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Exploring Predictors of Complication in Older Surgical Patients: A Deficit Accumulation Index and the Braden Scale

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Abstract

OBJECTIVES—To determine whether readily collected perioperative information might identify older surgical patients at higher risk for complication.

DESIGN—Retrospective cohort study

SETTING—Medical chart review at a single academic institution

PARTICIPANTS—102 patients aged 65 years and older who underwent abdominal surgery between January 2007 and December 2009.

MEASUREMENTS—Primary predictor variables were the first postoperative Braden Scale score (within 24 hours of surgery) and a Deficit Accumulation Index (DAI) constructed based on 39 available preoperative variables. The primary outcome was presence or absence of complication within 30 days of surgery date.

RESULTS—Of 102 patients, 64 experienced at least one complication with wound infection being the most common complication. In models adjusted for age, race, sex, and open vs. laparoscopic surgery, lower Braden Scale scores were predictive of 30-day postoperative complication (OR 1.30 [CI 95%, 1.06, 1.60]), longer length of stay ($\hat{a} = 1.44$ (0.25) days; $p_{\text{value}} = 0.0001$) and discharge to institution rather than home (OR 1.23 [CI 95%, 1.02, 1.48]). The cut-off value for the Braden Score with the highest predictive value for complication was 18 (OR 3.63 [CI 95%, 1.43, 9.19]; c statistic of 0.744). The DAI and several traditional surgical risk factors were not significantly associated with 30-day postoperative complications in this cohort.

CONCLUSION—This is the first study to identify the perioperative score on the Braden Scale, a widely used risk-stratifier for pressure ulcers, as an independent predictor of other adverse outcomes in geriatric surgical patients. Further studies are needed to confirm this finding as well as investigate other utilizations for this tool, which correlates well to phenotypic models of frailty.

Keywords

Braden Scale; Deficit Accumulation Index; Postoperative Complication; Frailty; Multi-disciplinary

INTRODUCTION

Due to demographic trends, persons aged 65 years and older constitute an increasing proportion of surgical cases^{1, 2}. Older surgical patients are often medically complicated and suffer higher rates of morbidity and mortality than their younger counterparts^{3–8}. These adverse outcomes have been attributed in part to older patients' more frequent occurrence of postoperative complications^{9, 10}, which result in longer hospital stays^{4, 8, 11–13} and higher costs^{8, 11, 13}. To avert the most serious and lasting consequences of complication, recent findings highlight the importance of early detection and brisk response also known as "rescue"^{14–16}. The ability to easily identify older surgical patients at highest risk of postoperative complication might increase awareness to potential difficulties in these patients paving the way for successful "rescue" and possibly reducing downstream morbidity and mortality.

Several risk factors for postoperative complication and mortality have been identified, including age^{3–7, 17}, American Society of Anesthesiology (ASA) class^{3, 4, 8, 12, 17}, emergency procedures^{4, 12, 17}, and low albumin^{17, 18}. However, lone predictors may fail to capture the complex and often multi-factorial nature of risk in older surgical candidates. Much recent work has suggested that a key concept in older patients' risk determination is the frailty syndrome^{19–24}. Frailty is defined as a state of vulnerability to stressors resulting from diminished physiologic reserve^{25–28}. Several models of frailty have been proposed, and multiple tools exist to characterize frail older adults^{29–31}. Although various indices accurately identify patients at high risk of adverse events, their clinical use is sometimes limited by the volume of data required or by their reliance on functional data and performance-based measures not routinely collected in preoperative assessment (i.e. gait speed or grip strength).

The objective of the current study is to determine whether readily collected perioperative information might identify older surgical patients at higher risk for complication. Specifically, the study evaluated two tools which have demonstrated utility as predictors of risk in older adults: 1) a deficit accumulation index, which was based on one popular frailty model²⁹ and was constructed from data available in chart review and 2) the postoperative Braden Scale (within 24 hours of surgery), which incorporates functional, nutritional, and cognitive information about the patient and is widely used by nurses to identify patients at highest risk of pressure ulcer^{32–34}.

METHODS

Design

This study is a retrospective cohort analysis based on medical chart review. A pre-selected set of variables were abstracted from medical records into an electronic database by one author (RRC) with weekly adjudication of items in question. The initial set of predictor and outcome variables were agreed upon by the authors (RRC, HEW, MTH, and SL) prior to the initiation of data abstraction. When preliminary chart review suggested the availability of other potential predictors of complication, such variables were added to the database after discussion and consensus between two or more authors. A random sample of 5% of the medical record was re-abstracted and entered into the database with an item error rate of < 1%. This study was approved by the Duke University Institutional Review Board.

Study Sample

The study population is a convenience sample of 102 patients aged 65 years or older who underwent abdominal surgery within one of the gastrointestinal surgery units at Duke University Hospital from January 2007 to December 2009. The cohort was restricted to this

unit because of the surgical author's familiarity with clinical and documentation practices on this service, improving the accuracy of variable determination. Exclusion criteria included minor procedures (g-tube (n = 1)), biopsy (n=1), immunocompromised patients status post bilateral lung transplant presenting for esophageal surgery (n=5), and death unrelated to abdominal surgery (n=2).

Measurements

Primary Predictor Variables

Braden Scale: The first Braden Scale score recorded after surgery was abstracted from each chart. These scores were determined by the patient's nurse and were available within 24 hours of surgery. The Braden Scale is a validated tool to assess the risk of developing pressure ulcers³². The scale includes measures of six domains: sensory perception and communication, moisture, activity, mobility, nutrition, and skin friction + shear. Each domain is scored separately and summed to derive a total score ranging from 6 to 23. Lower scores correlate to higher risk of pressure ulcer with a suggested threshold value of 18^{32–34}.

Deficit Accumulation Index—The Deficit Accumulation Index (DAI) was constructed based on methods described by Rockwood et al²⁹. Whereas many frailty models rely on a small number of specific phenotypic features to identify high-risk elders (such as muscle weakness, weight loss, or slow movement^{30, 35}), Rockwood's model asserts that a key determinant of risk is the sheer number of problems or deficits. According to this model, DAIs can be constructed based on available data about diseases, symptoms, disabilities, signs, and laboratory, electrolyte or radiographic information³⁶.

The DAI is calculated as a ratio of the number of risk factors present in a patient divided by the total number of variables assessed (usually between 30–40)³⁶. Higher DAI scores have been correlated to frailty phenotypes and worse outcomes in multiple populations³⁷. In accordance with published recommendations³⁶, the DAI constructed for this study was based on 39 preoperative variables typically recorded in the medical chart. Selected variables were not specific to a surgical population. Some items, which are traditionally included in Rockwood's DAIs, such as specific functional limitations, could not be included because the data were inconsistently documented in the medical record.

Table 1 lists the 39 variables included in this study's DAI. Preoperative laboratory values were abstracted from the electronic medical record. Medical diagnoses, health behaviors (smoking, alcohol or drug abuse), and functional abilities were assessed in the preoperative screening form completed by patients or family members. This information was supplemented by complete chart review and if either source indicated presence of the risk factor, it was coded as present. For example, if the pre-operative screening form was marked "No" for hypertension, but other documentation in the record revealed that the patient did in fact have preoperative hypertension, the hypertension variable was coded as present. In determining patients' DAI scores, missing values were coded as absence of the risk factor. To examine the role of missing/uncertain data, a sensitivity analysis was performed using a 35-item DAI which excluded 3 variables with a high percentage of missing data (albumin, incontinence, and cognitive impairment) and 1 variable with potentially redundant information (history of cancer). Results were unchanged, so the presented analyses use the original, 39-variable DAI.

Other Predictors of Surgical Complication—Several variables which have served as determinants of risk in other surgical populations were abstracted from the medical charts. These include: polypharmacy (5 or more preoperative medications); ASA class³³; specific classes of preoperative medications (benzodiazepines, anticoagulants, and

diuretics); length of operation (minutes); emergent vs. scheduled procedure; and presence of chronic pain.

Primary Outcome: 30-day Surgical Complication—The primary outcome was the occurrence of any surgical complication in the first 30 days following surgery. Suspected cases of surgical complication were verified with a surgical author (SL). Eight specific types of complication were defined at the beginning of the study including urinary tract infection (UTI), delirium/alerted mental status (AMS), wound infection, myocardial infarction, pneumonia, deep venous thrombosis/pulmonary embolism (DVT/PE), postoperative bleeding, and sepsis. When chart review suggested additional types of complications, these were added to the database after discussion and consensus between two or more authors.

Of the 102 cases reviewed, 94 (92%) had a general surgery service outpatient encounter, known death, or acute care encounter (hospital or emergency department) from which 30-day post-surgical outcomes could be abstracted. All but four cases had some type of post-discharge data in the computerized record.

Secondary Outcomes—Secondary outcomes included 30-day mortality, emergency department (ED) visit, readmission, multiple complications, discharge to institution (Skilled Nursing Facility (SNF)/Assisted Living Facility (ALF)/Rehabilitation vs. Home $\pm$ home health), and length of stay (LOS). All of these variables are dichotomous (yes or no) except for LOS (continuous number of days).

Other Variables Collected—Demographic information included age, sex, race (white vs. non-white) and preoperative location (home, SNF/ALF, hospital, other). Type of surgery was recorded as open or laparoscopic and emergent or non-emergent.

Statistical Analysis

Descriptive statistics were calculated for all variables, using mean with standard deviation or proportion. Chi-squared or t tests, as appropriate, were used for bivariate comparisons of risk indicators between participants with and without a complication. Multivariable logistic regression was employed to estimate the effect of the decreasing (i.e. worsening) total Braden score and the increasing (i.e. worsening) DAI separately and together, on the odds of the primary outcome of 30-day surgical complication. These estimates were adjusted by an a priori determined set of covariates: age, sex, race, and surgery type (open or laparoscopic). Bivariate Ordinary Least Squares (OLS) regression was used to estimate the relationship between the total Braden score with hospital length of stay. Finally, logistic regression was used to estimate the discriminative ability of the total Braden score at various cut points on the 30-day surgical complication outcome, as measured by the area under the receiver operating characteristic (ROC) curve (c-statistic). Because previous literature and bivariate analysis suggested that patients who undergo emergency procedures are at elevated risk of complication, a sensitivity analysis was performed to examine the predictive ability of the Braden Scale after the 14 emergent cases were excluded from the patient sample. All analyses were completed using Statistical Analysis Software (SAS) version 9.2, (SAS Institute, Cary NC).

RESULTS

Sample Characteristics

In this cohort of 102 surgical patients, the mean age was 72.2 ± 5.44 years old, 29.4% were non-white, and 50% were female. Ninety-eight percent of patients had three or more chronic

medical conditions and 60.8% were taking five or more medications prior to surgery. Other sample characteristics are displayed in Table 1.

Types of Postoperative Complications

Sixty four out of 102 patients had at least one documented complication (see Appendix). The most common complication was wound infection (n = 21 [Superficial: n = 16 (5/16 wound vac); Deep: n = 5 (2/5 wound vac, 2/5 CT guided drainage, 1/5 surgical exploration)] followed by postoperative ileus (n = 18), UTI (n = 14), arrhythmia (n = 12), AMS/delirium (n = 12), urinary retention (n = 10), abscess (n = 7), DVT/PE (n = 6), respiratory failure (n = 6), and acute renal failure (n = 5). Other types of complication occurred in fewer than five patients. Twenty-two patients had documented complications after discharge.

Braden Scale as a Predictor of Complication

First postoperative Braden Scale scores ranged from 9 to 23 (maximum). After adjustment, decreasing Braden Score was associated with postoperative complication (odds ratio [OR] 1.30, 95% Confidence interval [CI] 1.06, 1.60 for every 1-point decrease in Braden Score). See Table 3. The Braden score cut point with the most optimal predictive ability for complication was 18. This cut point yielded a c-statistic of 0.744 and an OR of 3.63 [CI 95%, 1.43, 9.19]. See Figure 1. In a sensitivity analysis which excluded the 14 emergent cases, the Braden Scale remained an independent predictor of complication and the predictive value of a Braden score of 18 was similar with a c-statistic of 0.736.

Deficit Accumulation Index as a Predictor of Complication

The number of deficits present in patients ranged from 1 to 23 of a possible total of 39. The mean was 9.25 ± 3.80 and the median 9. The 99% limit for number of deficits was 19 in this sample. Anemia, arthritis, hypertension, hyperlipidemia, tobacco abuse (historical or current) and vision impairment were the most prevalent conditions and were each present in more than 50% of the sample whereas most other variables had a prevalence of 30% or less. The deficit accumulation index was not predictive of 30 day postoperative complications in this sample. See Table 2.

Other Potential Independent Predictors of Complication

In bivariate analysis, the following potential perioperative predictors of risk were not significantly associated with the occurrence of 30-day complication in this cohort: ASA class, LOS, polypharmacy, chronic pain or diuretic, anticoagulation, and benzodiazepine use. However, open (vs. laparoscopic) procedures were more common among patients who experienced a complication (68.8%) compared to those who did not have a complication (50%), ($p=0.06$). The postoperative Braden Scale was significantly but modestly correlated with age (Spearman correlation coefficient [CC] -0.3 , $p=0.002$) and preoperative hematocrit (CC 0.3 , $p=0.002$); it was not correlated with preoperative DAI, creatinine, or number of pre-operative medications.

Secondary Outcome

ED utilization/Readmission—Of the 102 patients, 24.5% utilized the ED within 30 days of surgery and of these, 60% were readmitted to the hospital. The Braden Score as a continuous variable did not predict ED utilization (OR 1.10 [CI 95%, 0.86, 1.18]) or readmission (OR 1.10 [CI 95%, 0.84, 1.23]).

Multiple Complications—Of the 64 patients who had a complication, 54.7% (35 patients) had multiple complications. The Braden Score as a continuous variable did not predict multiple complications (OR 1.10, [CI 95%, 0.95, 1.27]).

Disposition—Eighty six patients (84%) were discharged to home. Twenty five patients with a complication versus ten patients without a complication needed home health. Eleven patients with a complication were discharged to an institution versus three without a complication. One patient with a complication was transferred to a different hospital where subsequent discharge status was unknown, and one patient did not survive to discharge. That death, due to aspiration pneumonia, was the only known case of 30-day postoperative mortality in this cohort. The Braden score as a continuous variable was predictive of discharge to an institution (OR of 1.23 [CI 95%, 1.02, 1.48]).

Length of Stay—The mean LOS for the full cohort was 8.45 ± 8.15 days (minimum = 1 day vs. maximum = 68 days) and was longer for those with a complication vs. those without a complication (10.6 days vs. 4.82 days, p -value = < 0.0001). A lower Braden score was predictive of longer LOS by Ordinary Least Squares with a beta coefficient of 1.44 (0.25) days with a p -value of 0.0001.

DISCUSSION

This study identifies the Braden Scale as an independent predictor of the incidence of 30-day postoperative complications in abdominal surgery patients over age 65. This finding could have substantial clinical impact because the Braden Scale is already widely collected by nursing staff and therefore readily available for risk stratification on most surgical services. In this study, older adults with a Braden score of 18 or less had more than threefold higher odds of thirty day complication after controlling for age, race, sex, and type of surgery. By contrast, several other potential risk factors, such as the Deficit Accumulation Index and ASA class 3, were not independent predictors of complication in this population.

The Braden Scale may identify older surgical patients at highest risk of postoperative complication and greater healthcare utilization (longer LOS and discharge to institution) because its six domains characterize many aspects of phenotypic models of the frailty syndrome including poor cognition, weakness, sense of exhaustion, and weight loss^{25, 26, 30, 31}. For example, patients with cognitive deficits may receive lower scores because of diminished ability to communicate pressure-related pain (Sensory Perception domain); patients with weight loss secondary to poor food intake may receive low scores in the Nutrition domain; and patients with weakness or exhaustion may receive low scores in the Mobility, Activity, and Friction + Shear domains. These results are consistent with a recent study in which the Norton Scale, a pressure ulcer risk scale similar to the Braden Scale, was predictive of complications in a population of older Israeli patients who underwent surgery for hip fractures³⁹. They also align with those of a recent study which reported that a phenotypic frailty index was predictive of 30-day postoperative complication, LOS, and institutionalization in a surgical population¹⁹. Whereas that study measured frailty preoperatively based on five criteria (weakness, exhaustion, low physical activity, weight loss and slow gait speed), the current study utilized a Braden score collected within 24 hours of surgery.

An immediate postoperative tool may have some advantage as a risk-stratifier. Surgery represents an acute “stress” event that could advance those with subclinical frailty not detected preoperatively to visible signs of frailty immediately after the procedure secondary to pro- inflammatory and hormonal processes⁴⁰. In turn, it is recognized that patients with poor Braden scores may be more likely to have cancer, be malnourished, and undergo higher risk procedures – all likely independent risk factors for surgical complication. The ability of the postoperative Braden Scale to capture these unmeasured confounders, including both

patient level and surgery-related factors, may account for this tool's ability to predict complication among very medically complex surgical patients.

The disadvantage of a postoperative risk stratifier is that it cannot help inform decisions about whether or not to recommend surgery in a particular patient. Future work might investigate factors that are not routinely recorded in the medical record but may correlate to postoperative Braden scores and adverse events (e.g. measures of cognition, function, nutrition, or self-rated health). Preoperative Braden Scales may be useful in risk stratification or clinical decision-making in the pre-operative period. Nonetheless, the potential value of the post-operative Braden Scale is supported by recent findings that morbidity and mortality associated with surgery can be reduced by brisk and appropriate response to complication^{14–15}. Thus, the postoperative Braden score could serve as a clinically valuable indicator of patients who merit extra vigilance toward potential complications after surgery. Future, prospective studies are needed to determine whether providing the clinical team with this risk indicator changes clinical practice or patient outcomes. Future studies may evaluate whether particular domains of the Braden Scale are most strongly associated with complications, or whether changes in the Braden Scale over time are informative.

One positive aspect of incorporating the Braden Scale in perioperative management is that it is inherently “whole person” and multi-disciplinary. Utilization of the Braden Scale may promote communication between doctors and nurses and inform a collaborative plan of care. Further, a low Braden score may be an efficient means for surgeons to identify patients who may benefit from early involvement of other disciplines such as medicine, physical therapy, or geriatrics.

Although the DAI is not predictive of complications in this surgical sample, others have reported that DAIs constructed from prospectively collected information were predictive of 30-day postoperative complication and institutionalization^{41, 42}. The DAI constructed for this study relied heavily on clinician notes and patient-reported history regarding chronic health conditions and behaviors. As a result, the DAI scores may have been subject to a diagnosis or reporting bias, whereby socioeconomically advantaged patients were more likely to know about certain conditions (such as diabetes, hyperlipidemia, and claudication). Further, DAIs typically incorporate more data on specific functional limitations than was available in the information abstracted from medical records. Alternatively, the DAI may be a less robust risk indicator in a tertiary care center population with a high morbidity burden and complication rate.

In addition to case mix, the high 30-day postoperative complication rate observed in this study (62.7%) may reflect inclusiveness in defining complications. Although patients with lower Braden scores were statistically more likely to experience a complication, it is notable that at least one complication occurred in 50.9% of patients with favorable Braden scores (19). In larger populations, it will be important to establish whether the Braden score reliably predicts the most serious complications.

The following limitations may impact the interpretation of findings. First, due to retrospective data collection, there was some subjectivity in translating available documentation into quantifiable data. To address this, weekly adjudication of variables in question occurred with two or more authors. Second, data were lacking on several factors which are likely robust indicators of risk (functional status, albumin, cognitive impairment). However, the objective was to identify predictor variables from routinely collected information, recognizing that the findings are less likely to change clinical practice if risk determination requires extra time and measurements. Third, this study was conducted at a

major referral center, and the generalizability of the findings should be assessed in other hospitals in community settings.

CONCLUSION

In this sample of older surgical patients with significant medical morbidity, the Braden Scale was predictive of 30-day postoperative complication rates, LOS, and institutionalization upon discharge. This finding is relevant and applicable in surgical clinical practice because it offers a readily available risk stratifier that is simple and cost effective. Other potential indicators were not predictive in this sample, possibly secondary to the limited data on physical function recorded in the medical chart or to the high rate of comorbidities and complications, rendering them less sensitive. Further studies are needed to confirm the findings prospectively as well as to explore other utilizations for the Braden Scale.

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Appendix

1. The Braden Scale for Predicting Pressure Sore Risk
 - Copyright. Barbara Braden and Nancy Bergstrom, 1988.
 - Ayello EA, Braden B. How and why to do pressure ulcer risk assessment. *Adv Skin Wound Care*. 2002;15: 125–131; quiz 132–133.
2. Type of Surgery and Complications

Type of Procedure	Number of Patients	Complications
Open Cholecystectomy	3	No Complications: 1/3 Wound infection: 2/3 Multiple Complications: 0/3
Laparoscopic Cholecystectomy	10	No complications: 5/10 AMS: 2/10 ARF: 2/10 Pressure ulcer: 1/10 Urinary retention: 1/10 Pneumonia: 1/10 UTI: 1/10 Other: 2/10 Multiple complications: 2/10
Laparoscopic Ventral Hernia Repair	7	No Complications: 3/7 Urinary Retention: 1/7 Pressure ulcer: 1/7 DVT: 1/7 Post-op ileus: 1/7 Take-back to the OR: 1/7 Wound infection: 1/7 Other: 1/7 Multiple Complications: 1/7
Open Ventral Hernia Repair	3	No complications: 2/3 Pressure Ulcer: 1/3 UTI: 1/3 Multiple complication: 1/3
Laparoscopic Paraesophageal Hernia Repair	5	No complications: 4/5 Arrhythmia: 1/5 Multiple Complication: 0/5
Ileostomy/Colostomy	6	No Complications: 3/6 Arrhythmia: 1/6 Pneumonia: 1/6

Type of Procedure	Number of Patients	Complications
		Respiratory Failure: 1/6 Death: 1/6 Wound infection: 1/6 ARF: 1/6 Post-op ileus: 1/6 Other: 1/6 Multiple complications: 2/6
Laparoscopic Partial Colectomy	10	No complications: 2/10 Post-op ileus: 2/10 UTI: 3/10 Abscess: 1/10 Suspected Anastomotic Leak: 1/10 Wound Infection: 3/10 Urinary Retention: 2/10 Arrhythmia: 2/10 DVT: 1/10 Multiple complications: 4/10
Open Partial Colectomy	28	No complications: 9/28 Post-op Ileus: 12/28 Arrhythmia: 4/28 Pneumonia: 2/28 Bowel Obstruction: 2/28 Abscess: 4/28 Urinary Retention: 2/28 ARF: 1/28 UTI: 3/28 Takeback to OR: 3/28 AMS: 5/28 Respiratory Failure: 4/28 Sepsis: 2/28 DVT: 2/28 Wound Infection 4/28 Anastomotic Leak: 1/28 Other: 2/28 Multiple complications: 13/28
Low Anterior Resection	13	No complications: 1/13 Wound Infection: 7/13 AMS: 3/13 Arrhythmia: 3/13 Urinary Retention: 3/13 UTI: 3/13 MI: 1/13 Post-op ileus: 1/13 Post-op bleeding: 1/13 Abscess: 1/13 ARF: 1/13 Sepsis: 1/13 Other: 4/13 Multiple Complications: 8/13
Total Proctocolectomy	3	No complications: 1/3 Urinary Retention: 1/3 DVT/PE: 2/3 UTI: 1/3 Other: 1/3 Multiple complications: 1/3
Open Small Bowel Resection	3	No complications: 1/3 AMS: 1/3 Arrhythmia: 1/3 Pressure Ulcer: 1/3 Multiple complications: 1/3
Other	11	No complications: 6/11 Wound infection: 3/11 Post-op ileus: 1/11 UTI: 2/11 Bowel Obstruction: 1/11 AMS: 1/11 Abscess: 1/11 Respiratory Failure: 1/11 Other: 2/11

Type of Procedure	Number of Patients	Complications
		Multiple complications: 3/11

• Other included: excision of sphincter (1), perineal repair of recto-urethral fistula (1), laparoscopic appendectomy (2), Laparoscopic splenectomy (1), perineal proctectomy (2), gastrojejunostomy (1), and diagnostic laparoscopy, adhesiolysis (2)

* NB: The complications do not add up to the denominator secondary to patients' having multiple complications.

OR THIS SECOND OPTION:

	Open Cholecystectomy	Laparoscopic Cholecystectomy	Laparoscopic Ventral Hernia Repair	Open Ventral Hernia Repair	Laparoscopic Paraesophageal Hernia Repair	Ileostomy/Colostomy	Laparoscopic Partial Colectomy	Open Partial Colectomy	Low Anterior Resection	Total Proctocolectomy	Open Small Bowel Resection	Other
Number of Procedure	3	10	7	3	5	6	10	28	13	3	3	11
No Complication	1/3	5/10	3/7	2/3	4/5	3/6	2/10	9/28	1/13	1/3	1/3	6/11
Wound Infection	2/3		1/7			1/6	3/10	4/28	7/13			3/11
Acute Renal Failure		2/10				1/6		1/28	1/13			
Altered Mental Status		2/10						5/28	3/13		1/3	1/11
Pressure Ulcer		1/10	1/7	1/3							1/3	
DVT/PE			1/7				1/10	2/28		2/3		
Post-op Ileus			1/7			1/6	2/10	12/28	1/13			1/11
Pneumonia		1/10				1/6		2/28				
Arrhythmia					1/5	1/6	2/10	4/28	3/13		1/3	
MI									1/13			
UTI		1/10		1/3			3/10	3/28	3/13	1/3		2/11
Post-operative Bleeding									1/13			
Urinary Retention		1/10	1/7				2/10	2/28	3/13	1/3		
Take back to the OR			1/7					3/28				
Respiratory Failure						1/6		4/28				1/11
Abscess							1/10	4/28	1/13			1/11
(Suspected or actual) Anastomotic Leak							1/10	1/28				

	Open Cholecystectomy	Laparoscopic Cholecystectomy	Laparoscopic Ventral Hernia Repair	Open Ventral Hernia Repair	Laparoscopic Paraesophageal Hernia Repair	Ileostomy/Colostomy	Laparoscopic Partial Colectomy	Open Partial Colectomy	Low Anterior Resection	Total Proctocolectomy	Open Small Bowel Resection	Other
Bowel Obstruction								2/28				1/11
Sepsis								2/28	1/13			
Other		2/10	1/7			1/6		2/28	4/13	1/3		2/11
Death						1/6						

* NB: The complications do not add up to the denominator secondary to patients' having multiple complications.

3. Definition of Complications

Complication	Definition
Urinary Tract Infection	<ol style="list-style-type: none"> 1 Dysuria, urgency, frequency, which resolved with antibiotics 2 Positive urine culture if taken prior to starting antibiotics
Delirium/AMS	<ol style="list-style-type: none"> 1 Documented in chart as change in AMS – can be lethargic/drowsy OR agitated OR disoriented 2 Psych consult for AMS 3 Mention of A+O < 3 for more than 1 day unless this is the patient's baseline 4 Treated for AMS (haldol, benzo), if less than 1 day
Wound Infection	<ol style="list-style-type: none"> 1 Noted in the chart by the surgeons and will be in the discharge summary 2 Erythema, cellulitis around the wound and open up the wound 3 Purulent discharge 4 If the patient was treated with antibiotics even without purulent discharge
Myocardial Infarction	<ol style="list-style-type: none"> 1 Positive cardiac biomarkers 2 New changes on EKG 3 Cardiac Catheterization or PCI
Pneumonia	<ol style="list-style-type: none"> 1 Typical: Fever, cough + sputum, SOB 2 Atypical: dry cough, other non-specific symptoms 3 Positive findings on CXR 4 Question evidence on CXR, but they were started on antibiotics
DVT/PE	<ol style="list-style-type: none"> 1 DVT: positive Doppler u/s of LE 2 PE: positive CT angiography or V/Q scan
Postoperative Bleeding	<ol style="list-style-type: none"> 1 In the surgeon's note 2 Treated either by return to OR, antifibrinolytic, transfusion
Sepsis	<ol style="list-style-type: none"> 1 SIRS + sign of infection
Urinary Retention	<ol style="list-style-type: none"> 1 Foley d/c'd, but unable to urinate. The foley must be placed back in and voiding trial attempted
Postoperative Ileus	<ol style="list-style-type: none"> 1 KUB confirmation (+ another definition) 2 Need for NGT Placement 3 Surgeon's note
Arrhythmia	<ol style="list-style-type: none"> 1 Postoperative EKG finding
Pressure Ulcer	<ol style="list-style-type: none"> 1 If the nurse states there is a pressure ulcer 2 A wound management consult is in the note 3 NOT dependent of Braden Score

Complication	Definition
Anastomotic Leak	1 Evidence of leak on imaging study or mention of anastomtic breakdown when patient undergoes re-operation
Abscess	1 Imaging study (CT scan) shows evidence of an abscess/fluid collection
Small Bowel Obstruction	1 Evidence with imaging to confirm
Respiratory Failure	1 Required intubation (transfer to SICU) 2 ABGs ordered postoperatively, increased oxygen requirements
Neuro Event	1 Severe neurologic deficit, brain dead, stroke 2 Neuro consult
Hyper/hypoglycemia	1 Hyperglycemia = 200+ for more than 24 hours 2 Hypoglycemia = < 70 for more than 24 hours
C. difficile infection	1 If any toxin test is positive regardless of whether antibiotics were given
Acute Renal Failure	1 Doubling of creatinine level
Fall, Failure to Thrive, Leukocytosis	- All based on specific documentation by providers in the medical chart

NB: Any of these complications were considered present when explicitly diagnosed in the medical chart or after adjudication with more than one author

Figure 1. Receiver Operating Characteristic (ROC) Curves for Braden Score Threshold Values to Predict the Occurrence of 30-day Postoperative Complication

LEGEND: ROC curves are a graphical plot of two operating characteristics (sensitivity and specificity) of any binary classification system. The optimal cut-point of a scale can be determined by comparing the discriminatory power of different threshold values. The optimal cut-point yields a ROC curve with the greatest area under the curve (highest c statistic). For the Braden Scale as a predictor of 30-day post-operative complication, a score of 18 or less yielded the steepest curve (c statistic 0.744).

Table 1

Characteristics of the Cohort

Characteristic	Full Cohort n = 102	Participants with Complication n = 64	Participants Without Complication n = 38
Age (Mean $\pm$ SD ^a)	72.2 $\pm$ 5.44	71.84 $\pm$ 5.72	72.71 $\pm$ 4.99
% 65–69 years	37.3	37.5	36.8
% 70–79 years	52.9	53.1	52.6
% 80+ years	9.8	9.4	10.5
Sex, % Female	50	46.7	55.3
Race, % non-white	29.4	34.4	21.1
Pre-op location, %			
Home	75.5	73.4	79.0
SNF ^b /ALF ^c	1.96	1.6	2.6
Another Service	16.7	18.8	13.2
Other	5.88	6.3	5.3
Emergent Surgery	13.7	15.6	10.5
Multimorbidity ^d , % yes	98.0	98.4	97.4
DAI^e Variables, %			
Albumin < 3.2	19.6	23.4	13.2
Glomerular Filtration Rate – 60 or lower	32.4	31.3	34.2
Body Mass Index < 18.5 or $\geq$ 30	35.3	37.5	31.6
Alcohol or Drug Abuse	10.8	14.1	5.26
Tobacco Abuse ^f	59.8	62.5	55.3
Mobility Impairment	20.6	21.9	18.4
Cognitive Impairment	6.86	6.25	7.89
Falls Risk	6.86	7.81	5.26
Difficulties with Activities of Daily Living	16.7	21.9	7.89
Incontinence	21.6	23.4	18.4
Unplanned weight loss of 15 pounds or more in the last 6 months	13.7	18.8	5.26
Sleeping Difficulties	28.4	25.0	34.2
Hearing impairment	17.7	20.3	13.2
Vision Impairment	79.4	78.1	81.6
Presence of Pressure Ulcer	1.96	3.13	0.00
Anxiety	20.6	20.3	21.1
Chronic Pain	21.6	25.0	15.8
Anemia	51.0	51.6	50.0

Characteristic	Full Cohort n = 102	Participants with Complication n = 64	Participants Without Complication n = 38
Arrhythmia	20.6	23.4	15.8
Arthritis	52.0	45.3	63.2
Coronary Artery Disease	19.6	15.6	26.3
Cancer (active)	34.3	35.9	31.6
Cancer (history)	26.5	23.4	31.6
Congestive Heart Failure	10.8	12.5	7.89
Cirrhosis	0.98	1.56	0.00
Claudication/ Peripheral Vascular Disease	4.90	1.56	10.5
Chronic Obstructive Pulmonary Disease/Asthma	25.5	29.7	18.4
Cerebral Vascular Accident/ Transient Ischemic Attack	11.8	12.5	10.5
Depression	17.7	17.2	18.4
Diabetes	23.5	20.3	29.0
Dialysis	0.00	0.00	0.00
Hematologic disorder	12.8	12.5	13.2
Hypertension	71.6	79.7	57.9
Hyperlipidemia	59.8	57.8	63.2
Hyper/Hypothyroidism	11.8	12.5	10.5
Neurologic Disorder	37.3	39.1	34.2
Osteoporosis/Osteopenia	17.7	18.8	15.8
Upper Respiratory Infection symptoms or Active Cough	12.8	10.9	15.8
Venothromboembolism	7.84	9.38	5.26

^aSD = Standard Deviation

^bSNF = Skilled Nursing Facility

^cALF = Assisted Living Facility

^dMultimorbidity = 3+chronic conditions

^eDAI = Deficit Accumulation Index; number of the 39 assessed risk factors which were present

^fTobacco Abuse – Current or former

Table 2

Braden Score and DAI as Predictors of 30-day Postoperative Complication

Variables	Braden Score, OR ^b (95% CI ^c)	DAI OR (95% CI)	Full Model OR (95% CI)
Braden Score (decreasing)	1.30 (1.06, 1.60)		1.29 (1.05, 1.60)
DAI ^a		1.05 (0.94, 1.17)	1.02 (0.91, 1.15)
Age	0.75 (0.37, 1.54)	1.00 (0.52, 1.93)	0.75 (0.37, 1.55)
Sex = Male	1.75 (0.72, 4.36)	1.52 (0.65, 3.54)	1.79 (0.73, 4.37)
Race = White	0.36 (0.13, 1.01)	0.47 (0.18, 1.25)	0.37 (0.13, 1.05)
Surgery = Open	1.67 (0.68, 4.08)	2.32 (0.99, 5.44)	1.68 (0.68, 4.12)

DAI^a = Deficit Accumulation Index; number of the 39 assessed risk factors which were presentOR^b = Odds RatioCI^c = Confidence Interval

Table 3

Bivariate Comparison of Potential Predictors of 30-day postoperative complication

Variables	Participants With Complications (N = 64)	Participants Without complication (N = 38)	p value
% with Post-operative Braden 18	78.3%	21.7%	0.003
No. of DAI ^a variables present, mean $\pm$ SD ^b	9.7 $\pm$ 3.9	9.0 $\pm$ 4.0	0.36
% with ASA ^c class 3	79.4%	81.6%	0.79

DAI^a = Deficit Accumulation Index; number of the 39 assessed risk factors which were presentSD^b = Standard DeviationASA^c = American Society of Anesthesiology