficial surgical site infections.
∥Includes all complications except superficial surgical site infections and unexpected transfer (to the intensive care unit or cardiac telemetry ward).

Higher ASA classification predicted risk for all serious complications ($P < .001$). As in prior studies, patients with complications had higher Goldman scores[7,22,23] (5.0 ± 4.4 vs 3.9 ± 4.1 points; *t* test, $P = .02$) and Detsky scores[6,24] (5.1 ± 5.1 vs 4.0 ± 4.9 points; *t* test, $P = .05$) than patients without complications.

COMMENT

This study provides evidence to support the use of self-reported exercise tolerance in perioperative risk assessment. While other studies indicate that poor performance on formal exercise testing is associated with an

Table 4. Patient Characteristics Associated With an Increased Risk for All Serious Perioperative Complications*

Patient Characteristics	No. of Patients With Complications/Total	Odds Ratios (95% CI)†	
		Age-Adjusted	Multivariable Model‡
Poor exercise tolerance	70/343	2.13 (1.33-3.42)	1.94 (1.19-3.17)
Smoking ≥20 pack-years	59/280	2.01 (1.29-3.13)	2.16 (1.36-3.44)
Coronary disease	32/142	1.64 (1.01-2.66)	NS
Peripheral vascular disease	20/76	1.97 (1.12-3.48)	NS
Prior myocardial infarction	19/72	1.98 (1.11-3.54)	NS
Congestive heart failure	19/52	3.38 (1.83-6.26)	2.88 (1.52-5.48)
Ventricular arrhythmia	14/44	2.55 (1.29-5.03)	NS
Dementia	5/10	4.54 (1.26-16.33)	5.54 (1.51-20.41)
Parkinson disease	5/8	8.26 (1.93-35.37)	8.14 (1.76-37.67)

*CI indicates confidence interval; NS, not significant.
†Age-adjusted odds ratios for all serious complications.
‡Independent variables in the logistic regression model include each of the patient characteristics shown and age.

Table 5. Surgical Characteristics Associated With an Increased Risk for All Serious Perioperative Complications*

Surgical Characteristics	No. of Patients With Complications/Total	Odds Ratios (95% CI)†	
		Age-Adjusted	Multivariable Model‡
Surgical oncology	64/302	2.10 (1.33-3.30)	NS
Peritoneal	40/187	1.73 (1.10-2.70)	1.67 (1.02-2.74)
Duration of anesthesia ≥8 h	44/99	6.81 (4.18-11.10)	6.68 (4.03-11.08)
Otolaryngology	26/93	2.32 (1.38-3.90)	NS
Thoracic	11/18	9.77 (3.65-26.15)	10.25 (3.42-30.74)

*CI indicates confidence interval; NS, not significant.
†Age-adjusted odds ratios for all serious complications.
‡Independent variables in the logistic regression model include each of the surgical characteristics shown and age.

increased risk for postoperative cardiopulmonary complications,[12-17] this is the first study, to our knowledge, to demonstrate the reliability of self-reported exercise tolerance in predicting perioperative risk. Poor exercise tolerance predicted risk for all serious complications independent of all other patient characteristics, including age, cardiovascular illness, and smoking. All patients reporting poor exercise tolerance were at increased risk, regardless of the cause of their limitation, although the risk was particularly high in those limited by cardiac symptoms.

There are a number of possible explanations for these findings. Patients with poor exercise tolerance may have more significant medical problems, and this was certainly true for our patient population. Patients with poor exercise tolerance were also older and more likely to have diabetes, obstructive lung disease, congestive heart failure, hypertension, and higher ASA scores. Since the severity of many cardiopulmonary illnesses is defined by the patient's exercise capacity (eg, angina),[6] self-reported exercise tolerance may simply be a surrogate marker for the severity of medical illness. Because numerous medical problems can limit a patient's exercise tolerance, it is not surprising that poor exercise tolerance may not predict which specific complications will occur.

Alternatively, patients with good exercise tolerance may better tolerate the physical rigors of surgery and mobilize more rapidly postoperatively. Surgery is a physically challenging event. Fluid shifts, pain, anemia, prolonged bed rest, and other factors in the perioperative period result in hemodynamic fluctuations[25] and compromise pulmonary function.[26] The cardiovascular and pulmonary systems of patients with good exercise tolerance are undoubtedly better prepared to handle these physiologic stresses. Additionally, patients who are limited in their exercise capacity preoperatively are likely to have difficulty with ambulation postoperatively. Since early ambulation may be important in reducing complications and lessening the length of stay, patients with poor exercise tolerance may stay in the hospital longer and may have more complications.

We identified several other patient characteristics that were associated with perioperative complications. Our data were consistent with previous studies linking a history of congestive heart failure,[6,7,27,28] significant tobacco use,[3,5,29] dementia,[5,30] Parkinson disease,[31,32] and higher ASA classification[4,5,9-11,22] to increased operative risk. Interestingly, in our study group, age was not an independent predictor of surgical risk. While at least one other study has shown similar findings,[33] most other studies have shown age to be an important factor.[4,5,7,8,27,28] Several characteristics related to the surgical procedure were also associated with higher risk. Our data confirmed prior reports showing patients with thoracic or peritoneal procedures[3,7] to be at increased risk for complications. As in previous studies,[3-5] perioperative complications were associated with prolonged duration of anesthesia. In our data, this was particularly striking when the duration of anesthesia was 8 hours or more. This may be caused by the physiologic stress of the anesthesia, blood loss, or hypothermia,[34] or it may simply reflect the complexity and severity of the procedure (eg, number of tissue planes crossed and number of services involved).

Applied to our patient population, the original Goldman[7] and Detsky[6] scores predicted cardiovascular events, despite the fact that our study differed in several respects from their original research. Our population included only outpatients, reflecting the change in medical practice over the intervening years. Cardiovascular complications were defined differently in some cases, and we included some events that were not used in their original studies (eg, hypotension). As in the original study by Goldman et al,[7] postoperative testing was performed only as clinically indicated, and patients were evaluated only until the time of discharge. As a result, some subclinical events may have been missed. Given the relatively long length of stay of our patients and the combination of our own reporting system with information from the medical center, we believe that we captured all clinically significant events. Finally, although our patients were not examined by blinded examiners, the reviewers who confirmed all complications were blinded to the study design and the results of the preoperative evaluation.

Our study group was drawn from a single tertiary care medical center and may not be representative of other populations. The vast majority of patients in our study (94%) were white. Patients from other ethnic backgrounds may report their exercise tolerance differently. Half of the patients in our study had oncologic procedures, and few had routine urologic, vascular, neurosurgical, or thoracic procedures. Therefore, the relationship between self-reported exercise tolerance and serious perioperative complications should be evaluated in other patient groups.

In summary, our data confirm that both the severity of a patient's medical problems and the intensity of the procedure to be performed are important factors in determining perioperative risk. Self-reported exercise tolerance is another important factor to consider when evaluating a patient's overall medical status and risk for surgery. Surgery is a physically stressful event, and patients with poor exercise capacity do not tolerate it well. Poor exercise tolerance may reflect the severity of a patient's underlying medical illness or a lower functional status. Regardless of the cause, self-reported exercise tolerance predicts perioperative risk independent of other patient characteristics. Furthermore, this information is readily available to clinicians, requires no additional testing, and predicts risk even when simple and familiar measures of exercise tolerance are used. We recommend that self-reported exercise tolerance be considered when assessing perioperative risk.

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Appendix 1. Cardiac Risk Indices: Goldman Multifactorial Index of Cardiac Risk*

Criteria	Points
History	
Age >70 y	5
Myocardial infarction within 6 mo	10
Physical examination	
S_3 gallop or jugular venous distention	11
Significant aortic stenosis	3
Electrocardiogram	
Rhythm other than sinus with premature atrial contractions on preoperative electrocardiogram	7
More than 5 premature ventricular contractions per minute at any time preoperatively	7
Poor general medical status†	3
Operation	
Intraperitoneal, intrathoracic, or aortic procedure	3
Emergency surgery	4

Goldman Classification	Total Points
1	0-5
2	6-12
3	13-25
4	>25

*From Goldman et al.[7]

†Po_2 level lower than 60 mm Hg or Pco_2 level higher than 50 mm Hg, potassium level lower than 3.0 mmol/L or bicarbonate level lower than 20 mmol/L, blood urea nitrogen level higher than 17.8 mmol/L or creatinine level higher than 265 µmol/L (3.0 mg/dL), abnormal aspartate aminotransferase level, signs of liver disease, or bedridden for noncardiac causes.

Appendix 2. Cardiac Risk Indices: Detsky Modified Multifactorial Index*

Criteria	Points
Coronary artery disease	
Myocardial infarction within 6 mo	10
Myocardial infarction for more than 6 mo	5
Canadian Cardiovascular Society angina	
Class III	10
Class IV	20
Alveolar pulmonary edema	
Within 1 wk	10
Ever	5
Arrhythmias	
Rhythm other than sinus with premature atrial contractions on last electrocardiogram	5
More than 5 premature ventricular contractions per minute at any time preoperatively	5
Suspected critical aortic stenosis	20
Poor general medical status†	5
Age >70 y	5
Emergency operation	10

Detsky Classification	Total Points
1	0-15
2	16-30
3	>30

*From Detsky et al.[6]

†Po_2 level lower than 60 mm Hg or Pco_2 level higher than 50 mm Hg, potassium level lower than 3.0 mmol/L or bicarbonate level lower than 20 mmol/L, blood urea nitrogen level higher than 17.8 mmol/L or creatinine level higher than 265 µmol/L (3.0 mg/dL), abnormal aspartate aminotransferase level, signs of liver disease, or bedridden for noncardiac causes.