Risk Factors for Morbidity and Mortality After Colectomy for Colon Cancer

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PURPOSE: Comorbid conditions affect the risk of adverse outcomes after surgery, but the magnitude of risk has not previously been quantified using multivariate statistical methods and prospectively collected data. Identifying factors that predict results of surgical procedures would be valuable in assessing the quality of surgical care. This study was performed to define risk factors that predict adverse events after colectomy for cancer in Department of Veterans Affairs Medical Centers. METHODS: The National Veterans Affairs Surgical Quality Improvement Program contains prospectively collected and extensively validated data on more than 415,000 surgical operations. All patients undergoing colectomy for colon cancer from 1991 to 1995 who were registered in the National Veterans Affairs Surgical Quality Improvement Program database were selected for study. Independent variables examined included 68 preoperative and 12 intraoperative clinical risk factors; dependent variables were 21 specific adverse outcomes. Stepwise logistic regression analysis was used to construct models predicting the 30-day mortality rate and 30-day morbidity rates for each of the ten most frequent complications. RESULTS: A total of 5,853 patients were identified; 4,711 (80 percent) underwent resection and primary anastomosis. One or more complications were observed in 1,639 of 5,853 (28 percent) patients. Prolonged ileus (439/5,853; 7.5 percent), pneumonia (364/5,853; 6.2 percent), failure to wean from the ventilator (334/5,853; 5.7 percent), and urinary tract infection (292/5,853; 5 percent) were the most frequent complications. The 30-day mortality rate was 5.7 percent (335/5,853). For most complications, 30-day in-hospital mortality rates were significantly higher for patients with a complication than for those without. Thirty-day mortality rates exceeded 50 percent if postoperative coma, cardiac arrest, a pre-existing vascular graft prosthesis that failed after colectomy, renal failure, pulmonary embolism, or progressive renal insufficiency occurred. Preoperative factors that predicted a high risk of 30-day mortality included ascites, serum sodium >145 mg/dl, "do not resuscitate" status before surgery, American Society of Anesthesiologists classes III and IV OR V, and low serum albumin. CONCLUSIONS: Mortality rates after colectomy in Veterans Affairs hospitals are comparable with those reported in other large studies. Ascites, hypernatremia, do not resuscitate status before surgery, and American Society of Anesthesiologists classes III and IV OR V were strongly predictive of perioperative death. Clinical trials to decrease the complication rate after colectomy for colon cancer should focus on these risk factors. [Key words: Colon cancer; Surgical mortality; Colectomy; Veterans Affairs Medical Center; National Surgical Quality Improvement Program]

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Surgical extirpation of the primary tumor remains the most effective therapy for potentially curable colon cancer. The safety of colectomy has been improved by advances in surgical technique, anesthesia, intensive care therapy, introduction of modern antibiotic treatments, and other supportive measures. Although the results of surgery for colon cancer at the turn of the century were dismal, the resectability rate has steadily increased since then, and the operative mortality has decreased.[1] At the present time, mortality rates appear to have reached a plateau at approximately 5 to 6 percent and are approximately equal for right-sided and left-sided resections.[2] Although it is not always easy to determine resectability rates from recent studies, the average is approximately 90 percent. When assessing reported results, it is important

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to consider potential sources of bias. Referral bias is usually assumed to affect studies from specialized centers. When operative mortality, complication, and resectability rates are examined in studies in which every patient operated on for colon cancer is included, the statistics have been somewhat different. There are probably differences in mortality rates and complication rates for palliative *vs.* potentially curative excisions.[3] Well-designed clinical trials have shown that postoperative morbidity rates after resection for colon cancer can be decreased substantially by several simple measures. Reduction in the rate of sepsis,[4] as an example, has been achieved by the use of systemic antibiotics[5] and mechanical bowel preparation.[6]

Historically, estimates of the risks of adverse outcomes have been based on univariate and bivariate analyses of possible risk factors such as type of procedure or principal diagnosis.[7, 8] Stratification of patients into groups with varying risks of complications based on comorbid conditions is an area of current research interest. Risk adjustment schemes such as The American Society of Anesthesiologists (ASA) Physical Status scale,[9] the Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity,[10] and the Admission Severity Group[11] are examples that have proved useful, but these will likely be superseded by more sophisticated models such as those derived from the National Veterans Affairs Surgical Quality Improvement Program (NSQIP).

Most studies involving outcome after potential curative resection for colon cancer have been retrospective analyses from highly specialized centers that often lack detailed information on how preoperative variables affected morbidity and mortality risks. NSQIP is a prospective registry of more than 415,000 major surgical operations. Each of these cases was selected according to defined criteria, assessed for 68 preoperative and 12 intraoperative variables predictive of complications and death, and monitored postoperatively for 30-day mortality and for 21 specific and well-defined adverse outcomes. These data are collected by trained personnel, usually nurses, and permit the construction of risk-prediction models using standard statistical techniques. We have previously reported results from this database involving the outcome of proctectomy for rectal cancer.[12] The present article deals with colectomy for colon cancer in Department of Veterans Affairs patients.

PATIENTS AND METHODS

Details of NSQIP have been described elsewhere.[13] It is an ongoing prospective observational study in which trained personnel based at 123 Veterans Affairs Medical Centers (VAMCs) collect preoperative, intraoperative, and postoperative data on patients undergoing noncardiac operations under general, spinal, and epidural anesthesia. In the VAMCs that perform fewer than 140 eligible surgical procedures each month, all operations are entered into the study. In those performing more than 140 eligible surgical procedures each month, the first 36 eligible operations are entered into the study in each consecutive eight-day period, beginning with a different day each period. Four of the 123 VAMCs use this sampling procedure because of the high volume of surgery in those institutions.

In the present study, all patients undergoing colectomy for colon cancer were selected from the NSQIP database for analysis. The *International Classification of Diseases, Ninth Revision, Clinical Modification* codes used to define colon cancer were 153.0 to 154.0 (malignant neoplasm of colon). The procedure codes to define colectomy included *Current Procedural Terminology* codes 44140 (colectomy, partial, with anastomosis), 44141 (colectomy, partial, with skin level cecostomy), 44143 (colectomy, partial, with end colostomy and closure of distal segment), 44144 (colectomy, partial, with colostomy and creation of mucous fistula), 44150 (colectomy, total abdominal, without proctectomy, with ileostomy or ileoproctostomy), and 44160 (colectomy with removal of terminal ileum and ileocolostomy). Vital status as of March 1997 was determined by matching Social Security numbers from the NSQIP Phase I (October 1, 1991, to December 31, 1993) and Phase II (January 1, 1994, to August 31, 1995) data sets with records in the Veterans Affairs Beneficiary Identification and Records Locator Subsystem. Stepwise logistic regression analysis was used to construct models predicting morbidity (defined as $\geq$1 complication) and 30-day mortality. Independent variables examined included 68 preoperative clinical parameters, including laboratory test values, and 12 intraoperative risk factors previously used by the NSQIP. The dependent variables were 21 specific operationally defined adverse outcomes and mortality (Table 1). Standard measures of logistic regression model fit such as the c index, Hosmer-Lemeshow goodness-of-fit test, and model chi-squared determination were calculated. In addition, R^2, the coefficient of determi-

Table 1.
Prevalence of Postoperative 30-Day Complications After Colectomy in Colon Cancer and Associated Mortality Rate, N = 5,853

Complication	No. of Patients	Incidence	30-Day Mortality Rate	
			With Complication	Without Complication
Coma >24 hours	39	0.7	79.5	5.6‡
Cardiac arrest requiring CPR	111	1.9	78.4	4.7‡
Graft prosthesis failure	6	0.1	66.7	6†
Acute renal failure	54	0.9	59.3	5.6‡
Pulmonary embolism	19	0.3	57.9	5.9‡
Progressive renal insufficiency	83	1.4	50.6	5.4‡
Systemic sepsis	216	3.7	40.3	4.7‡
Unplanned intubation	223	3.8	38.1	4.8‡
Failure to wean after 48 hours	334	5.7	37.1	4.2‡
Myocardial infarction	56	1	35.7	5.8‡
Bleeding/transfusion >4 units	206	3.5	33.5	5.1‡
Pulmonary edema	170	2.9	28.2	5.4‡
Major neurological deficits	26	0.4	26.9	6†
Pneumonia	364	6.2	25.3	4.8‡
CNS cerebrovascular accident	27	0.5	22.2	6†
Wound dehiscence	157	2.7	14	5.8†
Deep wound infection	202	3.5	12.4	5.8†
Deep venous thrombosis or thrombophlebitis	36	0.6	11.1	6
Prolonged ileus	439	7.5	8.7	5.8*
Urinary tract infection	292	5	8.6	5.9
Superficial wound infection	220	3.8	5.9	6.1

CPR = cardiopulmonary resuscitation; CNS = central nervous system.
Figures are percentages unless otherwise specified.
* = $P < 0.05$.
† = $P < 0.001$.
‡ = $P < 0.0001$.

nation, was calculated for each model to allow estimation of the proportion of variation in the dependent variable explained by the model.[14]

R^2, the coefficient of determination (also called the multiple correlation coefficient), is a measure of the amount of variation in the dependent variable explained by the independent variables. It is a measure of the success of predicting the dependent variable from the independent variables. Nagelkerke's maximum rescaled R^2 is a modification of R^2 to adapt it for use in discrete models, *i.e.*, models whose likelihood is a product of probabilities. In such models, R^2 achieves a maximum of less than one, even when all of the variation in the dependent variable is explained by the independent variables. Thus, it is necessary to rescale R^2 to account for the maximum value possible ($R^2/\max R^2$).[14] The c-index of 0.85 for the mortality model represents the proportion of paired observations with predicted probabilities of events where the observation with the lower probability did not have an event. In this way, the c-index is a measure of the effectiveness of the model in discriminating between those observations with an event and those without an event. The Hosmer-Lemeshow statistic was another measurement of the goodness of fit of the models. For both the mortality and the morbidity models, the test was not significant, which indicated that the models were good fits.

The 80 variables considered for the logistic regression models were screened univariately with a *t*-test for the continuous variables and a chi-squared test for the categorical variables. Those with a P value less than 0.2 were then entered into a stepwise logistic regression procedure where multivariate screening was done in which the most significant variable was entered into the model and then the other variables were screened for entry with and without the first variable. This procedure was then repeated with the other variables. In this way, multivariate screening was done to see which variables were to be included with which other variables. In the morbidity model, there were 16 variables in the final model with 303 events, a ratio of 18.9, which was within the 10 guideline. In the final morbidity model, there were 17 variables with 1,602 events in the final model, a ratio of 94.5, which was in excess of 20 for all 80 variables that were originally considered.

RESULTS

Demographics

A total of 5,853 patients who underwent colectomy for colon cancer were identified from Phase I and II NSQIP data, representing approximately 2 percent of all patients in the NSQIP database. The median age was 68 (range, 19–100) years; 5,759 (98 percent) were males.

Patient Preoperative Risk Factors

Of the 5,853 patients, 1,756 (30 percent) were smokers, 831 (14 percent) drank more than two alcoholic drinks per day, 82 (1.4 percent) were drug addicts, 936 (16 percent) were diabetic using insulin or oral hypoglycemic agents, 995 (17 percent) had chronic obstructive pulmonary disease, 351 (6 percent) had a history of angina, 293 (5 percent) had a history of congestive heart failure, 2,458 (42 percent) had hypertension requiring medication, and 147 (2.5 percent) had a history of transient cerebrovascular ischemic attacks. Of the 5,853 patients, 230 (4 percent) were chronic steroid users, 127 (2 percent) had a chronic bleeding disorder, 201 (3 percent) had more than 4 units of packed red blood cells transfused before surgery, and 823 (14 percent) had sustained a weight loss of >10 percent of body weight in the six months before surgery.

Patient Preoperative Laboratory Tests

Several preoperative laboratory values are of interest. The median serum albumin concentration was 3.7 g/dl (range, 1.0–5.6; n = 4,991), the median serum alkaline phosphatase concentration was 86 U/l (range, 14–984; n = 5,120), the median serum total bilirubin concentration was 0.6 mg/dl (range, 0.2–30.3; n = 5,274), the median serum urea nitrogen (BUN) level was 13 mg/dl (range, 1–158; n = 5,714), the median serum creatinine concentration was 1.1 mg/dl (range, 0.2–25.5; n = 5,773), and the median serum glutamic-oxaloacetic transaminase level was 23 u/l (range, 0–3,888; n = 4,983). When laboratory values were categorized into normal and abnormal values, the following were observed for the 5,853 patients: 908 (16 percent) had serum sodium concentration ≤135 meq/l, 148 (2.5 percent) had serum sodium concentration >145 meq/l, 554 (9.5 percent) had serum potassium concentration ≤3.5 meq/l, 213 (3.6 percent) had serum potassium concentration >5 meq/l, 241 (4.1 percent) had serum glucose concentration ≤70 mg/dl, 2,106 (36 percent) had serum glucose concentration >120 mg/dl, 428 (7.3 percent) had a serum white blood count concentration ≤4,500 cells/mm^3, 1,006 (17.2 percent) had a serum white blood cell count >11,000 cells/mm^3, 2,950 (50.4 percent) had serum hematocrit ≤38 percent, 738 (12.6 percent) had serum hematocrit >45 percent, 485 (8.3 percent) had serum platelet count ≤150,000 platelets/mm^3, and 809 (13.8 percent) had a serum platelet count >400,000 platelets/mm^3.

Operative Variables

Of the 5,853 patients, 4,975 (85 percent) underwent elective surgery, 5,677 (97 percent) had general anesthesia, and 5,736 (98 percent) of the operations were performed by a general surgeon. Operative time ranged from 0.3 to 19.7 (median, 3.0) hours. Of the 5,853 patients, 4,975 (85 percent) did not require an intraoperative blood transfusion, 702 (12 percent) had 1 to 2 units of blood transfused, 117 (2 percent) had 3 to 4 units of blood transfused, and 59 (1 percent) required 5 or more units of blood.

Outcomes

The 30-day in-hospital mortality rate was 5.7 percent (335/5,853). Twenty-eight percent (1,642/5,853) of patients had one or more complications after colectomy. Incidence rates for each complication are depicted in Table 1 along with the associated 30-day mortality rate for patients with and without the complication. Prolonged ileus, pneumonia, and failure to wean were the most frequently reported complications (7.5, 6.2, and 5.7 percent, respectively). For all complications except superficial wound infection, urinary tract infection and deep venous thrombosis/thrombophlebitis, 30-day in-hospital mortality rates were significantly higher for patients with the complication than for those without. Thirty-day mortality rates were highest for coma >24 hours (79.5 percent), cardiac arrest requiring cardiopulmonary resuscitation (78.4 percent), graft prosthesis failure (66.7 percent), acute renal failure (59.3 percent), pulmonary embolism (57.9 percent), and progressive renal insufficiency (50.6 percent).

Logistic Regression Models

Sixteen factors were predictive of 30-day mortality in the logistic regression analysis (Table 2). The odds of death within 30 days were 4.7 times greater for patients whose ASA classification was a IV (threat to life) or V (moribund) than for patients whose ASA classification was I (healthy patient) or II (no functional limitations). In addition, those patients whose ASA classification was III (functional limitations) were 2.2 times more likely to die within 30 days than patients whose ASA classification was I or II. The odds of death within 30 days were increased by a factor of 3.2 for patients with ascites, 2.6 for patients with sodium >145 meq/l, 2.3 for patients with "do not resuscitate" (DNR) status before surgery, 2.1 for patients with platelets ≤150,000 platelets/mm^3, 2.1 for patients with potassium ≤3.5 meq/l, 2 for patients with sodium ≤135 meq/l, 1.9 for patients using steroids for chronic conditions, 1.9 for patients with residual neurologic deficits resulting from prior cerebrovascular accident, 1.8 for patients with disseminated cancer, and 1.7 for patients with impaired sensorium. With the exception of preoperative serum albumin, all independent variables in the final model displayed odds ratios above 1.0. Although the odds ratio is less than 1 for preoperative albumin, this does not indicate that it has low predictive ability. As indicated by the P value (0.0001), it is of high predictive ability. For each gram per deciliter increase in preoperative serum albumin, the odds of death decrease by 0.50. This is the equivalent of the following statement: for each gram per deciliter decrease in preoperative serum albumin, the odds of death increase by a factor of 2. At first glance, age also appears not to predict a high risk of 30-day mortality (odds ratio = 1.032), although the P value suggests otherwise (0.0001). This is most likely because of the coding of the variable. The effect on 30-day mortality of age is measured in one-year intervals. An increase of one year in age is unlikely to have a large impact on mortality. However, an increase of ten years, for example, would be expected to produce a much greater effect. The model predicted quite well (c = 0.85; maximum rescaled R^2 = 36.5) with no gross lack of fit (Table 2).

Of the factors predictive of 30-day mortality, nine factors were also predictive of 30-day morbidity (one or more complications; Table 3): ASA classification III, ASA classification IV OR V, low preoperative serum albumin level, preoperative BUN, sodium ≤135

Table 2.
Independent Predictions of 30-Day Mortality Among Patients After Colectomy for Colon Cancer, N = 5,043

Variable	Parameter Estimate	P Value	Odds Ratio
ASA IV or V (threat to life or moribund)	1.5507	0.0001	4.715
Ascites (yes/no)	1.1726	0.0003	3.231
Preoperative sodium >145 meq/l	0.9603	0.0010	2.612
DNR status prior to surgery (yes/no)	0.8534	0.0015	2.348
ASA III (functional limits)	0.7981	0.0023	2.221
Preoperative potassium ≤3.5 meq/l	0.7391	0.0001	2.094
Preoperative platelets ≤150 (thous/mm^3)	0.7277	0.0001	2.07
Preoperative sodium ≤135 meq/l	0.6821	0.0001	1.978
Steroid use for chronic conditions (yes/no)	0.6402	0.0137	1.897
CVA with residual neurologic deficit (yes/no)	0.618	0.0024	1.885
Disseminated cancer (yes/no)	0.5868	0.0027	1.798
Impaired sensorium (yes/no)	0.5128	0.0108	1.67
Age at surgery (yr)	0.0318	0.0001	1.032
Preoperative BUN (mg/dl)	0.0205	0.0001	1.021
Preoperative alkaline phosphatase (u/l)	0.0033	0.0001	1.003
Preoperative serum albumin (g/dl)	−0.6467	0.0001	0.524
Intercept	−5.0451		

ASA = American Society of Anesthesiologists; DNR = do not resuscitate; CVA = cerebrovascular accident; BUN = serum urea nitrogen.

Model fit: Model chi-squared = 587.859 (P = 0.001); Hosmer-Lemeshow Goodness of Fit = 8.336 (P = 0.4016); c index = 0.848; Cox & Snell's R^2 = 11.00; Nagelkerke's maximum resealed R^2 = 36.52.

Table 3.
Independent Predictors of Postoperative 30-Day Morbidity* in Patients After Colectomy for Colon Cancer, N = 5,692

Variables	Parameter Estimate	*P* Value	Odds Ratio
Preoperative pneumonia (yes/no)	0.9328	0.0002	2.542
ASA IV or V (threat to life or moribund)	0.9235	0.0001	2.518
Totally dependent functional status (yes/no)	0.7078	0.0001	2.029
ASA III (functional limits)	0.4721	0.0001	1.603
Sodium >145 meq/l	0.4306	0.0234	1.538
Open wound/infection (yes/no)	0.4108	0.0057	1.508
WBC >11 (thousand/mm^3)	0.3117	0.0002	1.366
Platelets ≤150 (thousand/mm^3)	0.3016	0.0059	1.352
CVA with neurologic deficit (yes/no)	0.3004	0.0148	1.35
Partially dependent functional status (yes/no)	0.2748	0.0045	1.316
Hx of COPD (yes/no)	0.2697	0.0009	1.31
Sodium ≤135 meq/l	0.2482	0.0038	1.282
PT >12 seconds	0.1882	0.0032	1.207
Preoperative BUN (mg/dl)	0.0145	0.0001	1.015
Age at surgery (yr)	0.0086	0.0103	1.009
Preoperative albumin (g/dl)	−0.2099	0.0001	0.811
DNR status prior to surgery (yes/no)	−0.3368	0.1068	0.714
Intercept	−1.7883		

ASA = American Society of Anesthesiologists; WBC = white blood cell count; CVA = cerebrovascular accident; Hx = history; COPD = chronic obstructive pulmonary disease; PT = prothrombin time; BUN = serum urea nitrogen; DNR = do not resuscitate.

Model fit: Model chi-squared = 582.485 (P = 0.0001); Hosmer-Lemeshow Goodness of Fit = 12.21 (P = 0.1421); c index = 0.684; Cox & Snell's R^2 = 9.73; Nagelkerke's maximum rescaled R^2 = 13.99.

* 30-day morbidity = 1 or more complications.

meq/l, platelets ≤150,000 platelets/mm^3, age at surgery, sodium >145 meq/l, and residual neurologic deficits resulting from prior cerebrovascular accident. Seven additional factors were predictive of 30-day morbidity only. The odds of a postoperative complication were increased by a factor of 2.5 for patients with preoperative pneumonia, 2.5 for patients whose ASA classification was IV OR V, 2 for patients with totally dependent functional status, 1.6 for patients whose ASA classification was III, 1.5 for patients with sodium >145 meq/l, and 1.5 for patients with open wound infection. As in the analysis of 30-day mortality, almost all of the abnormal preoperative laboratory values in the final model were positively associated with 30-day morbidity, with the exception of preoperative albumin. The 30-day morbidity model predicted less well (c = 0.68; maximum rescaled R^2 = 14.0) than the mortality model because of the aggregation of all complications, the predictors of which may vary widely.

Separate logistic regression models were then run for each of the top ten complications. Fourteen variables were predictive in more than two models. Age at surgery, the ASA classification of III, the ASA classification of IV OR V, and preoperative serum albumin were each predictive in six models. A white blood cell count of >11,000 cells/mm^3, partially dependent functional status, and totally dependent functional status were each predictive in five models. A platelet count of ≤150,000 platelets/mm^3 and potassium ≤3.5 meq/l were each also predictive in four models. Variables predictive in three models were prothrombin time >12 seconds, weight loss >10 percent of body weight, preoperative pneumonia, preoperative BUN, and steroid use for chronic conditions. The average c-index across the ten logistic regressions of complications was 0.704, and the average maximum rescaled R^2 was 9.9. The five complications that were at or above this average fit are discussed below.

The predictors of pneumonia were preoperative BUN, the ASA classification of III, the ASA classification of IV OR V, preoperative serum albumin, partially dependent functional status, totally dependent functional status, steroid use for chronic conditions, potassium ≤3.5 meq/l, white blood cell count >11,000 cells/mm^3, age at surgery, and whether the patient was a current cigarette smoker. Surprisingly, history of chronic obstructive pulmonary disease was not predictive of pneumonia. The odds of pneumonia were increased by a factor of 3.6 for patients whose ASA classification was IV OR V, 2.5 for patients with totally dependent functional status, 2.5 for patients whose ASA classification was III, 2.3 for patients using steroids for chronic conditions, 1.7 for patients with partially dependent functional status, and 1.5 for patients with potassium ≤3.5 meq/l. Low preoperative serum albumin was positively associated with postoperative pneumonia. The model predicted reasonably well (c = 0.75; maximum rescaled R^2 = 12.4) with no gross lack of fit.

Eighteen variables were identified as significant predictors of failure to wean. Of all the logistic regression models predicting complications, explained variation was highest for failure to wean (c = 0.846; maximum rescaled R^2 = 28.11). The odds of failure to wean were increased by a factor of 6.1 for patients whose ASA classification was IV OR V. No other predictor affected the odds of failure to wean to the same degree. The odds of failure to wean were increased by a factor of 3 for patients who were ventilator dependent preoperatively, 2.7 for patients whose ASA classification was III, 2.6 for patients with totally dependent functional status, 2.2 for patients with preoperative pneumonia, 2 for patients with ascites, 1.9 for patients with partially dependent functional status, 1.9 for patients with ≤150,000 platelets/mm^3, 1.8 for patients with a history of chronic obstructive pulmonary disease, 1.6 for patients with a history of chronic obstructive pulmonary disease, 1.6 for patients with white blood cell count ≤4,500 cells/mm^3, and 1.6 for patients with white blood cell count >11,000 cells/mm^3. Hematocrit ≤38 percent, disseminated cancer, and low preoperative serum albumin were associated with a higher failure to wean.

Significant predictors of bleeding and need for transfusion were ≤150,000 platelets/mm^3, the ASA classification of III, the ASA classification of IV OR V, age at surgery, totally dependent functional status, steroid use for chronic conditions, weight loss >10 percent of body weight, potassium ≤3.5 meq/l, transfusions >4 units packed red blood cells/whole blood preoperatively, and white blood cell count >11,000 cells/mm^3. The odds of bleeding and need for transfusion were increased by a factor of 4.8 for patients whose ASA classification was IV OR V, 2.8 for patients transfused with >4 units of packed red blood cells/whole blood preoperatively, 2.5 for patients with ≤ 150,000 platelets/mm^3, 2.2 for patients with totally dependent functional status, 2 for patients with white blood cell count >11,000 cells/mm^3, 2 for patients using steroids for chronic conditions, 2 for patients whose ASA classification was III, 2 for patients with weight loss >10 percent of body weight, and 1.5 for patients with potassium ≤3.5 meq/l. The model predicted reasonably well (c = 0.78; maximum rescaled R^2 = 16.1) with no gross lack of fit.

The predictors of systemic sepsis were the ASA classification III, the ASA classification IV OR V, potassium ≤3.5 meq/l, preoperative BUN, preoperative pneumonia, weight loss >10 percent of body weight, ≤150,000 platelets/mm^3, and preoperative serum albumin. The odds of systemic sepsis were increased by a factor of 3.3 for patients whose ASA classification was IV OR V, 2.4 for patients with preoperative pneumonia, 1.7 for patients with ≤150,000 platelets/mm^3, 1.6 for patients whose ASA classification was III, 1.6 for patients with potassium ≤ 3.5meq/l, and 1.5 for patients with weight loss >10 percent of body weight. Preoperative serum albumin was negatively associated with systemic sepsis. The model predicted reasonably well (c = 0.74; maximum rescaled R^2 = 11.4) with no gross lack of fit.

The predictors of unplanned intubation were age at surgery, ≤150,000 platelets/mm^3, potassium ≤3.5 meq/l, sodium ≤135 meq/l, active hepatitis, preoperative pneumonia, steroid use for chronic conditions, partially dependent functional status, totally dependent functional status, and preoperative serum albumin. The odds of unplanned intubation were increased by a factor of 5.4 for patients with active hepatitis, 2.9 for patients with preoperative pneumonia, 2.3 for patients with totally dependent functional status, 2.1 for patients using steroids for chronic conditions, 1.8 for patients with ≤150,000 platelets/mm^3, 1.8 for patients with partially dependent functional status, and 1.6 for patients with potassium ≤3.5 meq/l. Preoperative serum albumin was negatively associated with unplanned intubation. The model predicted reasonably well (c = 0.72; maximum rescaled R^2 = 9.2) with no gross lack of fit.

DISCUSSION

The operative morbidity and mortality rates for colectomy clearly depend on patient selection and underlying pathology. The main causes of death are myocardial infarction, bronchopneumonia, pulmonary embolism, anastomotic leakage, and cerebrovascular accident.[15] It is usually easy for a clinician to judge how sick patients are when they present for treatment, but this judgment is qualitative only. Identification of risk factors, linking risk factors to adverse outcomes, and assigning quantitative values to those factors has been surprisingly difficult.

Outcomes after colectomy for colon cancer have been extensively reported[16, 17] but are difficult to interpret because of weaknesses in study design. Operative mortality rates appear to have plateaued at 5 to 6 percent,[18–23] but these results have been achieved in specialized centers where emergency cases have often been excluded and indigent, poorly educated, and noncompliant patients are typically underrepresented. All of these sources of bias, and others as well, affect traditional first-generation analyses of risk. In an effort to adjust expected outcomes after major surgery at Department of Veterans Affairs hospitals for how sick patients are before surgery, the NSQIP has been able to successfully stratify risk because of the meticulous design.[24]

The mortality rate after resection of colorectal carcinoma ranges from 1 to 6 percent in many retrospective analyses, which also suggest that other factors such as whether the operation is elective or emergent, the patient's age, and pre-existing comorbid conditions also affect risk. The experience of the operating surgeon has also been correlated with patient mortality rates. Of interest is the recent article comparing operative mortality rates of board certified colorectal surgeons and other institutional general surgeons who performed 2,805 colorectal operations for both benign and malignant disease from 1989 to 1994.[25] The overall mortality rate in 1,565 cases performed by colorectal surgeons was 1.4 percent in contrast to the 7.3 percent mortality rate among other surgeons, which was also comparatively lower as patient severity of illness increased. Further auditing of databases will need to be conducted before any widespread conclusions can be drawn about whether subspecialty training affects outcome. The relationship between hospital surgical volume and operative mortality has remained a debated issue. A recent cohort study from the Department of Veterans Affairs reported that, among several operations (colectomy for cancer, colectomy without cancer, amputation above the knee, coronary artery bypass grafting for old myocardial infarction, and open heart valvuloplasty), only the last demonstrated a significant inverse relationship between hospital surgical volume and operative mortality rate.[26]

One previous retrospective study reported a multifactorial index of preoperative risk factors in colon resections. Among 972 resections performed on 825 patients using 17 preoperative risk factors generated from various medical risk categories, 11 of the 17 risk factors were significant in predicting outcomes. These included emergent operation, age ≥75 years, congestive heart failure, prior abdominal or pelvic radiation therapy, corticosteroid use, albumin <2.7 g/dl, chronic obstructive pulmonary disease, previous myocardial infarction, diabetes, cirrhosis, and renal insufficiency.[27]

One aim of the NSQIP is the development and validation of models that can predict morbidity and mortality for individual patients. Because there are frequent incremental advancements in surgical technique and patient care, it is quite important that risk modeling be done on large recent patient populations. Here lies a great strength of NSQIP data: it is a current, constantly enlarging database that will allow future analyses to focus ever more sharply on details of risk modeling with increasing statistical power. The strength of the NSQIP database resides in its meticulous design. Information is gathered from a national patient population, and analysis of data is performed with statistical sophistication. Furthermore, because the majority of surgical operations performed today have low postoperative mortality rates, outcome measures other than risk-adjusted mortality rate will need to be developed to enable the comparative assessment of quality of care among individual surgeons operating at specific institutions.

Using NSQIP data, we have clearly demonstrated that morbidity and mortality rates for patients undergoing colectomy for colon cancer in VAMCs are well within the range seen in non–Veterans Affairs institutions.[19–23] The validity of most of the putative risk factors incorporated in NSQIP study design have been confirmed. Six factors appear to predict a high risk of 30-day mortality: ASA classification III and IV OR V, serum sodium >145 meq/l, DNR status before surgery, ascites, and low serum albumin. The death rate is also very high for patients who develop postoperative graft prosthesis failure, coma >24 hours, cardiac arrest, postoperative acute renal failure, cerebral vascular accident, or pulmonary embolism. The large sample size permits a good estimation of the actual risk of adverse outcomes. As the NSQIP database grows, its statistical power will increase. Even with the current model, hypotheses regarding risk can now be generated. These can be tested in other patient populations and other medical care systems to prove or refute the conclusions of the NSQIP analyses. Such evaluations will increase the generalizability of conclusions.

The results of this study demonstrate that the complication rate after colectomy is quite high. NSQIP data show that most complications are associated with increased 30-day mortality. As expected from first-generation analyses, perioperative cardiac arrest, stroke, graft prosthesis failure, renal failure, and pulmonary embolism strongly predict perioperative death. The surgeon should be attentive to the fact that ASA classification III and IV OR V, serum sodium >145 meq/l, DNR status before surgery, ascites, and preoperative serum albumin predict a high risk of 30-day mortality and many specific complications. Conclusions that withstand the predictable future repeated analyses will certainly affect clinical practice and serve to generate intervention trials in which modification of certain risk factors will be attempted.

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