Predicting Risk of Death in General Surgery Patients on the Basis of Preoperative Variables Using American College of Surgeons National Surgical Quality Improvement Program Data

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Abstract

Objectives: To use the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database to develop an accurate and clinically meaningful preoperative mortality predictor (PMP) for general surgery on the basis of objective information easily obtainable at the patient's bedside and to compare it with the preexisting NSQIP mortality predictor (NMP).

Methods: Data were obtained from the ACS NSQIP Participant Use Data File (2005 to 2008) for current procedural terminology codes that included open pancreas surgery and open/laparoscopic colorectal, hernia (ventral, umbilical, or inguinal), and gallbladder surgery. Chi-square analysis was conducted to determine which preoperative variables were significantly associated with death. Logistic regression followed by frequency analysis was conducted to assign weight to these variables. PMP score was calculated by adding the scores for contributing variables and was applied to 2009 data for validation. The accuracy of PMP score was tested with correlation, logistic regression, and receiver operating characteristic analysis.

Results: PMP score was based on 16 variables that were statistically reliable in distinguishing between surviving and dead patients ($p < 0.05$). Statistically significant variables predicting death were inpatient status, sepsis, poor functional status, do-not-resuscitate directive, disseminated cancer, age, comorbidities (cardiac, renal, pulmonary, liver, and coagulopathy), steroid use, and weight loss. The model correctly classified 98.6% of patients as surviving or dead ($p < 0.05$). Spearman correlation of the NMP and PMP was 86.9%.

Conclusion: PMP score is an accurate and simple tool for predicting operative survival or death using only preoperative variables that are readily available at the bedside. This can serve as a performance assessment tool between hospitals and individual surgeons.

Introduction

Accurate estimation of the risk of death can help patients and their physicians to make decisions and to manage expectations; however, surgeons lack an easily accessible preoperative bedside evaluation system to calculate mortality. Various scoring systems to assess perioperative mortality have been reported in the literature, including the Physiologic and Operative Severity Score for the enUmeration [*sic*] of Mortality and Morbidity,[1] Surgical Risk Score,[2] Biochemistry and Haematology Outcome Models,[2] Acute Physiology and Chronic Health Evaluation,[3,4] Cleveland Clinic Foundation Colorectal Cancer Model,[5] and the French Association of Surgery's colorectal scale.[6,7] However, these are not easily calculated at the bedside. None of these scoring systems has the ability to predict accurately death or survival solely on the basis of preoperative variables, nor do they account for interhospital variability in outcomes.

The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database has been described by the Institute of Medicine as the best in the nation for measuring and for reporting surgical quality and outcomes. It is based on three important quality measurement principles: 1) data are collected and independently entered by specially trained nurse reviewers, thus eliminating the possible bias inherent in traditional surgical databases; 2) all cases are followed up for 30 days, even if the patient is discharged from the hospital, thus increasing the accuracy and thoroughness of reporting; and 3) cases are categorized by current procedural terminology codes, which standardizes analysis and reporting across institutions. NSQIP has developed models that use these data to predict mortality and morbidity across broad categories, such as general and vascular surgery.[8]

ACS NSQIP assesses surgical quality at more than 200 hospitals in the US by collecting thorough data on preoperative risk factors and postoperative morbidity and mortality.[8] Comprehensive computerized procedures and on-site auditing ensure data integrity. NSQIP also has a reliable postdischarge mortality predictor. The NSQIP mortality predictor (NMP)[9-11] is calculated from 35 variables related to the patient's physiologic status, demographic data, medical history, laboratory values, and American Society of Anesthesiologist (ASA) scores. It was designed with stepwise logistic regression. The probabilities from the regression analyses yield a probability (0 to 1) that a patient will experience a mortal event on the basis of the preexisting, or preoperative, conditions. These numbers can be converted to percentages. Therefore, a 0.59 probability can be expressed as a 59% chance of death.

Objectives

The purpose of this study was to use the ACS NSQIP database to develop an accurate, reliable, and clinically meaningful preoperative general surgery model to predict death or survival on the basis

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of information obtainable at the patient's bedside. NMP, the ACS NSQIP risk predictor, is available in the semiannual report provided to the hospital; however, the up-to-date NMP is not available to the surgeon at the time of patient admission. The preoperative mortality predictor (PMP) we developed in this study is based entirely on objective preoperative variables and is designed to be useful during preoperative counseling and the informed consent process.

Table 1. Current procedural terminology codes

Operation	CPT Codes
Open colon/rectal	44140, 44141, 44160, 45119, 44143-44146, 45110-45112
Lap colon/rectal	45395, 45397, 44204-44208, 44210-44212
Open gallbladder	47600, 47605, 47610
Lap gallbladder	47562-47564
Open hernia	49505, 49507, 49520, 49521, 49525, 49550, 49553, 49560, 49561, 49565, 49566, 49585, 49587
Lap hernia	49650-49657
Open pancreas	48140-48155

CPT = current procedural terminology; lap = laparoscopic.

Methods

Overview

A model to predict death or survival was developed and tested using data from the ACS NSQIP database for patients who underwent common surgical procedures from January 1, 2005, through December 31, 2009. The project was reviewed and approved by the WellSpan Health Medical/Surgical institutional review board. The study comprised three steps. Step 1 was to create the PMP using data from 2005 through 2008. Step 2 was to apply the PMP to the 2009 data for verification. Step 3 was to compare the PMP with the NMP to determine the accuracy of the new tool.

Patient Selection and Data Collection

For the present study, two datasets (2005 to 2008, 2009) were created from the ACS NSQIP database. The goal was to create the PMP model using the 2005 to 2008 dataset and then to apply it to the 2009 dataset to test its accuracy. We applied the same inclusion criteria to all data. All eligible patients were included.

Inclusion criteria were age 18 years or older, and 1 of 7 common surgeries: open pancreas surgery or open/laparoscopic colorectal, hernia (ventral, umbilical, or inguinal), or gallbladder surgery (Table 1). These 7 categories of surgery were chosen to represent 2 aspects of general surgery: the variety of cases,[12] and their operative complexity. Regarding variety, the procedures we selected comprise a mixture of elective and emergent surgeries, such as perforation and obstruction. They also address the concern raised by Aust et al, that operative complexity must be evaluated to accurately estimate operative mortality.[13]

We included all variables available in the ACS NSQIP database. Some variables were redefined to facilitate analysis. For example, patients were categorized as surviving or dead on the basis of year of death. To assess the effects of comorbidities on mortality, we created summary variables: pulmonary (including ventilator, history of chronic obstructive pulmonary disease, and current pneumonia), liver (including ascites and esophageal varices), renal (including dialysis and renal failure), neurologic (including history of transient eschemic attack and cardiovascular event with or without neurologic deficit), and cardiac (including dyspnea and history of congestive heart failure, myocardial infarction, angina, peripheral artery disease, and hypertension requiring medication) morbidity. Poor functional health status was defined as total assistance required for all daily activities (see Sidebar: National Surgical Quality Improvement Program definition: poor functional health status).

In an exploratory analysis of the entire dataset, only 4 (blood urea nitrogen, white blood cell count, serum glutamic-oxaloacetic transaminase, and partial thromboplastin time) of 13 (30.8%) laboratory variables were statistically significant predictors of death, with an odds ratio (OR) barely greater than 1. The statistically significant OR for albumin was less than 1 (0.350), indicating that death is less likely to occur on the basis of albumin levels. However, for 8 of the 13 (61.5%) laboratory variables, 19% (hematocrit) to 75% (albumin) of data were missing. Instead, we used a variable that has been shown to be an independent predictor of death

National Surgical Quality Improvement Program definition: poor functional health status

Functional Health Status (before surgery): This variable focuses on the patient's abilities to perform activities of daily living (ADLs) in the 30 days before surgery. ADLs are defined as "the activities usually performed in the course of a normal day in a person's life." ADLs include: bathing, feeding, dressing, toileting, and mobility. The corresponding level of self-care for ADLs demonstrated by the patient at the time the patient is being considered as a candidate for surgery are a) levels before the current illness, and b) levels at the time of surgery (no longer than 30 days before surgery). The level of functional health status is defined by the following criteria.

1. Independent: The patient does not require assistance from another person for any ADLs. This includes a person who is able to function independently with prosthetics, equipment, or devices.
2. Partially dependent: The patient requires some assistance from another person for ADLs. This includes a person who uses prosthetics, equipment, or devices but still requires some assistance from another person for ADLs.
3. Totally dependent: The patient requires total assistance for all ADLs.
4. Unknown: If unable to ascertain the functional status before surgery, report as unknown.

All patients with psychiatric illnesses should be evaluated for their ability to perform ADLs with or without assistance on the same basis as the nonpsychiatric patient. For instance, if a patient with schizophrenia is able to care for him/herself without the assistance of nursing care, s/he is considered independent.[1]

Reference

1. User guide for the participant use data file [monograph on the Internet]. Chicago, IL: American College of Surgeons. National Surgical Quality Improvement Program; 2007 Aug [cited 2012 Aug 20]. Available from: http://site.acsnsqip.org/wp-content/uploads/2012/03/ACS-NSQIP-Participant-User-Data-File-User-Guide_06.pdf.

Table 2. Patient characteristics by year

Characteristic	2005–2008, n (%)	2009, n (%)	p
Sex		<0.001	
Women	99,632 (49.10)	45,340 (48.20)	
Men	103,100 (50.90)	48,715 (51.80)	
Race		<0.001	
White	151,044 (74.50)	74,012 (78.70)	
Black	18,497 (9.10)	9037 (9.60)	
Other	33,200 (16.40)	11,011 (11.70)	
Age, years		<0.001	
18-64	138,645 (68.40)	63,467 (67.50)	
65-69	18,490 (9.10)	9364 (10.00)	
70-79	29,828 (14.70)	13,797 (14.70)	
≥80	15,778 (7.80)	7432 (7.90)	
Inpatient/outpatient		<0.001	
Inpatient	111,547 (55.00)	50,088 (53.30)	
Outpatient	91,194 (45.00)	43,972 (46.70)	
BMI		<0.001	
Underweight	6935 (3.40)	2712 (2.90)	
Normal	53,363 (26.50)	23,006 (24.70)	
Overweight	66,891 (33.20)	30,645 (32.90)	
Obese	74,015 (36.80)	36,907 (39.60)	
Current smoker within 1 year	40,888 (20.20)	18,942 (20.10)	0.853
Disseminated cancer	3453 (1.70)	1472 (1.60)	0.006
DM with oral agents or insulin	23,704 (11.70)	12,260 (13.00)	<0.001
DNR	1095 (0.50)	418 (0.40)	0.001
Functional status[a]	9539 (4.70)	4246 (4.50)	0.022
Pulmonary morbidity[b]	9588 (4.70)	4675 (5.00)	0.004
Cardiac morbidity[c]	91,746 (45.30)	44,309 (47.10)	<0.001
Sepsis	14,501 (7.20)	6127 (6.50)	<0.001
Liver morbidity[d]	2859 (1.40)	814 (0.90)	<0.001
Renal morbidity[e]	2584 (1.30)	1196 (1.30)	0.946
Weight loss[f]	5741 (2.80)	2336 (2.50)	<0.001
Neurological morbidity[g]	9446 (4.70)	4478 (4.80)	0.223
Steroid use for chronic condition	7075 (3.50)	3006 (3.20)	<0.001
Bleeding disorders	7909 (3.90)	3502 (3.70)	0.019
Surgery type		<0.001	
Open colon/rectal	31,730 (15.90)	14,180 (15.30)	
Lap colon/rectal	15,773 (7.90)	8390 (9.10)	
Open gallbladder	6751 (3.40)	2670 (2.90)	
Lap gallbladder	58,188 (29.20)	21,833 (23.60)	
Open hernia	71,775 (36.00)	33,400 (36.10)	
Lap hernia	7859 (3.90)	9134 (9.90)	
Open pancreas	7184 (3.60)	3034 (3.30)	

[a] See Sidebar: National Surgical Quality Improvement Program definition: poor functional health status.
[b] ventilator dependent, chronic obstructive pulmonary disorder, pneumonia.
[c] dyspnea, congestive heart failure, myocardial infarction, revascularization, percutaneous coronary intervention, angina, hypertension.
[d] ascites, esophogeal varices.
[e] dialysis, renal failure.
[f] >10% loss body weight in last 6 months.
[g] transient ischemic attack, stroke.
BMI = body mass index; DM = diabetes mellitus; DNR = do not resuscitate; lap = laparoscopic.

and that is easy to determine from medical history: loss of >10% body weight in the last 6 months.[14] Weight loss is a predictor of death after intra-abdominal surgery and lung surgery.[15,16]

The predictive ability of ASA score has been debated since its inception because of its subjective descriptions.[17-19] In the exploratory phase of the present study, ASA strongly predicted operative death, and its contribution to the mortality score far outweighed other variables. We excluded ASA from our analysis because we wanted to investigate objective factors on the basis of the history taken by and the physical examination performed by the surgeon. Recently, concerns have been raised that ASA class can be manipulated so it appears that the hospital is caring for sicker patients. ASA may lack precision and poor inter-rater consistency, which can lead to inaccuracy. There is significant interdependence between ASA and other preoperative NSQIP variables that can be used to calculate risk.[20,21]

Statistical Analysis and Development of the Score

All analyses were performed using SPSS 19 (IBM, Armonk, New York). To create the PMP model with the 2005 to 2008 data, we selected a set of preoperative variables on the basis of published studies.[22,23] We conducted a χ^2 analysis to determine which preoperative variables were significantly associated with death.

We analyzed those significant variables with logistic regression, which identified a number of variables with high ORs ($\beta > 1.3$, $p < 0.001$). To construct the scoring system, we performed a frequency analysis of the variables (for deceased patients only) that were significant on logistic regression ($p > 0.05$). The purpose of the frequency analysis was to determine the frequency of these characteristics among patients who died in hospitals nationwide. The ORs calculated with logistic regression were then weighted according to the frequencies of the corresponding characteristics to arrive at a score for each variable. A 1-point increase in score would indicate a predictable increase in overall mortality. Therefore, each variable's score was based on 2 factors: 1) its OR and 2) the frequency of the corresponding characteristic in patients who died in hospitals nationwide.

We compared the PMP to the NMP using Spearman correlation, a nonparametric test to determine the strength of association between two variables, with scores ranging from -1 (no correlation) through 1 (perfect correlation). Typically, results are presented as percentages; eg, a 0.85 Spearman correlation coefficient means that 85% of the variation in one variable is related to variation in the other.

To test the accuracy of the PMP and NMP, three logistic regressions (2005 to 2008 data, 2009 data, and combined data) were run to determine how well the PMP and NMP predicted death. Logistic regression uses both categorical and quantitative

Table 3. Comparison of patient characteristics by outcome

	2005-2008			2009		
Characteristic	**Surviving, n (%)**	**Dead, n (%)**	**p value**	**Surviving, n (%)**	**Dead, n (%)**	**p value**
Sex			0.296			0.06
Women	98,334 (49.20)	1298 (48.10)		44,693 (48.20)	647 (50.80)	
Men	101,702 (50.80)	1398 (51.90)		48,089 (51.80)	626 (49.20)	
Race			<0.001			0.001
White	148,900 (74.40)	2144 (79.50)		73,008 (78.70)	1004 (78.90)	
Black	18,233 (9.10)	264 (9.80)		8885 (9.60)	152 (11.90)	
Other	32,912 (16.50)	288 (10.70)		10,894 (11.70)	117 (9.20)	
Age, years			<0.001			<0.001
18-64	137,944 (69.00)	701 (26.00)		63,122 (68.00)	345 (27.10)	
65-69	18,181 (9.10)	309 (11.50)		9219 (9.90)	145 (11.40)	
70-79	29,024 (14.50)	804 (29.80)		13,429 (14.50)	368 (28.90)	
≥80	14,896 (7.40)	882 (32.70)		7017 (7.60)	415 (32.60)	
Inpatient/outpatient			<0.001			<0.001
Inpatient	108,912 (54.40)	2635 (97.70)		48,845 (52.60)	1243 (97.60)	
Outpatient	91,133 (45.60)	61 (2.30)		43,942 (47.40)	30 (2.40)	
BMI			<0.001			<0.001
Underweight	6664 (3.40)	271 (10.30)		2586 (2.80)	126 (10.10)	
Normal	52,521 (26.40)	842 (32.00)		22,593 (24.60)	413 (33.20)	
Overweight	66,145 (33.30)	746 (28.30)		30,310 (32.90)	335 (27.00)	
Obese	73,240 (36.90)	775 (29.40)		36,538 (39.70)	369 (29.70)	
Current smoker within 1 year	40,374 (20.20)	514 (19.10)	0.151	18,684 (20.10)	258 (20.30)	0.91
Disseminated cancer	3161 (1.60)	292 (10.80)	<0.001	1335 (1.40)	137 (10.80)	<0.001
Diabetes mellitus	23,043 (11.50)	661 (24.50)	<0.001	11,923 (12.80)	337 (26.50)	<0.001
DNR	885 (0.40)	210 (7.80)	<0.001	331 (0.40)	87 (6.80)	<0.001
Functional status	8105 (4.10)	1434 (53.20)	<0.001	3583 (3.90)	663 (52.10)	<0.001
Pulmonary morbidity	8544 (4.30)	1044 (38.70)	<0.001	4186 (4.50)	489 (38.40)	<0.001
Cardiac morbidity	89,518 (44.70)	2228 (82.60)	<0.001	43,260 (46.60)	1049 (82.40)	<0.001
Sepsis	13,060 (6.50)	1441 (53.40)	<0.001	5442 (5.90)	685 (53.80)	<0.001
Liver morbidity	2416 (1.20)	443 (16.40)	<0.001	673 (0.70)	141 (11.10)	<0.001
Renal morbidity	2137 (1.10)	447 (16.60)	<0.001	983 (1.10)	213 (16.70)	<0.001
Weight loss[a]	5404 (2.70)	337 (12.50)	<0.001	2215 (2.40)	121 (9.50)	<0.001
Neurologic morbidity	8974 (4.50)	472 (17.50)	<0.001	4265 (4.60)	213 (16.70)	<0.001
Steroid	6703 (3.40)	372 (13.80)	<0.001	2803 (3.00)	203 (15.90)	<0.001
Bleeding disorders	7324 (3.70)	585 (21.70)	<0.001	3221 (3.50)	281 (22.10)	<0.001
Surgery type			<0.001			<0.001
Open colon/rectal	30,224 (15.40)	1506 (63.40)		13,448 (14.70)	732 (65.90)	
Lap colon/rectal	15,611 (7.90)	162 (6.80)		8323 (9.10)	67 (6.00)	
Open gallbladder	6573 (3.30)	178 (7.50)		2612 (2.90)	58 (5.20)	
Lap gallbladder	58,040 (29.50)	148 (6.20)		21,777 (23.80)	56 (5.00)	
Open hernia	71,572 (36.40)	203 (8.50)		33,289 (36.40)	111 (10.00)	
Lap hernia	7856 (4.00)	3 (0.10)		9121 (10.00)	13 (1.20)	
Open pancreas	7007 (3.60)	177 (7.40)		2961 (3.20)	73 (6.60)	

[a] > 10% loss body weight in last 6 months.
BMI = body mass index; DNR = do not resuscitate; lap = laparoscopic.

variables to predict a dichotomous variable. The classification number generated indicates how well a group of variables predict another variable. In this study, death was the dichotomous variable being predicted by the quantitative variables of the PMP and NMP.

The PMP was further tested with a receiver operating characteristic curve. Receiver operating characteristic curves are used to test discrimination, or, in the case of this study, the ability of a model to distinguish between dead and surviving patients. This is tested using the area under the curve, which is expressed as a percentage and indicates how well the model discriminates between dead and surviving patients.

Results

The analysis includes 202,741 (68%) patients from the 2005 to 2008 period and 94,060 (32%) patients from 2009. Demographic and clinical patient characteristics were compared by year (Table 2). A χ^2 analysis of 2005 to 2008 patient characteristics by outcome (death/survival) showed that 18 variables are significantly associated with death (Table 3).

Logistic regression showed that 15 of the 18 variables (including 3 age groups) were strong predictors of death or survival (Table 4). Some of these variables had a stronger association with death than others. For example, 98% of those who died were inpatients, whereas only 11% of those who died had disseminated cancer. The value of the logistic regression coefficient β was then weighted by the frequency of the characteristic to provide a score. Scores were assigned to each variable on the basis of their OR and frequency (Table 5). PMP scores could range from -1 through 30.

Spearman correlation of NMP and PMP scores for the 2005 to 2008 data was 87.5%. Spearman correlation of NMP and PMP for the 2009 data was 85.5%. Spearman correlation of NMP and PMP for all (combined) data was 86.9% (linear relationship) (Figure 1). As NMP scores increase, so do PMP scores. Regression results for 2005 to 2008 data, 2009 data, and all (combined) data indicated that PMP score was statistically reliable ($p < 0.05$) in distinguishing between dead and surviving patients and correctly classified 98.7%, 98.6%, and 98.6% of cases, respectively. Receiver operating characteristic curve analysis found that the PMP was 93% accurate at predicting death (Figure 2).

Differences occurred in outcomes among patients with different scores. When scores were grouped into 5-point intervals, mortality rate increased with increasing interval (Figure 3). For example, <1% of people in the 0-5 score range died, whereas 73% of those in the 20 to 30 range died.

Table 5. A 30-point bedside preoperative mortality predictor scoring system

Patient variable	Score
Inpatient	6
Sepsis	4
Poor functional status[a]	3
Disseminated cancer	1
Age, years	
≥80	2
70-79	1
65-69	0.5
Comorbidities	
Cardiac	5
Pulmonary	3
Renal	1
Liver	1
Steroid for chronic condition	1
Weight loss[b]	1
Bleeding disorder	1
DNR	1
Obesity	-1
Highest possible score	30

[a] total assistance required for all daily activities.
[b] >10% body weight in last 6 months.
DNR = do not resuscitate.

Table 4. Characteristics associated with 30-day mortality in 202,741 patients, 2005–2008

Characteristic	p	OR	95% CI
Inpatient	<0.001	4.943	3.909-6.249
Age ≥80 years	<0.001	3.884	3.490-4.322
Liver morbidity	<0.001	3.181	2.792-3.626
Functional status	<0.001	3.138	2.869-3.433
Disseminated cancer	<0.001	3.080	2.706-3.507
Renal morbidity	<0.001	2.879	2.523-3.287
Sepsis	<0.001	2.824	2.584-3.086
Pulmonary morbidity	<0.001	2.517	2.301-2.752
DNR	<0.001	2.335	1.966-2.772
Age 70-79 years	<0.001	2.189	1.973-2.429
Steroid	<0.001	1.729	1.534-1.949
Age 65-69 years	<0.001	1.649	1.446-1.880
Cardiac morbidity	<0.001	1.622	1.465-1.796
Weight loss[a]	<0.001	1.572	1.387-1.782
Bleeding disorder	<0.001	1.465	1.321-1.625
Open pancreas surgery	<0.001	1.396	1.206-1.617
Obese	0.159	0.931	0.842-1.029

[a] >10% body weight in the last 6 months.
CI = confidence interval; DNR = do not resuscitate; OR = odds ratio.

Discussion

Operative mortality can be used to compare quality of care in different health care settings. This information is sought by both the payer and the patient and is also valued by surgeons assessing their outcomes. PMP score accurately predicted death or survival after a common general surgery operation. This information could be used as a standardized indicator to compare observed and expected mortality rates at different hospitals and to assess their performance. Additionally, the PMP could be a useful audit tool for surgeons. Optimal patient care requires a successful interface between the surgeon, operating room staff, nursing staff, and ancillary staff. The success of this interaction reflects the performance of the hospital. The PMP could be used as a reliable measure of quality at the system level, replacing older tools that focused only on patient variables.

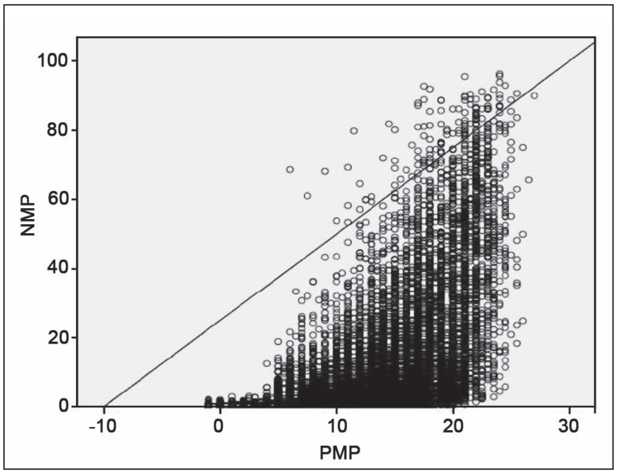

Figure 1. Correlation between preoperative mortality predictor and National Surgical Quality Improvement Program (NSQIP) mortality predictor.

NMP = NSQIP mortality predictor; PMP = preoperative mortality predictor.

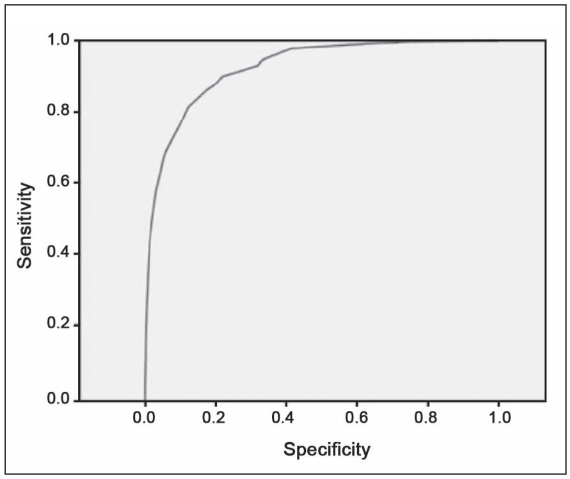

Figure 2. Receiver operating characteristic curve to test preoperative mortality predictor.

In our analysis, inpatient status had the greatest contribution to PMP score. The practice of ambulatory surgery is increasing in the US, but inpatient surgery is still required for sicker patients and for more complex operations. Inpatient status exposes patients to hospital-acquired infections, which contributes indirectly to mortality. Five percent to 10% of patients admitted to acute care hospitals in the US will acquire a nosocomial infection. Health care-associated bloodstream infections are associated with attributable mortality that makes them the eighth-leading cause of death in the US.[24]

Our analysis reveals that advanced age independently predicted death or survival. The assigned score for age increased from 1 to 1.5 to 2.5 as patients moved between age groups, from 65-69 to 70-79 to ≥80 years. Several studies have confirmed old age as a risk factor for operative mortality. [25-31] Advanced age leads to progressive decline in physiologic reserve and ability to compensate for stress. Elderly patients have both more and more serious medical comorbidities, which may be related to delayed presentation, poor communication, or increased incidence of certain diseases, such as colorectal cancer and diverticulitis. Abdominal pathology in older patients often presents emergently.[32,33] Elderly patients are a vulnerable group and need special attention and care. Health care professionals may have to alter practices to accommodate their needs, eg, by minimizing sleep interruptions, altering dosage and type of medicines, or having a geriatrician follow-up with the patient while in the hospital. Improving perioperative practices could be one avenue to lower mortality among geriatric patients. Approximately 403,000 cholecystectomies were performed in the US in 2007.[34] The mortality rates associated with these common general surgery procedures are minimal but may escalate if cholecystectomy is performed in elderly patients in emergent settings, as shown by Dolan et al[35] and Kurian et al.[36] More than 33% of cholecystectomies and 50% of partial colectomies were being performed in patients older than age 65 years. In 2007, those aged at least 65 years accounted for just 13% of the US population but 37% of hospital discharges and 43% of days of care.[34,a]

Poor functional status (PFS) and do-not-resuscitate (DNR) directives were independent predictors of mortality.[37-40] Patients with PFS and DNR directives are generally sicker, have more comorbidities, are more vulnerable to neglect, and may present later in their disease process, which may result in higher mortality. The decision to operate on patients with PFS and DNR directives should be thoroughly reviewed with a detailed preoperative workup and optimization. A study in the United Kingdom also indicated that patients with DNR directives may require specialized care, and limited access to such care may contribute to higher mortality.[41] PFS has been shown to be a strong predictor of postoperative cardiac[42] and neurologic[43] adverse events.

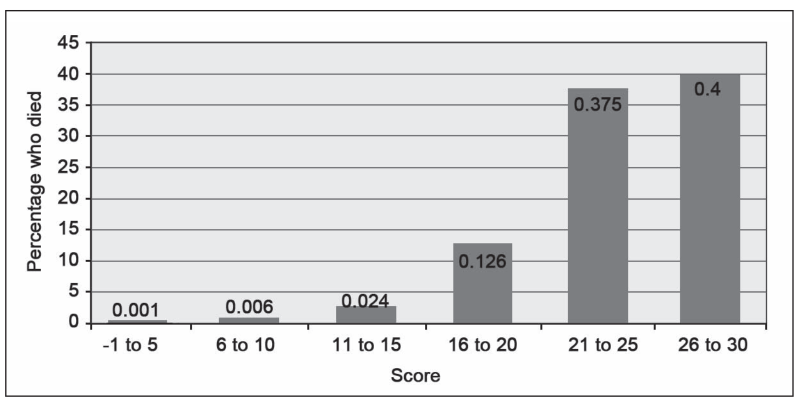

Figure 3. Percentage of mortality within each group.

Patients with renal failure who are on hemodialysis and patients with cirrhosis are known to have higher postoperative mortality rates than their age peers.[44-47] The present study identified liver and renal failure as independent risk factors that predicted death. Medical comorbidities such as cardiac problems, pulmonary dysfunction, and bleeding disorders also independently predicted death. Preoperative optimization of these conditions may be an avenue for risk reduction.

PMP score can be used as a quick bedside/office tool to determine a patient's risk of perioperative death. In contrast to the risk calculators developed by Khuri[9-11] and Aust,[13] the PMP does not require any laboratory data to predict mortality.

Sepsis emerged as an independent predictor of death. Patients presenting in sepsis are generally operated on emergently. The mortality rate associated with emergency laparotomies is greater than mortality for elective operations, which has also been reported by McIlroy et al[48] and Pederson et al.[49] The hospitalization rate of those with a principal diagnosis of septicemia or sepsis more than doubled from 2000 to 2008, increasing from 11.6 to 24.0 per 10,000. In-hospital deaths increased from 2% to 17% among patients hospitalized with a diagnosis of sepsis, compared to other diagnoses. For patients younger than age 65 years, 13% who were hospitalized for septicemia or sepsis died in the hospital, compared with 1% of those hospitalized for other conditions. For patients age 65 years and older, 20% of septicemia or sepsis hospitalizations ended in death, compared with 3% for other hospitalizations.[24] Adhering to the Surviving Sepsis Campaign[50] and similar guidelines could potentially decrease mortality.

Steroid use in the preoperative phase was an independent predictor of death. Ismael et al, in their study using 2005 to 2008 NSQIP data, demonstrated that steroid use increased the rate of surgical site infections but also may have increased mortality almost fourfold.[51]

Presence of disseminated cancer also independently predicted death. A recent study by Kwok et al has shown that metastatic cancer is the only diagnostic variable that is a significant predictor of death.[52] Surgical complexity was only minimally predictive, and only in very complex procedures, such as pancreatectomy. Aust et al proposed a similar hypothesis about surgical complexity.[13]

PMP score can be used as a quick bedside/office tool to determine a patient's risk of perioperative death. In contrast to the risk calculators developed by Khuri[9-11] and Aust,[13] the PMP does not require any laboratory data to predict mortality.

The strength of the present study is that we incorporated a high volume of patients by including data from 2005 through 2008. This study was able to successfully validate the PMP with 2009 ACS NSQIP data. The limitation may be that the results cannot be generalized to institutions that do not participate in the ACS NSQIP. Significant differences between ACS NSQIP and non-ACS NSQIP hospitals seem unlikely given the diverse array of representation in the current ACS NSQIP. It would be interesting to see if this tool can be successfully used in health care settings outside the US.

Conclusion

The PMP is an accurate, simple, effective, and clinically meaningful tool to calculate the risk of perioperative death using only preoperative variables. Risk can be easily calculated at the bedside without any laboratory values. The PMP would give physicians the ability to reliably report the risk of death for a wide range of patients undergoing common general surgery procedures, both elective and emergent. It would be helpful in providing accurate information about the risk of death and in obtaining informed consent. In addition to being a useful counseling tool, the PMP could also provide data on the performance of surgeons and hospitals. ❖

[a] Starting from 2002, the expression "days of care" was replaced by the expression "occupancy/billing days." This is an adaption to the terminology of the lump-sum pay system. In the field of the prevention or rehabilitation facilities the expression "days of care" further exists. The number of occupancy/billing days is the sum of the fully inpatient patients of each day of the reporting year at 12 pm (sum of midnight stock). The reported values of occupancy/billing days include the hourly cases. Days of intensive care treatment/intensive care monitoring are occupancy/billing days for patients who are treated in intensive care beds.

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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