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Comparison of Common Risk Stratification Indices to Predict Outcomes among Stage IV Cancer Patients with Bowel Obstruction Undergoing Surgery

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Abstract

Background and Objectives—Among patients with disseminated malignancy (DMa), bowel obstruction is common with high operative morbidity. Since preoperative risk stratification is critical, we sought to compare three standard risk indices, the American Society of Anesthesiology (ASA) classification, Charlson comorbidity index (CCI), and modified frailty index (mFI).

Methods—We identified 1,928 DMa patients with bowel obstruction who underwent an abdominal operation from 2007–2012 American College of Surgeons National Surgical Quality Improvement Program. Multivariate analyses assessed predictors of prolonged length of stay (LOS), 30-day serious morbidity and mortality. Receiver operating characteristics' areas under the curves (AUCs) for risk indices scores and 30-day mortality were assessed.

Results—Serious morbidity and mortality rates were 20.4% and 14.8%. ASA and CCI did not predict serious morbidity or prolonged LOS, but were predictors of mortality. The mFI did not predict prolonged LOS, but did predict serious morbidity and mortality. Subgroup analyses showed similar results. There were no significant differences between ASA, CCI, and mFI AUCs for mortality.

Conclusions—ASA, CCI and mFI are limited in their ability to predict postoperative adverse events among DMa patients undergoing surgery for bowel obstruction. These data suggest that a more tailored preoperative risk stratification tool would improve treatment planning.

Keywords

Disseminated Malignancy; Malignant Bowel Obstruction; NSQIP; Risk Stratification; Palliative Surgery

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Introduction

Malignant bowel obstruction is common among patients with advanced malignancy with incidence rates of 28–51% for gastrointestinal and gynecological cancers.[1] This condition may signify a terminal event with an associated median life expectancy of four months.[2] Therefore, goals of care for this high-risk population are palliative requiring careful consideration of patient quality of life through either medical or surgical treatment approaches. Despite the potential palliative benefits of surgery for patients with malignant bowel obstruction, surgery is associated with rates of serious complications as high as 44%.[1] Furthermore, these patients are at risk for prolonged hospitalization which may consume a considerable percentage of their limited life expectancy. Therefore, careful surgical risk stratification is essential for informed consent prior to proceeding with surgical intervention.

Traditional methods of operative risk stratification include the American Society of Anesthesiologist (ASA) physical status classification and the Charlson comorbidity index (CCI).[3–5] In addition, a growing body of research has demonstrated the use of measures of frailty, including the modified frailty index (mFI), to predict postoperative morbidity and mortality for numerous surgical interventions including pancreatectomy, hepatectomy, and colorectal surgery.[6–8] Frailty is defined as decreased physiologic reserve and, therefore, increased vulnerability to disability due to inability to withstand stressors.[9] The mFI was developed specifically to measure frailty using the American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) dataset and consists of eleven variables measuring frailty based on the Canadian Study on Health and Aging (CSHA).[6,10] Limited data are available evaluating the performance of the ASA classification, the CCI, and the mFI to predict postoperative outcomes among advanced cancer patients undergoing surgical intervention, particularly patients with malignant bowel obstruction.

Our objective was to compare the ASA classification, CCI, and mFI as independent predictors for postoperative outcomes among disseminated malignancy (DMa) patients undergoing surgical intervention for bowel obstruction. We were specifically interested in the ability of these measures to predict serious complications, prolonged length of stay (LOS), and 30-day mortality, as such outcomes have the potential to significantly impact terminal cancer patients' remaining quality and quantity of life. We hypothesized that higher ASA, CCI and mFI scores would be associated with greater rates of serious morbidity, prolonged LOS, and 30-day mortality.

Methods

The ACS-NSQIP database was queried from January 1, 2007 to December 31, 2012. ACS-NSQIP is a national registry consisting of prospectively collected data on surgical patients from 603 NSQIP-affiliated hospitals shown to have high-reliability reporting and data quality.[11] We did not include data after 2012 due to missing data for multiple variables which are key components of the mFI and CCI. Patients were selected based on the following three inclusion criteria: (1) principal diagnosis of bowel obstruction based on International Classification of Diseases, 9th Revision (ICD-9) codes (560.0–560.9 and 537.3), (2) diagnosis of DMa based on ACS-NSQIP definition, [12] and (3) a principal

abdominal operation based on Current Procedural Terminology (CPT) codes. ACS-NSQIP defines DMa as “cancer that: (1) has spread to one or more sites in addition to the primary site and (2)” the presence of such “indicates the cancer is widespread, fulminant, or near terminal.”[12] Patients who underwent a hernia repair or pancreatic, hepatobiliary, or gynecological operation were excluded. We identified 1,928 patients who met these specific inclusion and exclusion criteria, and we abstracted 29 patient demographic, operative, and hospital stay characteristics along with perioperative outcomes for these patients.

Our main predictor variables were ASA classification, CCI, and mFI scores. ASA classification was abstracted directly from NSQIP as reported using a scale of 1 to 5.[12] Four patients were classified as ASA 1 (indicative of a normal healthy patient) and were combined with ASA 2 patients (indicative of mild systemic disease) for analysis.

The CCI was calculated based on the following ACS-NSQIP variables (with assigned point values) as described previously[13,14]: age (1 point for each decade ≥50 years), myocardial infarction (MI) within 6 months prior to surgery (1), congestive heart failure (CHF) (1), peripheral vascular disease (PVD) or rest pain (1), history of transient ischemic attack (TIA) or cerebrovascular accident (CVA) (1), chronic obstructive pulmonary disease (COPD) (1), diabetes mellitus (1), hemiplegia (2), end-stage renal disease (ESRD) (2), ascites or varices (2), and disseminated cancer (6). Previous research has shown that modified age-adjusted CCIs have equivalent prognostic value compared to the original CCI.[3,15] As all patients had DMa with a corresponding score of 6, no patient had a score <6, and CCI values for all patients ranged from 6 to 18. Patients with scores ≥12 were combined into one category to increase statistical power as few patients had scores in this range.

The mFI score was created using established methods.[6–8] Patients were assigned 1 point for each of the following 11 ACS-NSQIP variables: impaired functional status prior to surgery (partial or total dependence); diabetes; severe COPD or current pneumonia; hypertension requiring medication; CHF; MI within 6 months prior to surgery; percutaneous cardiac intervention, cardiac surgery or angina; PVD or rest pain; impaired sensorium; TIA or CVA without neurological deficit; and CVA with neurological deficit. The maximum score was 11. Although previous authors have divided the points for each patient by 11 to create a ratio, we chose to use whole numbers instead for simpler interpretation. For our cohort, mFI scores ranged from 0 to 9. Given that very few patients had mFI scores ≥ 6, we combined patients with scores ≥5 into one category for data analyses.

The primary outcomes of our analyses were 30-day serious morbidity, prolonged LOS and 30-day mortality. A secondary outcome was 30-day overall morbidity. Thirty-day serious morbidity was defined as sustaining at least one postoperative complication which required further invasive procedures (surgical, endoscopic or radiologic), led to lasting disability, and/or was life-threatening requiring lCU level care (i.e. Clavien III and IV complications).[16,17] Serious morbidity complications included pulmonary embolism, respiratory failure, prolonged intubation, acute renal failure requiring dialysis, reoperation, stroke, cardiac arrest and systemic shock, among others as previously described.[16,17] Prolonged LOS was defined as a length of hospitalization ≥75^{th} percentile for all patients in our cohort, which was ≥ 20 days.[16,18] Thirty-day mortality was defined relative to the principal operation.

All patient information was deidentified and, therefore, exempt from the University of California, Davis, Institutional Review Board approval.

Statistical Analysis

We performed univariate analysis utilizing Pearson's chi squared and Fisher's exact tests as appropriate. Predictors selected for multivariate analyses were determined based on statistical significance in the univariate analysis in ≥1 of the primary outcomes and consisted of the following: age, body mass index (BMI), albumin, hematocrit, functional status, preoperative sepsis, and classification as an emergency operation. As age was a component of CCI and functional status was a component mFI, these variables were not included in each respective analyses. Three separate multivariate logistic regression models were employed for ASA classification, CCI and mFI to ensure independence of the predictors in each model as there was overlap of components in these three risk stratification methods. Receiver operator characteristics areas under the curves (AUCs) were calculated for ASA classification, CCI, and mFI and mortality. The DeLong method was used to compare AUCs between these three methods. Due to the heterogeneity of procedures performed in this patient population, we performed subgroup analyses using multivariate logistic regression models by procedure type (i.e. bowel resections, celiotomy/lyses of adhesions, gastrointestinal bypass and ostomy creation). P values of < 0.05 were considered statistically significant and all tests were two-tailed. Statistical analysis was performed using SAS version 9.4 (SAS Institute Inc).

Results

Patient Demographic, Preoperative, and Operative Characteristics

We identified 1,928 patients with DMa who underwent an abdominal operation with a principal diagnosis of bowel obstruction. Patient demographic, preoperative, and operative characteristics are presented in Table 1. Fifty-five percent (n=1,063) were female with a mean age of 63 ±13 years. Few had impaired functional status preoperatively (21.0%, n=404). Rates of emergency operations were 34.7% (n=668). Few (n=99, 6.5%) had received radiotherapy within 90 days and 34.9% (n=534) had undergone preoperative chemotherapy within 30 days of surgery. The most common operations performed were celiotomy/lysis of adhesions (n=440, 22.8%), small bowel resections (n=420, 21.8%), and large bowel resections (n=388, 20.1%). The median LOS was 13 days (range 0–127 days). The distributions of risk stratification scores are shown in Table 2.

Prolonged Length of Stay, 30-Day Morbidity, and Mortality

Rates of 30-day overall morbidity, serious morbidity and mortality were 35.8%, 20.4%, and 14.8%, respectively. Figures 1–3 illustrate rates of prolonged LOS, 30-day serious morbidity and 30-day mortality by ASA classification, CCI, and mFI scores. ASA classification was not a predictor of prolonged LOS, 30-day serious or overall morbidity ($p>0.05$). However, as shown in Table 3, ASA classification was a predictor of mortality (ASA 4 OR 2.54, 95%CI 1.27–5.07, p=0.008 and ASA 5 OR 4.99, 95%CI 1.20–20.73, p=0.03).

CCI scores were not predictors of 30-day overall or serious morbidity (p>0.05). Additionally, as illustrated in Figure 1, there was no significant trend demonstrating increasing rates of prolonged LOS with increasing CCI scores. Surprisingly, there was a decreased risk of prolonged LOS with a CCI score of 11 compared to a score of 6 (OR 0.43, 95%CI 0.23–0.81, p=0.0009). CCI scores predicted 30-day mortality in a limited capacity. Specifically, patients with a score of ≥12 had an increased risk of 30-day mortality (OR 2.18, 95%CI 1.09–4.36, p=0.03) compared to patients with a score of 6 (Figure 3, Table 3).

Similar to ASA and CCI, the mFI was not a significant predictor of prolonged LOS (p>0.05). Additionally, only select mFI scores were predictors of 30-day overall and serious morbidity. Specifically, patients with scores of 1 or 4 had increased risk of overall morbidity compared to non-frail patients with an mFI of 0 (OR 1.45, 95%CI 1.09–1.93, p=0.01 and OR 2.73, 95%CI 1.26–5.89, p=0.01 respectively). Furthermore, as shown in Figure 2, only patients with a score of ≥5 had an increased risk of serious morbidity compared to non-frail patients (OR 3.75, 95%CI 1.22–11.49, p=0.02). Despite these limitations, as shown in Table 3, mFI scores ≥1 were consistently predictive of 30-day mortality.

Figure 4 illustrates of the receiver operator curves for ASA classification, CCI and mFI and 30-day mortality. The AUC for ASA classification and mortality was 0.62 (95%CI 0.59–0.66), for CCI was 0.64 (95%CI 0.60–0.68), and for mFI was 0.65 (95%CI 0.62–0.69). There were no differences in AUCs for mortality between all 3 risk stratification methods (p>0.05 all).

Analyses of the individual components of the CCI and mFI to predict our primary outcome measures are presented in Table 4. While none of the individual components of the CCI predicted prolonged LOS (p>0.05), impaired functional status and hypertension, two components of mFI components, had an increased risk in prolonged LOS (OR 1.49, 95%CI 1.16–1.92, p=0.002 and OR 1.50, 95%CI 1.12–1.99, p=0.006). Similarly, impaired functional status and CHF were significant predictors of serious morbidity (OR 1.45, 95%CI 1.11–1.89, p=0.007 and OR 3.13, 95%CI 1.05–9.33, p=0.04), Multiple components of the mFI and CCI were predictive of 30-day mortality including impaired functional status, impaired sensorium, ascites/esophageal varices, CHF, TIA and CVA without deficits (p<0.05).

Importantly, multivariate analyses did show that albumin and preoperative functional status were consistent predictors of prolonged LOS, 30-day overall and serious morbidity and 30-day mortality in our analyses of ASA classification and CCI (p<0.05). For example, in our analysis of ASA classification, partially dependent functional status had a 1.40 odds (95%CI 1.08–1.83, p=0.01) of 30-day overall morbidity, 1.56 odds (95%CI 1.17–2.07, p=0.002) of prolonged LOS, and 1.68 odds (95%CI 1.20–2.36, p=0.003) of 30-day mortality compared to patients with normal functional status. Furthermore, total dependent functional status had a 1.87 odds (95%CI 1.05–3.34, p=0.04) of 30-day morbidity, 2.97 odds (95%CI 1.64–5.39, p=0.0003) of 30-day serious morbidity, 2.17 odds (95%CI 1.18–3.99, p=0.01) of prolonged LOS, and 3.66 odds (95%CI 1.96–6.86, p<0.0001) of 30-day mortality.

Risk Stratification by Operation Type

Table 5 describes risk stratification scores and patient outcomes by surgical procedure performed. There were no significant differences in ASA, CCI or mFI score distributions by operation type, specifically for bowel resections, celiotomy/lysis of adhesions, gastrointestinal (GI bypass), and ostomy creation ($p>0.05$ all). Thirty-day overall and serious morbidity was greatest for bowel resections (n=356, 43.4% and n=219, 26.7%) compared to celitiomies/lyses of adhesions (n=143, 32.5% and n=78, 17.7%), GI bypasses (n=81, 36.3% and n=38, 17.0%) and ostomy creations (n=71, 23.6% and n=39, 12.5%; $p<0.0001$ both). Rates of prolonged LOS were greatest for GI bypasses (n=67, 30.2%), followed by bowel resections (n=227, 27.7%), celiotomies/lyses of adhesions (n=99, 22.6%) and ostomy creations (n=58, 18.6%). There was no difference in rates of mortality by operation type ($p=0.14$).

Multivariate analyses evaluating ASA, CCI, and mFI scores as predictors of our primary outcomes by operation type showed minimal and inconsistent predictive ability of risk stratification scores for all indices. For example, ASA scores were not predictive of serious morbidity, prolonged LOS, or 30-day mortality ($p>0.05$) with one exception. For celiotomy/lysis of adhesion operations, ASA scores of 4 were predictive of 30-day mortality (OR 8.55, 95%CI 1.04–69.93, $p=0.045$). CCI scores were also not predictive of all three primary outcomes as well ($p>0.05$), except patients who underwent bowel resection and had a CCI score of 11 were less likely to experience prolonged LOS (OR 0.36, 95%CI 0.14–0.96, $p=0.04$). Furthermore, mFI scores were not significant predictors of prolonged LOS ($p>0.05$ all), only predictive of serious morbidity for celiotomy/lysis of adhesions surgeries with scores of 1 and ≥5 (OR 2.76, 95% CI 1.14–6.67, $p=0.02$ and OR 29.1, 95%CI 4.09–207.10, $p=0.0008$) and only predictive of 30-day mortality for bowel resections with a score of 3 (OR 2.91, 95%CI 1.19–7.09, $p=0.02$), for celiotomy/lysis of adhesions with a score 2 and ≥5 (OR 3.12, 95%CI 1.04–9.30, $p=0.04$ and OR 19.65, 95%CI 2.57–150.38, $p=0.004$) and for ostomy creation with a score of 2 and 3 (OR 4.98, 95%CI 1.44–17.24, $p=0.01$ and OR 9.13, 95%CI 2.17–38.42, $p=0.003$).

Discussion

In this analysis of DMa patients undergoing all surgical interventions for bowel obstruction, ASA classification, CCI and mFI were not consistent predictors of serious postoperative complications or prolonged LOS, but were significant predictors of 30-day mortality. These findings were also apparent in our subgroup analyses, in which ASA classification, CCI and mFI were inconsistent predictors of all primary endpoints when stratified by operation type. Overall, these findings were somewhat surprising, as all three risk stratification methods have previously been shown to reliably predict postoperative morbidity for various abdominal operations including colorectal surgery, pancreatic surgery, and hepatectomy.[4–8] Additionally, we observed limited ability of the CCI to predict 30-day mortality among DMa patients except for patients with scores ≥12 for all procedures, which is notable considering that the CCI was specifically created to predict mortality.[3]

Given these unexpected findings, questions arise as to (1) why were these risk stratification approaches inconsistent predictors of postoperative outcomes for DMa patients with bowel

obstruction and (2) what surgical risk stratification methods are available that we may use to appropriately determine operative risk for this high-risk population of DMa patients? Our findings may partially be explained by the ability of the individual components of the CCI and mFI to predict our outcomes of interest since only two of the eleven components of the mFI were individually predictive of prolonged LOS or serious morbidity, no individual component of the CCI predicted prolonged LOS, and only one component of the CCI predicted serious morbidity.

Additionally, the limitations inherent in these risk stratifications techniques may further explain the limited predictive ability of the mFI, CCI and ASA classification. For example, the mFI was modified to consist of 11 variables from the original 70-variable index created by the CSHA.[10] Some of the original CSHA variables not included in the mFI due to limitations in the data available from ACS-NSQIP are essential to a phenotypical model of frailty and are known predictors of postoperative morbidity and mortality including poor muscle tone, bradykinesia, falls, and malignancy. [10,16,19–21] Excluding these variables creates a measure of frailty that emphasizes patients' accumulation of deficits, rather than reduced physiologic reserve, similar to the ASA and CCI. It is likely that accumulated deficits have minimal impact on postoperative outcomes for advanced cancer patients, in contrast to measures of decreased physiological reserve including sarcopenia, hypoalbuminemia, and poor functional status.[22] This is evident in our findings that hypoalbuminemia and impaired functional status were consistent predictors of postoperative complications and mortality. Furthermore, limitations of the ASA classification revolve around the subjective nature of its assessment, as interrater reliability has been to be found to be fair to moderate.[23,24] Consequently, there is the potential for variability in ASA scoring to impact the prognostic effectiveness of this tool.

Moreover, the limited ability of these three risk stratification methods to predict postoperative adverse events may also be secondary to the baseline elevated perioperative risk which exists for DMa patients. DMa patients may be sufficiently "frail" by definition that standard risk stratification methods offer limited additional discrimination. In fact, patients with DMa are known to have higher rates of postoperative overall and serious morbidity, prolonged LOS and 30-day mortality compared to patients without DMa.[16] Additionally, DMa patients undergoing palliative surgery to treat malignant bowel obstructions have been shown to experience especially high rates of serious postoperative complications and 30-day mortality.[1] Therefore, the concomitant diagnoses of DMa and bowel obstruction may confer an elevated risk of postoperative complications that the additional effect of other medical comorbidities, which define the ASA, CCI and mFI , may be incremental and therefore difficult to discern.

Despite the limited ability of ASA classification, CCI and mFI scores to predict prolonged LOS or postoperative morbidity, it is important to note that these measures were predictors of 30-day postoperative mortality in our primary analyses.[6–8] As rates of 30-day postoperative mortality among DMa patients with bowel obstruction have been shown to be as high as 32%[1], these results are especially significant and provides some evidence supporting the use of the mFI and continued use of ASA classification to assess the individual mortality risk associated with surgery in this high-risk patient population.

Surgeons may use these risk stratification tools to aide in their perioperative decision-making and to provide patients and family members with an understanding of the likelihood of 30-day survival following surgery. Such information is valuable during preoperative discussions with patients and their families regarding goals and priorities of care. We continue to advise caution, however, as these measures showed low to moderate sensitivity and specificity with AUCs between 0.6 and 0.7. Additionally, in our subgroup analysis by operation type, ASA classification and the mFI were limited and inconsistent predictors of 30-day mortality.

Consistent with prior research, we found that impaired preoperative functional status and low albumin levels were consistent predictors for adverse post-surgical outcomes among DMa patients.[25,26] Such findings reinforce the prognostic information that these two variables provide, especially for determining operative risk in DMa patients with bowel obstruction.

The findings of this research illustrate the need for a more refined, tailored risk stratification tool for this at-risk patient population. Currently, the ACS-NSQIP surgical risk calculator may serve as a potential resource for this purpose. However, recent research investigating the reliability of the ACS-NSQIP calculator for palliative surgeries in cancer patients has noted various limitations.[27] For example, Rodriguez et al. compared palliative surgery outcomes among cancer patients at a single institution to ACS-NSQIP surgical risk calculator predicted outcomes and found that the ACS-NSQIP risk calculator underestimated hospital length of stay and overestimated the risk of complications. As our data and the Rodgriquez analysis demonstrates, DMa patients undergoing palliative surgical procedures consist of a unique patient population, and differences in patient demographics, frailty, and other undefined factors can significantly impact patient risk profiles and the predictive ability of various risk prediction models. Therefore, further research is needed to evaluate the accuracy of the ACS-NSQIP surgical risk calculator and other indices in DMa patients undergoing surgery for bowel obstruction.

This research was limited by inherent weaknesses of the ACS-NSQIP database. For example, we were unable to determine patients' primary cancer diagnoses or the etiology of the bowel obstruction. Due to limitations of the ICD-9 coding system, our patient sample consists of both small and large bowel obstructions and likely consists of patients with bowel obstructions secondary to both malignant and non-malignant etiologies. However, this limitation is common among studies utilizing large, national databases to evaluate malignant bowel obstruction.[2,28] In addition, we were not able to evaluate the effectiveness of individual operations in providing palliative benefit. Lastly, we were not able to compare outcomes among DMa patients with bowel obstruction who underwent medical management instead of surgery. Patients were likely selected for surgery for various reasons including obstruction severity, overall prognosis and beliefs about the patient's ability to withstand a surgical intervention. This is evident in the data as most of the patients had favorable frailty and ASA scores. These are important questions to address in future research.

In conclusion, ASA, CCI and mFI were inconsistent predictors of postoperative complications and prolonged LOS among DMa patients undergoing an abdominal operation

for bowel obstruction, but were predictors of 30-day mortality. In contrast to other disease settings, these risk stratification tools appear limited in their ability to predict the risk of postoperative non-mortality endpoints. More refined risk prediction techniques are needed to optimize patient counseling and surgical decision-making in this high-risk patient population.

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Synopsis

In a comparison of three common operative risk stratification indices, ASA, CCI and mFI were limited in their ability to predict postoperative adverse events among stage IV cancer patients undergoing surgery for bowel obstruction. These data suggest that a more tailored preoperative risk stratification tool would improve patient counseling and treatment planning for this at-risk population.

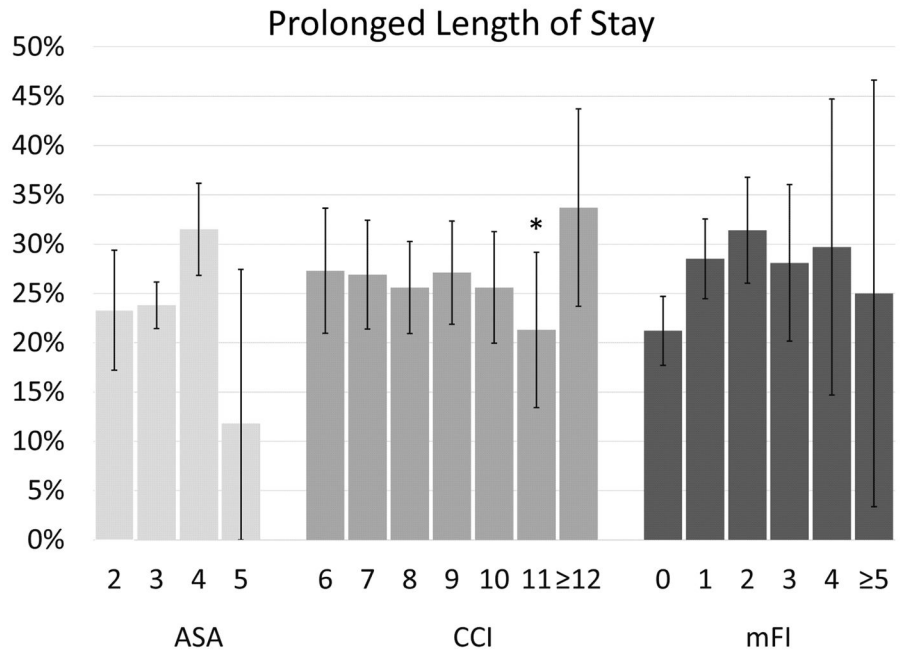

Figure 1.

Rates of prolonged length of stay (LOS) by American Society of Anesthesiologists (ASA) classification, Charlson comorbidity index (CCI) and modified frailty index (mFI). ASA classification and the mFI were not predictors of prolonged LOS on multivariate analyses. *CCI score of 11 had decreased risk of prolonged LOS compared to CCI score of 6 (p=0.009).

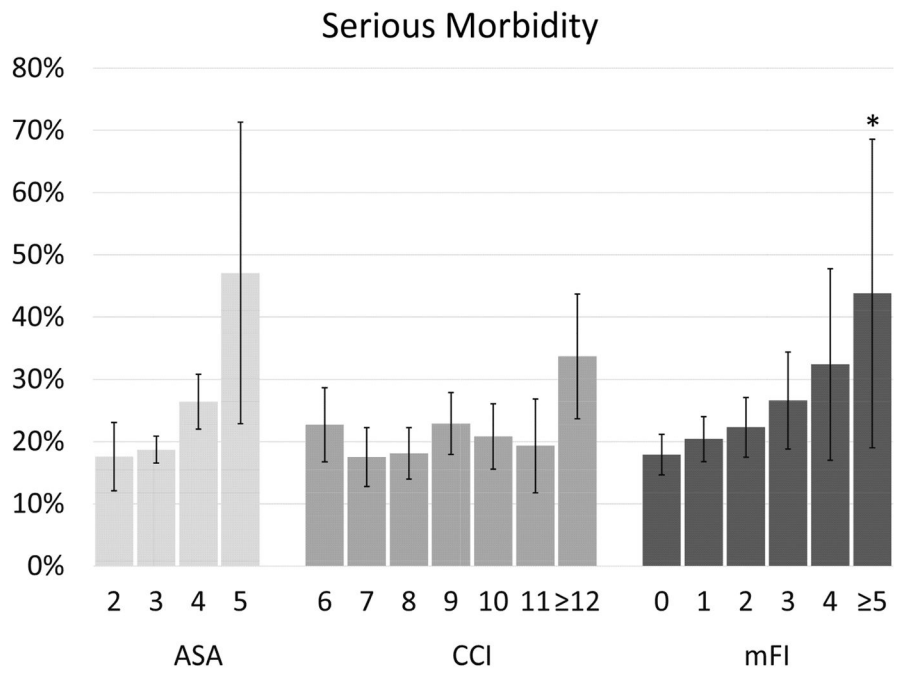

Figure 2.

Rates of 30-day serious morbidity by American Society of Anesthesiologists (ASA) classification, Charlson comorbidity index (CCI) and modified frailty index (mFI). ASA classification and the CCI were not predictors of serious morbidity on multivariate analyses. *Patients with an mFI score of ≥5 had a greater risk of serious morbidity compared to nonfrail patients (p=0.02).

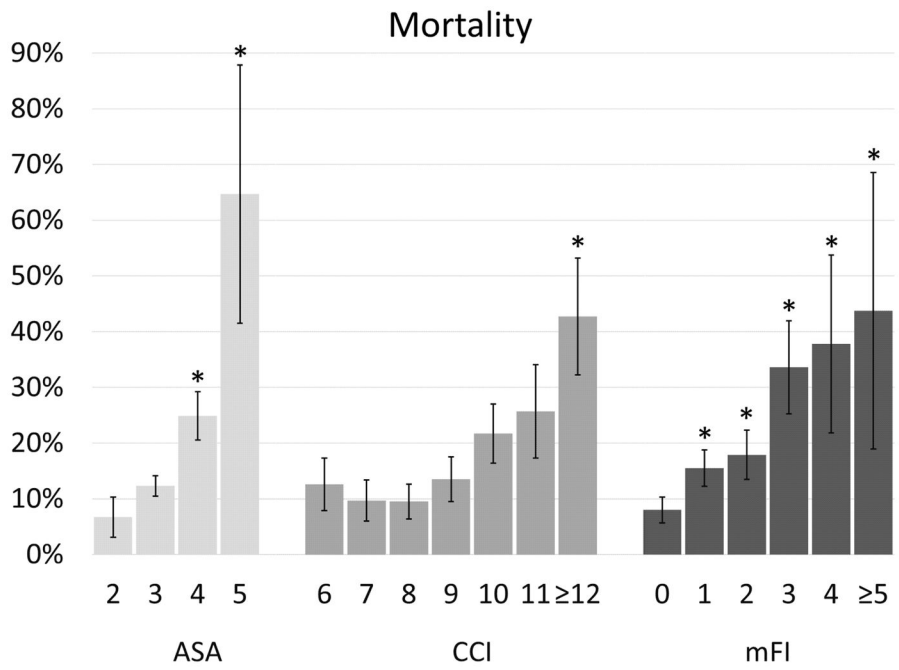

Figure 3.

Rates of 30-day mortality by American Society of Anesthesiologists (ASA) classification, Charlson comorbidity index (CCI) and modified frailty index (mFI). *ASA classification scores of ≥4 had greater risk of 30-day mortality compared to patients with an ASA score of 2; *CCI scores of ≥12 had a greater risk of 30-day mortality compared to patients with a CCI score of 6; and *mFI scores ≥1 had greater risk of 30-day mortality compared to nonfrail patients ($p<0.05$ all).

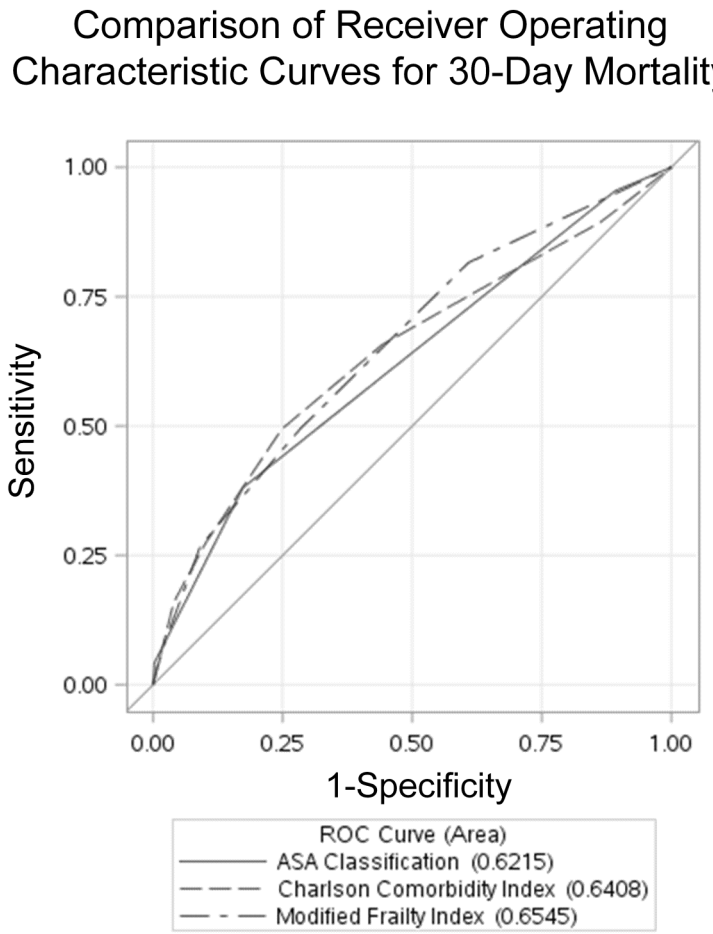

Figure 4.

Receiver operator characteristic (ROC) area under the curves (AUC) for American Society of Anesthesiologists (ASA) classification, Charlson comorbidity index (CCI) and the modified frailty index (mFI) and 30-day mortality. There were no significant differences in AUCs for 30-day mortality between all 3 risk stratification methods ($p>0.05$ all).

Table 1

Patient Demographic, Preoperative, and Operative Characteristics.

Variable	N or Mean (% or ±Standard Deviation) N = 1,928
Age	63.1 (±13.3)
Female	1063 (55.2%)
BMI	24.8 (±6.1)
Functional Status	
Normal	1516 (79.0%)
Partially Dependent	334 (17.4%)
Totally Dependent	70 (3.7%)
SIRS/Sepsis	
None	1453 (75.6%)
SIRS	341 (17.8%)
Sepsis	100 (5.2%)
Septic Shock	27 (1.4%)
Emergency Operation	668 (34.7%)
Albumin	3.1 (±0.7)
Hematocrit	33.2 (±5.3)
Preoperative Chemotherapy	534 (34.9%)
Preoperative Radiotherapy	99 (6.5%)
DNR	92 (6.0%)
Principal operation type	
Celiotomy/Lysis of adhesions	440 (22.8%)
Small bowel	
Resection	420 (21.8%)
Bypass	167 (8.7%)
Ostomy	83 (4.3%)
Large bowel	
Resection	388 (20.1%)
Ostomy	230 (11.9%)
Other small or large bowel	104 (5.4%)
Gastric	
Gastrostomy tube	10 (0.5%)
Bypass	56 (2.9%)
Other	7 (0.4%)
Other abdominal operation	23 (%)

BMI body mass index; SIRS Systemic Inflammatory Response Syndrome.

Table 2

Frequency of patient scores by risk stratification method.

Risk Stratification Method and Score	N (%)
ASA Classification	
2	292 (10.0%)
3	1320 (68.5%)
4	398 (20.7%)
5	17 (0.9%)
Charlson Comorbidity Index	
6	198 (13.0%)
7	257 (16.8%)
8	348 (22.8%)
9	288 (18.8%)
10	240 (15.7%)
11	109 (7.1%)
≥12	89 (5.8%)
Modified Frailty Index	
0	547 (35.9%)
1	496 (32.5%)
2	301 (19.7%)
3	128 (8.4%)
4	37 (2.4%)
≥5	16 (1.1%)

ASA American Society of Anesthesiologists;

Table 3

Multivariate analyses evaluating predictors of 30-day mortality.

Predictors	ASA Classification Model Odds Ratio (95% CI)	P Value	Charlson Comorbidity Index Model Odds Ratio (95% CI)	P Value	Modified Frailty Index Model Odds Ratio (95% CI)	P Value
Age	1.00 (0.99–1.01)	0.99			0.99 (0.97–1.00)	0.07
BMI	1.02 (1.00–1.04)	0.08	1.03 (1.01–1.06)	0.009	1.02 (0.99–1.04)	0.13
Albumin	0.49 (0.39–0.61)	<0.0001	0.48 (0.37–0.61)	<0.0001	0.46 (0.36–0.58)	<0.0001
Hematocrit	1.00 (0.97–1.03)	0.88	1.00 (0.96–1.03)	0.81	1.00 (0.97–1.03)	0.99
Functional Status *						
Partially Dependent	1.68 (1.20–2.36)	0.003	1.51 (1.04–2.18)	0.03		
Totally Dependent	3.66 (1.96–6.86)	<0.0001	3.84 (1.91–7.71)	0.0002		
Preoperative Sepsis	1.48 (1.21–1.81)	0.0002	1.63 (1.31–2.03)	<0.0001	1.62 (1.30–2.00)	<0.0001
Emergency Operation	1.40 (1.03–1.90)	0.03	1.58 (1.13–2.21)	0.008	1.64 (1.18–2.28)	0.004
ASA Classification *			**CCI** *		**mFI** *	
3	1.44 (0.75–2.79)	0.28	**7**	0.56 (0.29–1.06)	0.07	**1**	1.58 (1.01–2.45)	0.04
4	2.54 (1.27–5.07)	0.008	**8**	0.49 (0.27–0.90)	0.02	**2**	1.81 (1.09–2.98)	0.02
5	4.99 (1.20–20.73)	0.03	**9**	0.59 (0.32–1.07)	0.08	**3**	3.49 (1.94–6.29)	<0.0001
			10	1.01 (0.57–1.81)	0.96	**4**	3.88 (1.59–9.44)	0.003
			11	1.11 (0.56–2.20)	0.76	**≥5**	5.74 (1.77–18.67)	0.004
			≥12	2.18 (1.09–4.36)	0.03			

*Odds ratios are a comparison to the lowest scores for each variable respectively (i.e. normal functional status, ASA Classification 2, CCI of 6, and mFI of 0).

ASA American Society of Anesthesiologists; *CCI* Charlson Comorbidity Index; *mFI* modified Frailty Index.

Table 4

Risk of prolonged length of stay (LOS), 30-day serious morbidity and mortality for components of the Charlson comorbidity Index (CCI) and the modified frailty index (mFI).

	Prolonged LOS		Serious Morbidity		Mortality	
Predictor	**OR (95%CI)**	**P value**	**OR (95%CI)**	**P value**	**OR (95%CI)**	**P value**
mFI Component						
Impaired Functional Status	*1.49 (1.16–1.92)*	*0.002*	*1.45 (1.11–1.89)*	*0.007*	*1.61 (1.20–2.17)*	*0.002*
Pneumonia	1.72 (0.83–3.56)	0.15	1.71 (0.81–3.58)	0.16	1.97 (0.89–4.38)	0.10
History of PCI/PCS/Angina	1.02 (0.64–1.63)	0.93	0.97 (0.59–1.61)	0.91	1.16 (0.66–2.04)	0.61
Hypertension	*1.50 (1.12–1.99)*	*0.006*	1.08 (0.79–1.47)	0.63	0.85 (0.59–1.24)	0.40
Impaired Sensorium	1.09 (0.47–2.55)	0.84	1.50 (0.63–3.57)	0.35	*3.27 (1.26–8.44)*	*0.02*
CCI Component						
Ascites/Esophageal varices	1.00 (0.71–1.42)	1.00	1.17 (0.81–1.69)	0.42	*1.86 (1.25–2.78)*	*0.002*
ESRD	1.30 (0.40–4.25)	0.66	0.57 (0.13–2.60)	0.47	0.39 (0.07–2.15)	0.27
Paraplegia	0.38 (0.07–2.11)	0.27	0.79 (0.16–3.84)	0.77	1.94 (0.38–9.81)	0.42
mFI and CCI Component						
Diabetes	0.67 (0.45–1.01)	0.05	0.91 (0.59–1.39)	0.65	1.29 (0.81–2.06)	0.28
COPD	0.41 (0.22–0.76)	0.005	1.46 (0.87–2.46)	0.15	1.07 (0.57–2.00)	0.84
CHF	1.15 (0.34–3.92)	0.82	*3.13 (1.05–9.33)*	*0.04*	*5.33 (1.59–17.88)*	*0.007*
MI 6 months prior to surgery	3.45 (0.50–23.71)	0.21	0.58 (0.05–6.16)	0.65	6.18 (0.73–52.64)	0.10
History of PVD or Rest Pain	0.82 (0.28–2.45)	0.73	0.91 (0.28–2.93)	0.87	2.22 (0.74–6.70)	0.16
History of TIA	0.87 (0.34–2.24)	0.77	0.57 (0.18–1.79)	0.34	*2.64 (1.03–6.78)*	*0.04*
History of CVA without deficits	1.46 (0.64–3.34)	0.37	1.16 (0.46–2.97)	0.75	*2.59 (1.02–6.58)*	*0.046*
History of CVA with deficits	1.00 (0.38–2.61)	0.99	1.47 (0.56–3.86)	0.43	1.72 (0.62–4.79)	0.30

PCI percutaneous cardiac intervention; *PCS* previous cardiac surgery; *TIA* transient ischemic attack; *CVA* cerebrovascular accident; *ESRD* end stage renal disease; *CVD* cerebrovascular disease; *COPD* chronic obstructive pulmonary disease; *CHF* congestive heart failure; *MI* myocardial infarction; *PVD* peripheral vascular disease.

*Model also consists of following: age, BMI, albumin, hematocrit, preoperative sepsis, and emergency operation.

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Table 5

Risk stratification scores and patient outcomes by operation type.

	Bowel Resection N=820		Celiotomy/Lysis of Adhesions N=440		GI Bypass N=223		Ostomy Creation N=313		P Value
	N	%	N	%	N	%	N	%	
ASA Classification									0.16
2	100	12.2%	42	9.6%	17	7.6%	22	7.0%	
3	546	66.6%	296	67.3%	160	71.8%	219	70.0%	
4	166	20.2%	98	22.3%	46	20.6%	67	21.4%	
5	8	1.0%	4	0.9%	0	0.0%	5	1.6%	
Charlson Comorbidity Index									0.11
6	93	14.7%	36	10.3%	26	13.8%	28	11.0%	
7	97	15.3%	50	14.3%	37	19.7%	54	21.2%	
8	145	22.9%	73	20.9%	47	25.0%	57	22.4%	
9	110	17.4%	86	24.6%	27	14.4%	43	16.9%	
10	108	17.0%	49	14.0%	31	16.5%	42	16.5%	
11	44	6.9%	28	8.0%	12	6.4%	18	7.1%	
≥12	37	5.8%	27	7.7%	8	4.3%	13	5.1%	
Modified Frailty Index									0.33
0	223	35.2%	114	32.8%	74	39.6%	103	40.6%	
1	215	33.9%	110	31.6%	63	33.7%	72	28.4%	
2	119	18.8%	79	22.7%	33	17.7%	47	18.5%	
3	57	9.0%	27	7.8%	12	6.4%	25	9.8%	
4	16	2.5%	10	2.9%	4	2.1%	4	1.6%	
≥5	4	0.6%	8	2.3%	1	0.5%	3	1.2%	
Prolonged LOS	227	27.7%	99	22.6%	67	30.2%	58	18.6%	0.002
30-Day Overall Morbidity	356	43.4%	143	32.5%	81	36.3%	74	23.6%	<0.0001
30-Day Serious Morbidity	219	26.7%	78	17.7%	38	17.0%	39	12.5%	<0.0001

	Bowel Resection N=820		Celiotomy/Lysis of Adhesions N=440		GI Bypass N=223		Ostomy Creation N=313		P Value
	N	%	N	%	N	%	N	%	
30-Day Mortality	122	14.9%	73	16.6%	22	9.9%	48	15.3%	0.14