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Malnutrition Increases the Risk of 30-Day Complications After Surgery in Pediatric Patients with Crohn Disease

Mitchell R. Ladd, MD, PhD[1], **Alejandro V. Garcia, MD**[1], **Ira L. Leeds, MD, MBA**[1], **Courtney Haney**[2], **Maria M. Oliva-Hemker, MD**[3], **Samuel Alaish, MD**[1], **Emily Boss, MD**[4], **Daniel S. Rhee, MD, MPH**[1]

[1]Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD

[2]Department of Pediatric Nutrition, Johns Hopkins Hospital, Baltimore, MD

[3]Department of Pediatrics, Johns Hopkins University School of Medicine, Baltimore, Maryland

[4]Department of Otolaryngology-Head and Neck Surgery, Johns Hopkins School of Medicine, Baltimore, MD

Abstract

Background: Pediatric patients with Crohn disease (CD) are frequently malnourished, yet how this affects surgical outcomes has not been evaluated. This study aims to determine the effects of malnourishment in children with CD on 30-day outcomes after surgery.

Study Design: The ACS NSQIP-Pediatric database from 2012–2015 was used to select children aged 5–18 with CD who underwent bowel surgery. BMI-for-age Z-scores were calculated based on CDC growth charts and 2015 guidelines of pediatric malnutrition were applied to categorize severity of malnutrition into none, mild, moderate, or severe. Malnutrition's effects on 30-day complications. Propensity weighted multivariable regression was used to determine the effect of malnutrition on complications.

Results: 516 patients were included: 349 (67.6%) without malnutrition, 97 (18.8%) with mild, 49 (9.5%) with moderate, and 21 (4.1%) with severe malnutrition. There were no differences in demographics, ASA class, or elective/urgent case type. Overall complication rate was 13.6% with malnutrition correlating to higher rates: none 9.7%, mild 18.6%, moderate 20.4%, and severe 28.6% ($p<0.01$). In propensity-matched, multivariable analysis, malnutrition corresponded with increased odds of complications in mild and severely malnourished patients (mild OR=2.1 [p=0.04], severe OR 3.26 [p=0.03]).

Conclusion: Worsening degrees of malnutrition directly correlate with increasing risk of 30-day complications in children with CD undergoing major bowel surgery. These findings support BMI-for-age z scores as an important screening tool for preoperatively identifying pediatric CD patients

Corresponding Author: Daniel S. Rhee, MD, MPH, Johns Hopkins Children's Center, 1800 Orleans St Suite 7354, Baltimore, MD 21287, drhee1@jhmi.edu.

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Level of Evidence: IV

at increased risk for post-operative complications. Moreover, these scores can guide nutritional optimization efforts prior to elective surgery.

Keywords

Pediatric Crohn Disease; Surgery Outcomes; Nutrition; Malnutrition; Inflammatory Bowel Disease

1. Introduction:

Patients with Crohn disease (CD) are frequently malnourished, especially those who require surgical resection [1–6]. CD can lead to growth failure in children and is often an indication for intestinal resection [2]. Fortunately, pediatric patients with CD often have improved growth after resection of diseased intestine [1,2]. In adults, numerous studies have demonstrated that preoperative malnourishment is associated with an increased risk of post-operative complications, especially in CD [4,7–10]. While malnourishment in pediatric CD is common, there are no dedicated pediatric studies evaluating its effects on the risk of post-operative surgical complications. Moreover, there are only a few studies evaluating the effect of malnutrition on surgical outcomes in pediatric patients with the majority focusing on congenital heart defects. Due to the near-absence of relevant pediatric data, current recommendations on the management of pediatric CD are based primarily on inferences from the adult literature and the few studies that do exist in pediatric patients [2,11–16].

Malnutrition in children is different from adults, especially in the setting of CD. First, children require adequate nutrition for normal development and adequate assessment must include nutritional measures. Second, CD can impair overall growth and development. Children with CD often have improved growth after surgical resection of their disease. In contrast, resection of diseased bowel in adult patients may not improve overall nutrition postoperatively. One challenge in studying pediatric malnutrition in the context of surgical disease is the vastly different set of nutritional requirements of pediatric patients [17–20]. Moreover, there is often debate about the best way to measure malnutrition in children because the clinical parameters used in adults often do not correlate well with pediatric malnutrition [17]. For these reasons, it is difficult to extrapolate the interactions between adult nutrition and outcomes after surgery in CD patients to children.

In 2015, the American Society for Parenteral and Enteral Nutrition (ASPEN) published guidelines for defining malnourishment in children [21]. Recommended assessments of nutrition by ASPEN have the following attributes: evidence-based and consensus-derived, universally applied and validated, diverse applications, inexpensive, require minimal training, reproducibly identify and quantify malnutrition (undernutrition), and can monitor changes in nutritional status [21]. While historically malnutrition or failure to thrive was determined by falling off standard growth curves, these assessments took at least two data points to determine [21]. Unfortunately, multiple data points may not be available when pediatric patients present, thus anthropometric growth indices (weight-for-height, length/height, BMI-for-age) z scores are now recommended to assess nutritional status [21]. Of note, the ASPEN guidelines do not include any biochemical markers because these measures often act as acute phase reactants in the setting of acute illness.

Since data on how malnourishment affects post-operative outcomes in pediatric patients with CD is lacking, we sought to determine the effect of malnutrition on postoperative complications using the National Surgical Quality Improvement Program Pediatric (NSQIP-P) database. NSQIP-P tracks 30 day outcomes of selected surgical procedures [22,23]. We hypothesized that worsening malnutrition in pediatric CD patients undergoing major intestinal surgery would be associated with an increasing risk of 30-day post-operative complications.

2. Methods:

2.1 Data source:

This study was exempt from review by the Johns Hopkins University School of Medicine Institutional Review Board. Data from the 2012 to 2015 American College of Surgeons National Surgical Quality Improvement Program Pediatric (NSQIP-P) participant use data file (PUF) was queried to select children with CD undergoing major bowel surgery. NSQIP-P collects over 90 data points from most pediatric surgical subspecialties with the goal of obtaining highly reliable clinical data to compare surgical outcomes across participant hospitals in the program. NSQIP-P samples and collects data in 8 day cycles with 35 procedures per cycle by dedicated clinical abstractors. Demographic information, comorbid diagnoses, laboratory values, operative variables, and 30-day outcomes are recorded. Operations are recorded by their primary procedure Current Procedural Terminology (CPT) codes [24].

2.2 Patient selection:

Patients between 5 and 18 years of age were selected by both a diagnosis code for Crohn disease and procedure code for major bowel surgery. Diagnosis codes were based on International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes: 555, 555.0, 555.1, 555.2, 555.9. When available, International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes were used: K50.0 to K50.9. Current Procedural Terminology (CPT) codes were used to capture patients undergoing small bowel resection, ileocecectomy, partial colectomy, total abdominal colectomy, proctectomy, ostomy creation, and ostomy takedown (Appendix 1). The authors felt it important to explore the effects of malnutrition across a broad swath of surgical procedures. Thus, we felt it important to include both ostomy takedowns and ostomy creations in the analysis. Patients with primary perineal disease were not included in the study. We limited our evaluation between the ages of 5–18 due to the lack of certainty in diagnosing CD prior to age 5 (due to the increased incidence of monogenic inflammatory bowel disease [IBD] in this age group) [25]. Thus, nine patients under five years of age were excluded.

2.3 Predictors of outcome

Patient with missing height or weight data were excluded from the study. In NSQIP-P, weight is recorded either preoperatively or if measured within 30 days of an operation. Given the importance weight-based dosing in the pediatric population, the authors presume it is most likely that the majority of patients were weighed preoperatively. Additionally, patients with BMI greater than 40 were excluded from the study because it was felt that extreme outliers were a result of error in data entry. This resulted in the exclusion of 6 patients. The lowest BMI was 11.1 and no patients were excluded based on a low BMI. This left a BMI range of 11.1 to 38.1 with a median 19.1 (interquartile range 17.0–21.2). For each patient, body-mass-index (BMI)-for-age Z-scores were calculated based on Center for Disease Control (CDC) growth charts. Z-scores are defined as the deviation of the value (BMI) for an individual from the mean value of the reference population, divided by the standard deviation for the reference population. The CDC BMI-for Age charts are applicable beginning at 2 years of age when an accurate stature can be obtained (https://www.cdc.gov/growthcharts/percentile_data_files.htm). The 2015 consensus of pediatric malnutrition was used to categorize BMI-for-age-Z-score for patients into levels of malnutrition: none: >−1, mild: −1 to −1.9, moderate: −2 to −2.9, severe: <−3 [21].

Patient factors and comorbidities included age, gender, race, ethnicity, American Society of Anesthesiologists (ASA) class (<3, ≥3), case status (elective vs. urgent/emergent), preexisting cardiac, respiratory, neurologic, or renal comorbidities, preoperative parenteral nutrition (PN), preoperative sepsis (defined as meeting systemic inflammatory response syndrome within 48 hours of surgery), preoperative blood transfusion, preoperative steroid use, preoperative immunosuppressive medications, or preoperative hypoalbuminemia. Cardiac comorbidities include any minor, major, and severe cardiac risk factors as defined by NSQIP-P. Respiratory comorbidities included the presence of asthma, cystic fibrosis, history of chronic lung disease, oxygen supplementation, preexisting tracheostomy, structural pulmonary abnormality, preexisting pneumonia, or ventilator requirement. Neurologic comorbidity included preexisting coma, cerebral vascular accident, impaired cognitive status, seizure, cerebral palsy, structural central nervous system abnormality, neuromuscular disorder, or intraventricular hemorrhage. Renal comorbidity included patients with preexisting renal failure or dialysis dependence. Immunosuppression included patients regularly taking immunosuppressant medications such as for chronic inflammatory conditions, chemotherapy, or transplant medications. Steroid use was defined as having oral or parenteral corticosteroid medication in the 30 days prior to surgery. Information on duration of treatment or strength of dose were not available.

2.4 Outcomes

The primary outcomes of interest were development of a post-operative complication, reoperation, or readmission within 30 days of surgery. Given the small number of individual complications, a composite outcome of post-operative complications was used which included any wound infection or dehiscence, neurological complication, respiratory complication (pneumonia, unplanned reintubation, pulmonary embolism, new oxygen requirement on discharge, prolonged ventilator requirement >24 hours), renal complication, septic shock, central line infection, urinary tract infection, or death. Post-operative and total hospital length of stay were also recorded.

2.5 Statistical analysis

The association of preoperative risk factors and postoperative outcomes across degrees of malnutrition were compared using Fisher's exact test or Pearson's Chi-squared test where appropriate for categorical variables and Kruskal-Wallis equality of populations rank test for continuous variables. Potential covariates for multivariable regression were identified by univariate statistical significance and biological plausibility for confounding (e.g., immunosuppression, albumin).

An *a priori* propensity score weight-adjusted analysis of primary data was then performed in R 3.4.1 (R Project for Statistical Computing, Vienna, Austria) to address potential differences in underlying covariates' clustering across malnutrition severity. A previously reported multinomial propensity score weighting without matching methodology [26] was used via the *mnps* function of the *twang* package (RAND Corporation, Santa Monica, California) loaded into R Studio 1.01.153 (R Studio, Boston, MA) to assign each individual patient a propensity score relative to their individual representativeness of his or her respective malnutrition state. Propensity scores were estimated via a generalized boosted model – a 3,000-iteration tree-based regression model – with a balance rule based on minimizing the absolute standardized mean difference of all iterative pairwise comparisons. Propensity scores were trimmed to remove outlier cases with inverse probability scores greater than then 99th percentile as has been previously proposed [27].

Regression models were constructed using backwards stepwise logistic regression on potential covariates with an inclusion threshold of $p < 0.20$ and a significance definition of $p < 0.05$. Variables that *a priori* were identified by the authors to have a high biological likelihood for confounding (e.g., sex, age, operation type) were included into the model regardless of p value. All regression analyses were performed using Stata version 15 (StataCorp 2017, College Station, TX).

3. Results:

A total of 516 patients were included in the study, of which 97 (18.8%) had mild, 49 (9.5%) had moderate, and 21 (4.1%) had severe malnutrition. 349 (67.6%) were not malnourished by our criteria. Median age was 15.5 years and 218 (42.3%) were female. The majority of patients were white (82.4%). Elective cases were more common (87.8%) and ileocecectomy was the most common operation (45.5%). For the total cohort, 197 (38.2%) were on nonsteroidal immunosuppressive medication, 160 (31.0%) had preoperative steroid use 30 days prior to surgery, and 109 (21.1%) were on PN preoperatively. There were no differences in age, gender, ethnicity, ASA class, or case type (elective vs. urgent/emergent) across groups. The distribution of case types is also presented in Table 1. There was an increasing association of preoperative PN (p=0.01), preoperative sepsis (p=0.01), and preoperative blood transfusions (p=0.02) with worsening malnutrition, with the highest rates in the severely malnourished groups. Cardiac, respiratory, neurologic, and renal abnormalities were rare overall, with no difference seen across malnutrition groups.

Preoperative hypoalbuminemia was the highest in the severely malnourished group (68.4%) compared to the moderate (41.9%), mild (45.2%), and non-malnourished (37.1%) groups although this trend was not statistically significant (p=0.06). Of note, preoperative albumin data was missing in 200 patients.

There was a total of 68 (13.2%) post-operative complications, 27 (5.2%) reoperations, and 36 (7.0%) readmissions (Table 2). Of note, there were no post-operative deaths in this cohort. Comparing by degrees of malnutrition, the rate of post-operative complications increased with each degree of worsening malnutrition (p=0.01). Similarly, worsening malnutrition was associated with an increasing rate of reoperations (p=0.04). There was no difference in readmission rates by malnutrition (p=0.37). Median total length of stay and post-operative length of stay were longer for the severely malnourished group compared to other degrees of malnutrition (p=<0.01).

Table 3 shows analysis for preoperative risk factors for post-operative complications, finding that ASA class 3 or greater, urgent/emergent case, preoperative sepsis, and preoperative hypoalbuminemia were associated with increased risk of complications. Diagnostic tests of post-propensity score balance are included in Appendix 3. Propensity-weighted unadjusted and adjusted odds ratios for complications are shown in Table 4. In our model, the overall trend is that with worsening levels of malnutrition, the odds of complication increase. This was statistically significant for mild and severely malnourished groups, but statistical significance was not obtained in the moderate group. In addition, having an urgent/emergent operation increased the odds of complication.

While performing analysis of the effects of albumin levels on complications we observed a large effect of low serum albumin on complications (Table 1). Knowing that albumin levels often overlap or correlate to nutrition status, especially in the adult population, we sought to determine the interactions of albumin and BMI-for-age z scores on complications. Unfortunately, albumin levels were not available for 200 (39.1%) of our patient cohort, but stratified subgroup analysis by albumin level was performed with the information available (Table 5). An albumin cutoff for hypoalbuminemia of 3.5 g/dL was selected based on analysis with a Lowess plot of post-operative complications vs. preoperative albumin levels (Appendix 2). This analysis demonstrated that in patients with hypoalbuminemia, degree of malnutrition was not associated with increased odds of complications. However, in patients with normal serum albumin, a trend towards increased odds of complications with worsening malnutrition was observed with severe malnutrition reaching statistical significance.

4. Discussion:

Malnutrition has been known to increase the risk of post-operative complications for decades [3,4,8,17,28]. However, nearly all these studies were performed in adults. Few studies have closely investigated the effect of preoperative malnourishment on postoperative surgical complications in children [11–16]. In fact, we found only one study that evaluates the effects of preoperative malnutrition on pediatric general surgical procedures, but there are no specific studies for children with Crohn disease [11]. A recent review by Wessner and

Burjonrappa highlight the paucity of data on nutrition in the pediatric surgical population [17]. To our knowledge, this is the first study to evaluate how nutrition affects surgical outcomes in pediatric patients with CD. Our findings suggest that BMI-for-age z score can serve as a useful tool for identifying pediatric CD patients at increased risk for a post-operative complication, thus allowing opportunity for preoperative optimization to mitigate this risk.

NSQIP-P provides a valuable opportunity to assess malnutrition on surgical outcomes in children with CD using a national clinical database. Using the guidelines for malnourishment from ASPEN [21], we found that severity of malnutrition does increase the risk of post-operative complications after major bowel surgery in this population. Since children with CD are prone to malnutrition and disease progression, this study provides important information for counseling pediatric CD patients about their surgical risk and potentially allowing earlier or more aggressive interventions to improve nutritional parameters. As malnutrition has known deleterious effects on hematopoiesis and the immune system [29–31], the increased rates of sepsis and the need for blood transfusion found in this study are not surprising. Moreover, while only associations between malnourishment, hematopoiesis, and immune function are presented here, given that malnutrition is a known attributable cause of global immunosuppression in surgical patients, it is biologically plausible that malnutrition influenced these effects directly [32–36].

The complication rate in this cohort was 13.6% which is lower than other reports in the literature (22–77%) [37–39]. Of interest, Hansen *et al.* recently demonstrated that patients with ileal or ileocecal resection only had lower complication rates (6% and 24% respectively) compared to children undergoing hemi- or total colectomy (42% and 52% respectively) [38]. A relatively high proportion of our cohort had small bowel resection only (15.3%) or ileocecectomy (45.5%) perhaps accounting for our lower overall complication rate. The majority of the observed complications were infectious in nature or post-operative blood transfusions.

The propensity-weighted, adjusted model demonstrated a trend of increased odds of post-operative complications with worsening malnutrition. The mildly malnourished and severely malnourished odds reached statistical significance, however, the moderately malnourished group did not. There are several potential explanations for this finding. First, the mildly malnourished group may not have been recognized as malnourished. Thus, they may have been less likely to be nutritionally optimized preoperatively which put them at risk for complications. On the other end of the spectrum, the severely malnourished group is likely to be chronically malnourished, have multiple risk factors for complications, and be more likely to require urgent operations. Therefore, the severely malnourished group would be at higher risk for complications. In contrast, the moderate group may have presented with signs of malnutrition which were recognized resulting in their nutritional optimization prior to surgery. Hence, the moderately malnourished patients may represent the only group that is both recognized as malnourished and has the benefit of time for the condition to be treated thereby resulting in fewer 30 day complications. This explanation is limited by the lack of existing optimization data and is an important area of future research.

Given that albumin is a commonly used marker of malnutrition in adult patients, we thought it prudent to evaluate its associations with post-operative complications in pediatric CD patients. As already mentioned, ASPEN guidelines do not recommend using albumin to assess nutritional status in children because it is an acute phase reactant. This point is relevant and seems to be the predominant practice pattern given that we had a significant proportion of children that had no preoperative albumin levels available (200 patients were missing albumin values). Analysis did reveal that hypoalbuminemia is associated with increased complications, a well-established phenomenon [40]. Interestingly, in the subset of patients with hypoalbuminemia, the anthropometric BMI-for-age z score no longer predicted post-operative complications. However, in the subset with normal albumin, BMI-for-age z score values were important. These findings have several potential implications. First, these findings suggest that albumin may in fact be a useful marker in this population for worse surgical outcomes and that albumin may be linked to poor nutrition. Alternatively, it may, as has been shown in the literature, only be a marker of acute illness and metabolic response to injury that portends worse surgical outcome [40]. In other words, hypoalbuminemia may only directly indicate a malnourished state in the subset of CD patients without active disease that require resection since those with ongoing acute or chronic inflammation are likely to have alterations in their serum albumin levels as a result of the inflammation. Second, while low serum albumin correlates to worse surgical outcomes in this subset, it is insufficient for capturing all malnourished patients that may have worse outcomes. This is evident by the fact that those children with normal serum albumin and severe malnutrition by BMI-for-age z score have increased odds of complications. This finding highlights the inadequacy of albumin as a marker of nutrition as there are many reasons for malnourished patients to have normal serum albumin such as having received intravenous albumin, being severely dehydrated, or having recently received parenteral nutrition thereby increasing their albumin stores. While these findings are of great interest, they are not definitive and will require further study to fully elucidate their significance.

In children with Crohn disease, optimization of nutritional status is not always possible, especially in the acute setting where one would need an emergent operation. However, the majority of patients do not require emergent operations and attempts to nutritionally optimize these patients preoperatively should be carried out when possible, using the ASPEN recommendations as a goal. It is also important to note that some patients may be refractory to nutrition interventions due to growth failure from their disease. In these cases, deciding to perform an operation before developing severe malnutrition could provide a safer operation. The benefits of nutritional optimization have to be carefully weighed against the risk of treatment or treatment delay. For instance, prolonged use of parenteral nutrition is associated with an increased risk of sepsis, both through a central line associated blood stream infection and by inducing gut mucosal atrophy, predisposing to mucosal bacterial translocation [41]. Further prospective studies will be needed to determine if tracking changes in anthropometric measures (such as BMI-for-age, weight-for-age) is feasible and results in improved outcomes.

These findings must be interpreted in light of limitations within the study and NSQIP-P. Using BMI for age z-scores is a useful screening tool for malnutrition but does not provide the complete picture for a patient's nutritional status which is influenced by active disease including inflammation, malabsorption, or effects from disease treatment including steroids and immunosuppressive agents. Important components that are not available in NSQIP-P include duration and dosage of immunosuppression, etiology of sepsis, details of PN administration, and quantitative measure of degree of tissue injury or inflammation [22,42]. In this study, while no overall difference was found between use of immunosuppressive agents and malnutrition, lack of data on duration and dosage limits our ability to account for these agents affecting malnutrition and other factors such as preoperative SIRS/sepsis. Also, weight measurements alone can be unreliable in relation to fluid status; a particularly important point for patients with active inflammation leading to significant third spacing. Measurements such as repeated weight measures over time and mid-upper arm circumference are useful adjuncts in these circumstances, but are not available in NSQIP-P. It should also be noted that weight is likely to be affected by nutritional status prior to height and so BMI-for-age z score may not be as sensitive as other measures of malnutrition that are made over time. NSQIP-P does not temporally track weight, height, nor BMI. Thus, the authors are not able to distinguish between catabolic cachexia of disease and malnutrition. In addition, growth failure or delay, another component of nutrition, is difficult to capture in a retrospective database. While NSQIP-P has a highly reliable process of data entry, there still remains variation in physician coding [43]. Although we have observed significant associations, retrospective data do not allow us to define causality. These potential confounding effects are addressed with binary categorical variables (e.g., with or without preoperative sepsis) to the extent possible. While it is known that there can be variations in complications from hospital to hospital or surgeon to surgeon, NSQIP-P does not provide hospital site specific nor surgeon-level data to study variation in care. Finally, while we did find that rates of reoperation and median length of stay were increased in malnourished patients, this study was not adequately powered to perform multivariable models.

5. Conclusion:

Worsening degrees of malnutrition directly correlate with increasing risk of 30-day complications in children with CD undergoing major bowel surgery. After adjustment, mild and severe malnutrition had increased odds of complications after surgery. Additionally, albumin was found to be a powerful predictor for post-operative complications in this population but more investigation is needed to determine its interaction with malnutrition. This is the first study evaluating the effects of nutritional status on surgical outcomes in pediatric patients with CD. These data suggest that BMI-for-age Z-scores could be used to identify pediatric CD patients at high risk of post-operative complications due to malnutrition. Further studies are needed to determine whether BMI-for-age z scores can be used to guide nutritional optimization before major surgery in this population. Regardless, this study suggests that malnourished pediatric CD patients should have their nutritional status optimized prior to surgery when possible.

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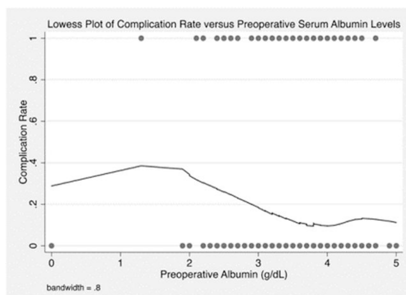
Appendix 1.

ICD-9 and ICD-10 codes for Crohn disease and CPT codes for operations evaluated.

	Codes
ICD-9, ICD-10	555, 555.1, 555.2, 555.9, K50, K50.0, K50.00, K50.01, K50.011, K50.012, K50.013, K50.014, K50.018, K50.019, K50.1, K50.10, K50.11, K50.12, K50.13, K50.14, K50.18, K50.19, K50.111, K50.112, K50.113, K50.114, K50.118, K50.119, K50.8, K50.80, K50.81, K50.811, K50.812, K50.813, K50.814, K50.818, K50.819, K50.9, K50.90, K50.91, K50.911, K50.912, K50.913, K50.914, K50.918, K50.919
Ostomy Takedown	44620, 44625, 44626
Ostomy Only	44310, 44187, 44320, 44322, 44188
Small Bowel	44120, 44125, 44130, 44202, 44615
Partial Colectomy	44204, 44140, 44141, 44143, 44144, 44145, 44146, 44206, 44207, 44208
Total Abdominal Colectomy	44150, 44151, 44155, 44156, 44157, 44158, 44210, 44211, 44212
Proctectomy	45110, 45111, 45112, 45113, 45114, 45119, 45120, 45123, 45397, 45499
Ileocecectomy	44160, 44205

Appendix 2



Appendix 3

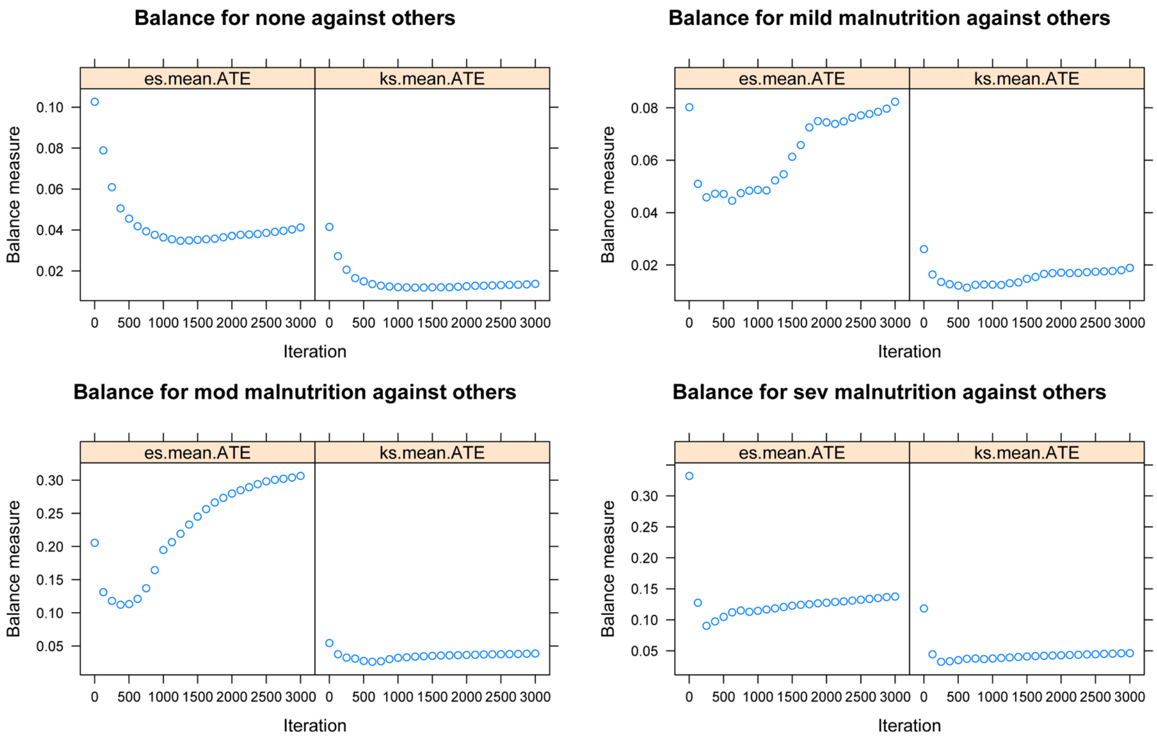


Figure A3.1.
Plotted Balance Metrics for Absolute Standardized Mean Differences ("es.mean") and Kolmogorov-Smirnov Statistic ("ks.mean") Demonstrating Asymptotic Approach to Optimal Balance

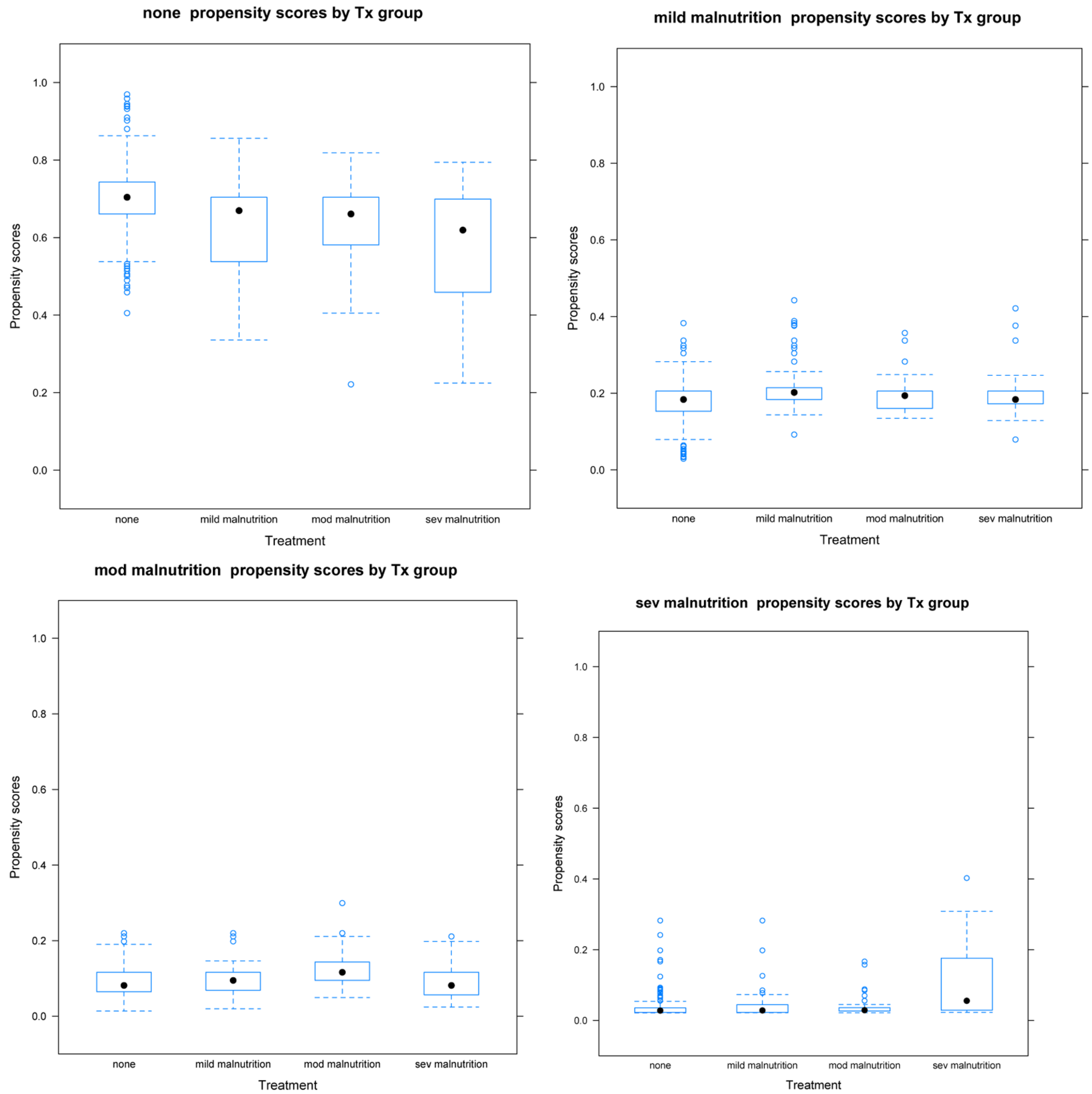


Figure A3.2.
Propensity Score Distributions of Each Malnutrition Category on the Four Others Demonstrating Appropriate Non-Zero Overlap Between All Groups

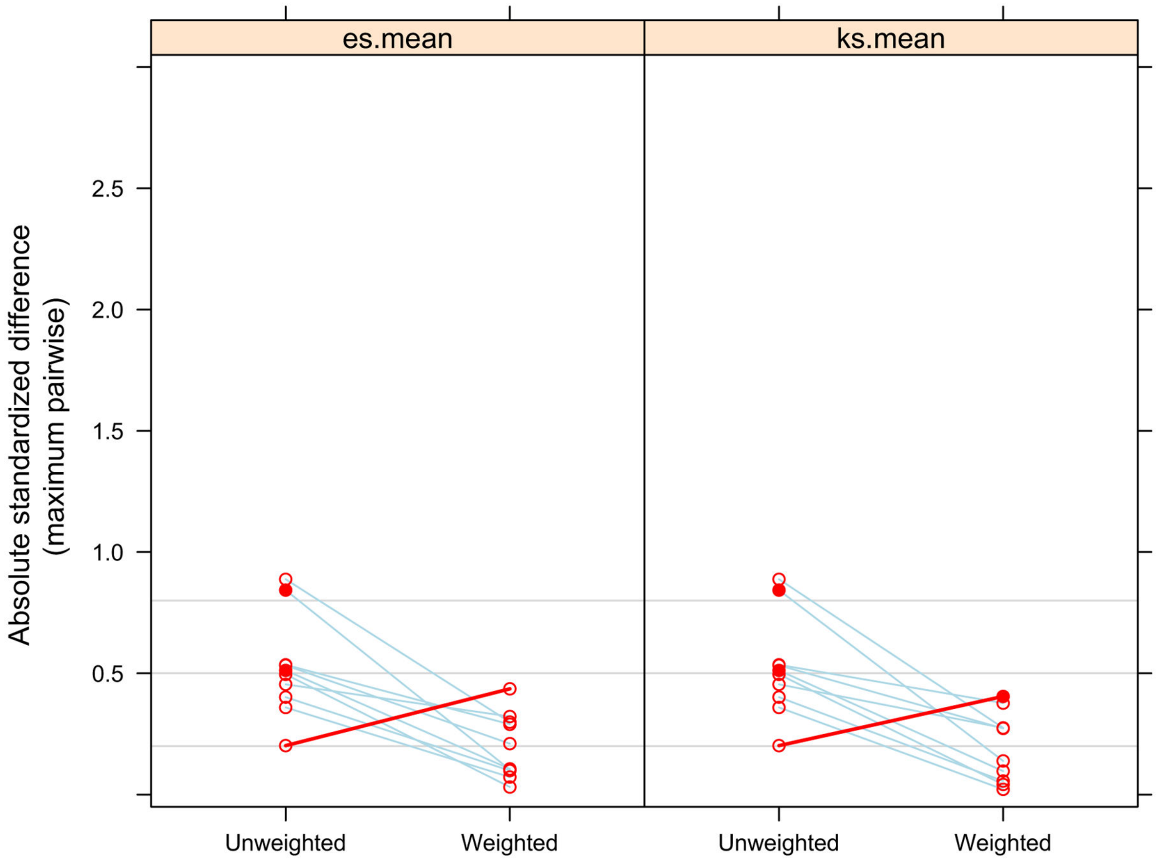


Figure A3.3.
Comparison of Overall Absolute Standardized Mean Difference of Covariates Between Malnutrition Groups Before and After Propensity Score Weighting

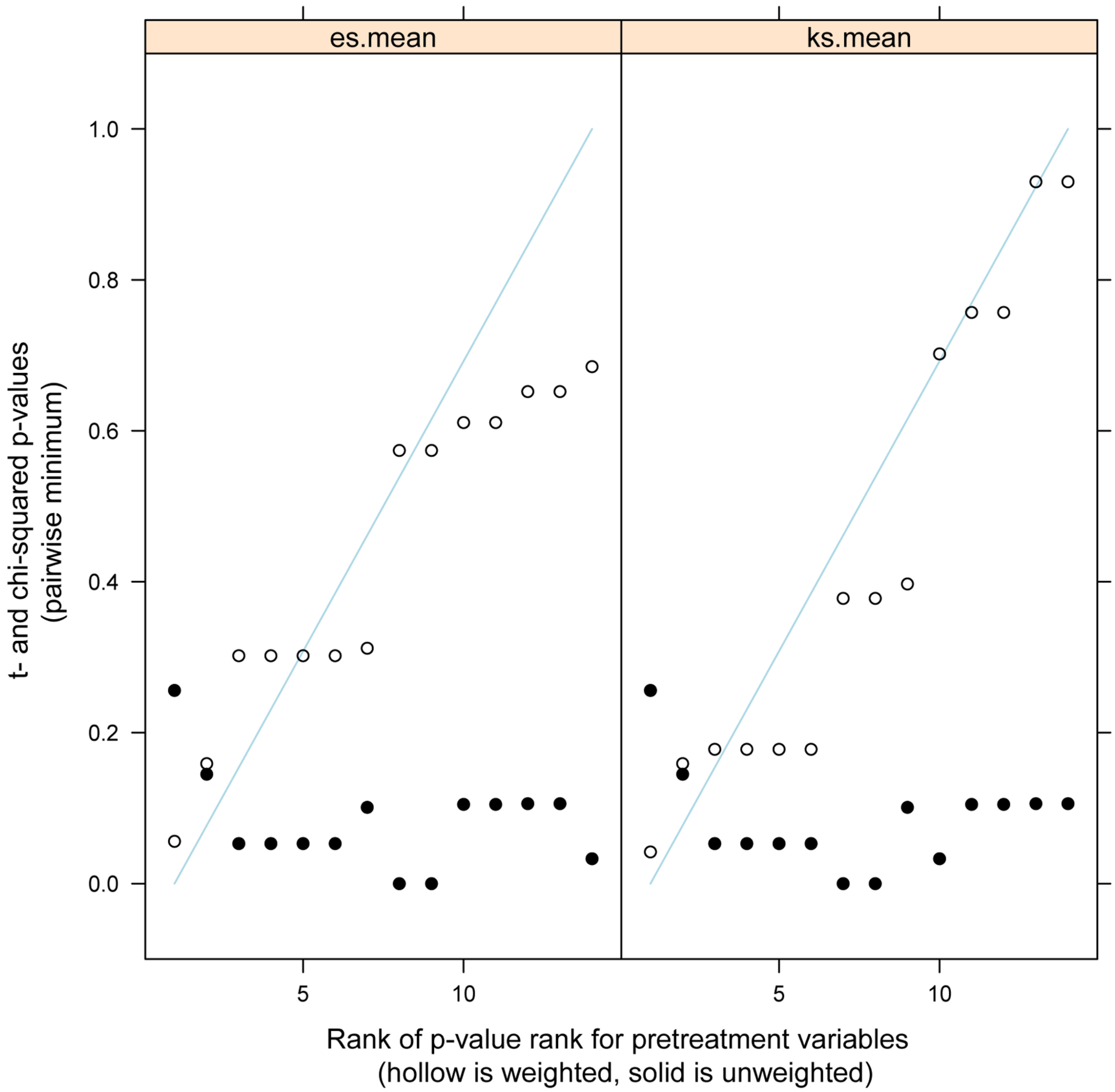


Figure A3.4.
t- and Chi- square p-values for Differences in Covariates between Malnutrition Groups Before (solid dot) and After (hollow dot) Propensity Score Weighting

Abbreviations:

CD	Crohn Disease
IBD	Inflammatory Bowel Disease
ASPEN	American Society for Parenteral and Enteral Nutrition
NSQIP-P	National Surgical Quality Improvement Program Pediatric
BMI	body-mass-index

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Table 1.

Patient Characteristics by Degree of Malnutrition

		Degree of Malnutrition				
	Total N=516	**None N=349**	**Mild N=97**	**Moderate N=49**	**Severe N=21**	**p-value**
Age, median (IQR)	15.5 (13.7–16.7)	15.6 (13.9–16.7)	15.4 (13.6–16.9)	15.0 (13.6–16.6)	15.7 (14.5–16.7)	0.71
Female n(%)	218 (42.3)	153 (43.8)	32 (33)	25 (51.0)	8 (38.1)	0.14
Race n(%)						0.02
White	425 (82.4)	281 (80.5)	85 (87.6)	44 (89.8)	15 (71.4)	
Black	55 (10.7)	47 (13.5)	5 (5.2)	1 (2.0)	2 (9.5)	
Other	4 (0.8)	4 (1.1)	0 (0)	0 (0)	0 (0)	
Unknown	32 (6.2)	17 (4.9)	7 (7.2)	4 (8.2)	4 (19.1)	
Hispanic n(%)	22 (4.3)	12 (3.5)	6 (6.3)	3 (6.4)	1 (4.8)	0.41
ASA class n(%)						0.19
<3	303 (58.7)	212 (60.7)	58 (59.8)	24 (49.0)	9 (42.9)	
≥ 3	213 (41.3)	137 (39.3)	39 (40.2)	25 (51.0)	12 (57.1)	
Case type n(%)						0.42
Elective	453 (87.8)	308 (88.3)	85 (87.6)	44 (89.8)	16 (76.2)	
Urgent/Emergent	63 (12.2)	41 (11.8)	12 (12.4)	5 (10.2)	5 (23.8)	
Operation type n(%)						0.24
Ostomy takedown	33 (6.4)	28 (8.0)	2 (2.1)	2 (4.1)	1 (4.8)	
Ostomy only	35 (6.8)	21 (6.0)	6 (6.2)	5 (10.2)	3 (14.3)	
Small bowel only	79 (15.3)	51 (14.6)	14 (14.4)	10 (20.4)	4 (19.1)	
Partial colectomy	87 (16.9)	53 (15.2)	22 (22.7)	8 (16.3)	4 (19.1)	
Total abdominal colectomy	44 (8.5)	26 (7.5)	14 (14.4)	4 (8.2)	0 (0)	
Proctectomy	3 (0.6)	2 (0.6)	0 (0)	1 (0)	0 (0)	
Ileocecectomy	235 (45.5)	168 (48.1)	39 (40.2)	19 (38.8)	9 (42.9)	
Comorbidity n(%)						
Cardiac	4 (0.8)	3 (0.9)	1 (1.0)	0 (0)	0 (0)	1.00
Respiratory	24 (4.7)	21 (6.0)	2 (2.1)	0 (0)	1 (4.8)	0.14
Neurologic	21 (4.1)	14 (4.0)	3 (3.1)	3 (6.1)	1 (4.8)	0.70
Renal	1 (0.2)	1 (0.3)	0 (0)	0 (0)	0 (0)	1.00
Immunosuppression n(%)	197 (38.2)	132 (37.8)	34 (35.1)	22 (44.9)	9 (42.9)	0.65
Preoperative steroid use n(%)	160 (31.0)	104 (29.8)	33 (34.0)	13 (26.5)	10 (47.6)	0.29
Preoperative PN n(%)	109 (21.1)	60 (17.2)	27 (27.8)	14 (28.6)	8 (38.1)	0.01
Preoperative SIRS/sepsis n(%)	29 (5.6)	17 (4.9)	6 (6.2)	1 (2.0)	5 (23.8)	0.01
Preoperative blood transfusion n(%)	6 (1.2)	2 (0.6)	2 (2.1)	0 (0)	2 (9.5)	0.02
Preoperative Hypoalbuminemia *	129 (41.1)	75 (37.1)	28 (45.2)	13 (41.9)	13 (68.4)	0.06

IQR= interquartile range, ASA=American Society of Anesthesiologists, PN=parenteral nutrition, SIRS=systemic inflammatory response syndrome

* For preoperative albumin, there are 200 missing values in the data, the total sample size for this row is 312

Table 2.

30-day Outcomes by Degree of Malnutrition

		Degree of Malnutrition				
Outcomes	**All Patients**	**None**	**Mild**	**Moderate**	**Severe**	**p-value**
Complication n(%)	68 (13.2)	34 (9.7)	18 (18.6)	10 (20.4)	6 (28.6)	0.01
Reoperation n(%)	27 (5.2)	13 (3.7)	6 (6.2)	5 (10.2)	3 (14.3)	0.04
Readmission n(%)	36 (7.0)	22 (6.3)	6 (6.2)	6 (12.2)	2 (9.5)	0.37
Total LOS, days median (IQR)	6 (4–10)	6 (4–8)	6 (4–13)	6 (4–13)	12 (6–19)	<0.01
Post-operative LOS, days, median (IQR)	5 (4–7)	5 (4–7)	5 (4–8)	5 (4–8)	7 (5–10)	<0.01

SSI=surgical site infection, DVT=deep venous thrombosis, IQR=interquartile range, LOS=length of stay (hospital)

Table 3.

Risk Factors for 30-Day Post-Operative Complications

		Complication		
Variable		**Yes**	**No**	**p-value**
Age, median (IQR)		15.5 (14.2–16.8)	15.5 (13.7–16.7)	0.55
Sex n(%)	Female	29 (13.3)	189 (86.7)	1.00
	Male	39 (13.1)	259 (86.9)	
Race n(%)	White	57 (13.4)	368 (86.6)	0.71
	Black	7 (12.7)	48 (87.3)	
	Other	1 (25.0)	3 (75.0)	
	Unknown	3 (9.4)	29 (90.6)	
Hispanic n(%)	Yes	3 (13.6)	19 (86.4)	1.00
	No	64 (13.3)	419 (86.8)	
ASA class n(%)	<3	30 (9.9)	273 (90.1)	0.01
	≥ 3	38 (17.8)	175 (82.2)	
Elective case n(%)	Yes	52 (11.5)	401 (88.5)	<0.01
	No	16 (25.4)	47 (74.6)	
Comorbidities n(%)				
Cardiac	Yes	0 (0)	4 (100.0)	1.00
	No	68 (13.2)	444 (86.8)	
Respiratory	Yes	4 (16.7)	20 (83.3)	0.54
	No	64 (13.0)	428 (87.0)	
Neurologic	Yes	3 (14.3)	18 (85.7)	0.75
	No	65 (13.1)	430 (86.9)	
Renal	Yes	0 (0)	1 (100.0)	1.00
	No	68 (13.2)	447 (86.8)	
Immunosuppression n(%)	Yes	23 (11.7)	174 (88.3)	0.50
	No	45 (14.1)	274 (85.9)	
Preoperative steroid use n(%)	Yes	28 (17.5)	132 (82.5)	0.07
	No	40 (11.2)	316 (88.8)	
Preoperative PN n(%)	Yes	19 (17.4)	90 (82.6)	0.15
	No	49 (12.0)	358 (88.0)	
Preoperative SIRS/sepsis n(%)	Yes	8 (27.6)	21 (72.4)	0.04
	No	60 (12.3)	427 (87.7)	
Preoperative blood transfusion n(%)	Yes	2 (33.3)	4 (66.7)	0.18
	No	66 (12.9)	444 (87.1)	
Preoperative hypoalbuminemia*	Yes	26 (20.2)	103 (79.8)	<0.01
	No	17 (9.2)	168 (90.8)	

IQR=interquartile range, ASA=American Society of Anesthesiologists, PN=parenteral nutrition, SIRS=systemic inflammatory response syndrome

*For preoperative albumin, there are 202 missing values in the data, the total sample size for this row is 314

Table 4.

Propensity-Weighted Unadjusted and Adjusted Odds Ratios for Post-operative Complications.

Variable	Unadjusted OR	95% CI	p-value	Adjusted OR	95% CI	p-value
Mild Malnutrition	1.99	1.02–3.91	0.04	2.10	1.04–4.24	0.04
Moderate Malnutrition	1.32	0.54–3.21	0.54	1.38	0.56–3.42	0.49
Severe Malnutrition	3.57	1.16–10.99	0.03	3.26	1.11–9.58	0.03
Gender	0.85	0.45–1.60	0.61	0.75	0.39–1.42	0.37
Age	0.92	0.49–1.73	0.79	1.02	0.53–1.94	0.95
Operation Type	0.81	0.32–2.08	0.67	0.65	0.25–1.68	0.38
Urgent/Emergent Case	3.86	1.76–8.46	<0.01	4.12	1.86–9.32	<0.01

Table 5.

Propensity-Weighted Adjusted Odds Ratio of Complications in Patients with Hypoalbuminemia versus Normal Serum Albumin

Albumin < 3.5 g/dL			
Variable	**OR**	**95% CI**	**p-value**
Mild Malnutrition	1.68	0.55–5.14	0.36
Moderate Malnutrition	1.35	0.28–6.46	0.71
Severe Malnutrition	1.13	0.26–4.82	0.87
Age	0.84	0.27–2.67	0.77
Operation Type	1.86	0.35–10.05	0.47
Urgent/Emergent	3.86	1.36–10.98	0.01
ASA Class	4.25	1.29–13.97	0.02
Albumin ≥ 3.5 g/dL			
Variable	**OR**	**95% CI**	**p-value**
Mild Malnutrition	3.32	0.84–13.12	0.09
Moderate Malnutrition	1.50	0.31–7.14	0.61
Severe Malnutrition	24.22	2.33–251.95	0.01
Age	0.68	0.18–2.49	0.56
Operation Type	0.67	0.74–6.02	0.72
Urgent/Emergent	4.67	1.07–20.45	0.04
ASA Class	0.45	0.14–1.47	0.19
Immunosuppressed	0.35	0.09–1.42	0.14