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# Effect of Lowest Postoperative Pre-albumin on Outcomes after Robotic-Assisted Pulmonary Lobectomy

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## ABSTRACT

**Objective:** Lower pre-albumin levels have been associated with increased rates of post-surgical complications, prolonged hospital length of stay (LOS), and death. This study aims to investigate the effect of postoperative pre-albumin levels on perioperative and long-term outcomes following robotic-assisted video thoracoscopic (RAVT) pulmonary lobectomy.

**Methods:** We retrospectively reviewed 459 consecutive patients who underwent RAVT pulmonary lobectomy by one surgeon for known or suspected lung cancer. The lowest pre-albumin values during the postoperative hospital stay were recorded. Twenty-three patients with no pre-albumin levels available were excluded from analysis. Patients were grouped as having normal (≥ 15 mg/dL) versus low (< 15mg/dL) pre-albumin. Outcomes and demographics were compared between groups using Pearson $\chi^2$, Student's t, or Kruskal-Wallis tests. Univariate and multivariate generalized linear regression, logistic regression, or Cox proportional hazard ratio models were used to assess the association between outcomes and variables of interest. Kaplan-Meier analyses were performed to estimate and depict survival probabilities for each group.

**Results:** Our study population comprised 436 patients. Lowest postoperative pre-albumin below 15 mg/dL was associated with more postoperative complications (44.2% vs 24.9%, $p < 0.001$), longer chest tube duration (6.9 vs 4.6 days, $p = 0.001$), and longer LOS (7.0 vs. 4.4 days, $p < 0.001$). In survival analysis, lowest perioperative pre-albumin levels were found to correlate with decreased 1 year ($p = 0.012$), 3-year ($p = 0.001$), and 5-year survival ($p = 0.001$).

**Conclusion:** Lower pre-albumin levels postoperatively are associated with more postoperative complications, longer chest tube duration and LOS, and decreased overall survival following robotic-assisted pulmonary lobectomy.

**Key Words:** Perioperative outcomes, Robotic surgery, Pulmonary lobectomy, Nutritional status.

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## INTRODUCTION

Malnutrition is common amongst lung cancer patients[1–3] and is associated with increased complications and mortality after surgery.[1,4–6] Nutritional impairment has been identified as a predictor for increased postoperative complications, increased need for postoperative ventilator support, and increased 90-day and 5-year mortality following surgery for lung cancer.[1,4,5]

The influences of nutritional status in minimally invasive surgery (MIS) for lung cancer has not been well documented. Of the MIS techniques used for pulmonary lobectomy, robotic-assisted video-thoracoscopic (RAVT) surgery is a newer modality associated with decreased postoperative complications, decreased hospital length of stay (LOS), and increased surgical precision.[7–9] As RAVT surgery is a newer modality with studies demonstrating improved outcomes compared to other surgical approaches, understanding the role of malnutrition in this surgical population is an important part of improving outcomes for surgical lung cancer patients.

Although historically albumin has often been used as a marker for nutritional status, pre-albumin has gained favor due to its rapid half-life of two days compared to albumin's half-life of 20 days.[10] Pre-albumin is also less affected by liver function and hydration status than albumin.[10] In a 1995 consensus statement, a panel recommended that all patients with pre-albumin below 15 mg per dL receive a consultation from the hospital's nutritional team.[11] Low pre-operative pre-albumin levels have been associated with an increased rate of postoperative complications, and both low preoperative and postoperative pre-albumin levels have been associated with earlier lung cancer recurrence following resection.[12,13]

The aim of this study is to investigate the influence of nutritional status, as measured by postoperative pre-albumin levels, on perioperative outcomes following RAVT pulmonary lobectomy. Outcomes studies include operative skin-to-skin time, estimated blood loss (EBL), postoperative complications, hospital LOS), chest tube duration, in-hospital mortality, and survival.

## METHODS

We retrospectively reviewed consecutive patients who underwent robotic-assisted pulmonary lobectomy by one surgeon between September 1, 2010 through August 31, 2018 at a single institution. The number of procedures performed by the surgeon during the specified time period determined the sample size of our study. Eligible patients were $\geq$ 18 years of age and had undergone elective RAVT lobectomy for clinically diagnosed or suspected lung cancer, with or without neo-adjuvant therapy.

As only a very limited number of patients had pre-operative pre-albumin values recorded in the charts, postoperative pre-albumin values were assessed instead. We tabulated the first postoperative pre-albumin level recorded within 48 hours of surgery, the lowest postoperative pre-albumin level recorded during the entire inpatient stay, and the postoperative pre-albumin value recorded just prior to discharge from this hospital. This paper focuses on the lowest pre-albumin level recorded during the entire postoperative inpatient stay, ranging from within 48 hours after surgery until discharge from the hospital, and its effects on various outcomes. We divided patients into high and low pre-albumin groups based on a cut-off level of 15 mg/dL, which was determined based on the Nutritional Care Consensus Group recommendation that patients with a pre-albumin level below 15 mg/dL receive nutritional consultation.[11]

In addition to the independent variable of nutritional status as measured by pre-albumin, other variables were analyzed including age, gender, body surface area (BSA), body mass index (BMI), and forced expiratory volume in 1 second as a percent of predicted (FEV1%) at surgery. Past medical history and smoking history were also obtained from the pre-operative history and physical examination. We defined current smokers as smokers who either still smoked or quit within 3 months of the surgical date. Former smokers include those patients who had quit smoking for at least 3 months prior to surgery. Perioperative outcomes studied include operative skin-to-skin time, EBL, postoperative complications, chest tube duration, hospital LOS, and in-hospital mortality, as well as survival at 1,3, and 5 years.

Differences in demographics between pre-albumin groups were assessed by independent sample $t$ test or Kruskal-Wallis test for continuous variables or by Pearson $\chi$-Squared test for dichotomous variables. Univariate and multivariable analyses for hospital LOS and chest tube duration was performed with generalized linear ($\gamma$ - log link) regression models (GLM), and for postoperative complications with logistic regression model. The difference in survival between the pre-albumin groups was assessed using log rank test. Probabilities of survival were calculated and plotted using the Kaplan-Meier method. Univariate and multivariable analysis for survival was performed using the Cox proportional hazard model and summarized as hazard ratios along with 95% confidence interval (CI). The statistical significance was set at 5% for all comparisons. All multivariable analyses were initially built by including all variables that were found statistically significant in a univariate analysis. The final multivariable models were selected by allowing variables with $P < 0.1$ to remain in the models.

## RESULTS

### Demographics and Pre-Operative Comorbidities

Of 459 patients who underwent robotic-assisted lobectomy during the study period, we identified 436 patients

**Table 1.**
Patient Demographics

| Patient Characteristics | Total N = 436 | Lowest Pre-albumin < 15 mg/dL N = 259 | Lowest Pre-albumin ≥ 15 mg/dL N = 177 | *p*-Value |
|---|---|---|---|---|
| Age*, yr | 67.5 ± 0.5 | 68.5 ± 0.6 | 66.2 ± 0.8 | **0.018** |
| BMI*, kg/m$^2$ | 28.0 ± 0.3 | 27.6 ± 0.4 | 28.6 ± 0.4 | 0.077 |
| BSA*, m$^2$ | 1.89 ± 0.01 | 1.87 ± 0.02 | 1.92 ± 0.02 | 0.057 |
| FEV1%* | 87.8 ± 0.9 | 85.9 ± 1.3 | 90.5 ± 1.3 | **0.012** |
| Gender, n (%) | — | — | — | 0.799 |
| Male | 183 (42%) | 110 (42.5%) | 73 (41.2%) | — |
| Female | 253 (58%) | 149 (57.5%) | 104 (58.8%) | |

*Mean ± standard error of mean (range).
BMI, body mass index; BSA, body surface area; FEV1%, forced expiratory volume in 1 second as percent of predicted.

who met the inclusion criteria, of which there were 183 (42%) men and 253 (58%) women (**Table 1**). The mean age at surgery was 67.5 years. There were 259 patients (59.3%) with a lowest postoperative pre-albumin level below 15 mg/dL (poor nutrition) and 177 patients (40.7%) with a lowest postoperative pre-albumin level at or above 15 mg/dL (adequate nutrition).

The demographic that significantly differed between nutritional status groups was age ($P$ = .018), with poor-nutrition patients being older compared to adequate-nutrition patients at the time of surgery (**Table 1**). Patients with poor nutrition also had decreased FEV1% ($P$ = .012) compared to patients with adequate nutrition (**Table 1**). Among pre-operative comorbidities, patients in the poor-nutrition group had a significantly higher rate of coronary artery disease (CAD) or myocardial infarction (MI) (20.1% vs 11.9%, $P$ = .024), cerebrovascular accidents (CVA) (5.8% vs 1.1%, $P$ = .013), gastroesophageal reflux disease (GERD) (23.2% vs 14.1%, $P$ = .019), chronic anemia (3.9% vs 0.6%, $P$ = .031), and pancreatitis (2.3% vs 0%, $P$ = .041) (**Table 2**). Additionally, patients with postoperative pre-albumin levels below 15 mg/dL had significantly larger tumors on average compared to patients whose postoperative pre-albumin levels remained at or above 15 mg/dL (3.6 cm vs 2.8 cm, $P < .001$) (**Table 3**). There were no significant differences in tumor pathology or pathological stage between groups.

### Intraoperative and Perioperative Outcomes

There were no significant differences in intraoperative complications between groups (**Table 4**). Patients with lowest postoperative pre-albumin levels below 15 mg/dL experienced a significantly greater rate of postoperative complications (44.2% vs 24.9%; $P < .001$) compared to patients with lowest postoperative pre-albumin at or above 15 mg/dL (**Table 5**). There was also a significantly higher EBL in the poor-nutrition group (200 mL vs 150 mL; $P < .001$) (**Table 6**). The poor-nutrition group experienced significantly longer median skin-to-skin duration (190 min vs 165 min, $P < .001$), chest tube duration (4 days vs 3 days, $P$ = .001), and hospital LOS (5 days vs 3 days, $P < .001$) (**Table 6**). Among postoperative complications, the poor-nutrition group experienced a significantly greater number of prolonged air leaks > 5 days (24% vs. 140.7%, $P$ = .017) and ≥ 7 days (21.3% vs 13.0%, $P$ = .026), pneumonias (100.1% vs 0.6%, $P < .001$), chyle leaks (50.8% vs 10.7%, $P$ = .034), and mucous plug requiring intervention (6.2% vs 0.6%, $P$ = .003) (**Table 5**).

### Univariate Analyses for Hospital Length of Stay, Chest Tube Duration, and Postoperative Complications

Univariate GLM analyses showed that pre-albumin, age, size of tumor, gender, and pre-operative CVA, hypertension, chronic obstructive pulmonary disease (COPD), kidney disease, chronic anemia, and FEV1% were significant predictors for length of stay (**Table 7**). The median hospital LOS for patients with lowest pre-albumin lower than 15 mg/dL was 1.6 days longer than patients with lowest pre-albumin above 15 mg/dL. Similarly, univariate GLM analyses showed that pre-albumin, gender, BMI, and pre-operative CVA, other arrhythmias, COPD, asthma, pneumonia, pulmonary fibrosis, GERD, chronic anemia, and

**Table 2.**
Smoking Status and Pre-operative Co-morbidities

| Preoperative Comorbidities | Total N = 436 | Lowest Pre-albumin < 15 mg/dL N = 259 | Lowest Pre-albumin ≥ 15 mg/dL N = 177 | *p*-Value |
|---|---|---|---|---|
| Smoking status: Current | 139 (31.9%) | 86 (33.2%) | 53 (29.9%) | 0.300 |
| Former | 216 (49.5%) | 131 (50.6%) | 85 (48.0%) | |
| Never | 81 (18.6%) | 42 (16.2%) | 39 (22.0%) | |
| COPD | 92 (21.1%) | 62 (23.9%) | 30 (16.9%) | 0.079 |
| Asthma | 32 (7.3%) | 21 (8.1%) | 11 (6.2%) | 0.457 |
| Heart valvular disease or cardiomyopathy | 30 (6.9%) | 20 (7.7%) | 10 (5.6%) | 0.401 |
| CAD or MI | 73 (16.7%) | 52 (20.1%) | 21 (11.9%) | **0.024** |
| CVA | 17 (3.9%) | 15 (5.8%) | 2 (1.1%) | **0.013** |
| Carotid stenosis | 22 (5%) | 14 (5.4%) | 8 (4.5%) | 0.678 |
| Congestive heart failure | 9 (2.1%) | 3 (1.2%) | 6 (3.4%) | 0.108 |
| Obstructive sleep apnea | 31 (7.1%) | 21 (8.1%) | 10 (5.6%) | 0.327 |
| Pulmonary embolism | 18 (4.2%) | 9 (3.5%) | 9 (5.1%) | 0.407 |
| Prior pneumonia | 37 (8.5%) | 24 (9.3%) | 13 (7.3%) | 0.479 |
| Pulmonary fibrosis | 5 (1.1%) | 5 (1.9%) | 0 (0.0%) | 0.063 |
| Cirrhosis or liver failure | 2 (0.5%) | 1 (0.4%) | 1 (0.6%) | 0.786 |
| Diabetes mellitus | 71 (16.3%) | 41 (15.8%) | 30 (16.9%) | 0.756 |
| GERD | 85 (19.5%) | 60 (23.2%) | 25 (14.1%) | **0.019** |
| Kidney disease | 16 (3.7%) | 10 (3.9%) | 6 (3.4%) | 0.797 |
| Chronic anemia | 11 (2.5%) | 10 (3.9%) | 1 (0.6%) | **0.031** |
| Coagulation disorders, hemophilia, or thrombocytopenia | 7 (1.6%) | 5 (1.9%) | 2 (1.1%) | 0.514 |
| Previous cancers | 189 (43.3%) | 106 (40.9%) | 83 (46.9%) | 0.217 |
| Hypertension | 245 (56.2%) | 150 (57.9%) | 95 (53.7%) | 0.381 |
| Hyperlipidemia | 212 (48.6%) | 129 (49.8%) | 83 (46.9%) | 0.550 |
| Atrial fibrillation | 31 (7.1%) | 15 (5.8%) | 16 (9.0%) | 0.195 |
| Other arrhythmias | 22 (5%) | 14 (5.4%) | 8 (4.5%) | 0.678 |
| Peripheral vascular disease | 17 (3.9%) | 11 (4.2%) | 6 (3.4%) | 0.650 |
| Pancreatitis | 6 (1.4%) | 6 (2.3%) | 0 (0.0%) | **0.041** |

COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease; MI, myocardial infarction; CVA, cerebrovascular accident; GERD, gastroesophageal reflux disease.

FEV1% were significant predictors of chest tube duration (**Table 8**). The median chest tube duration for patients with lowest pre-albumin lower than 15 mg/dL was 1.5 days longer than that for patients with lowest pre-albumin equal to or above 15 mg/dL.

Univariate logistic regression analysis showed that pre-albumin, age, female gender, and pre-operative other arrhythmias, hypertension, COPD, GERD, and chronic anemia were significant predictors of postoperative complications (**Table 9**). Patients with lowest pre-albumin less than 15 mg/dL had a 58% higher chance than patients with lowest pre-albumin greater than or equal to 15 mg/dL to develop postoperative complications. Variables found significant in univariate analyses were considered for inclusion in the multivariable models as control variables.

**Table 3.**
Tumor Characteristics

| Tumor Characteristics | Total | Lowest Pre-albumin < 15 mg/dL | Lowest Pre-albumin ≥ 15 mg/dL | *p*-Value |
|---|---|---|---|---|
| Tumor size[a], cm | N = 433<br>3.26 ± 0.1 (0.2–14.2) | N = 258<br>3.6 ± 0.1 (0.2–14.2) | N = 175<br>2.8 ± 0.1 (0.8–9.0) | **<0.001** |
| Pathology, n (%) | N = 435 | N = 258 | N = 177 | 0.594 |
| Primary lung cancer | 402 (92.2%) | 241 (93.1%) | 161 (91%) | — |
| Pulmonary metastasis | 30 (6.9%) | 15 (5.8%) | 15 (8.5%) | — |
| Other pathology[b] | 3 (0.7%) | 2 (0.8%) | 1 (0.6%) | — |
| Pathologic stage for primary lung cancers, n (%) | N = 400 | N = 240 | N = 160 | 0.261 |
| Stage IA | 168 (42.0%) | 93 (38.8%) | 75 (46.9%) | — |
| Stage IB | 50 (12.5%) | 27 (11.4%) | 23 (14.4%) | — |
| Stage IIA | 56 (14.0%) | 33 (13.8%) | 23 (14.4%) | — |
| Stage IIB | 27 (6.8%) | 21 (8.8%) | 6 (3.8%) | — |
| Stage IIIA | 82 (20.5%) | 54 (22.5%) | 28 (17.5%) | — |
| Stage IIIB | 6 (1.5%) | 5 (2.1%) | 1 (0.6%) | — |
| Stage IV | 11 (2.8%) | 7 (2.9%) | 4 (2.5%) | — |

[a]Mean ± standard error of mean (range)
[b]Benign or lymphoma.

**Table 4.**
Intra-operative Complications

| Complication Variable | Total N = 435 | Lowest Pre-albumin < 15 mg/dL N = 258 | Lowest Pre-albumin ≥ 15 mg/dL N = 177 | *p*-Value |
|---|---|---|---|---|
| Overall Intraoperative Complications | 27 (6.2%) | 20 (7.8%) | 7 (4.0%) | 0.107 |
| Bleeding (pulmonary artery) | 12 (2.8%) | 10 (3.9%) | 2 (1.1%) | 0.086 |
| Bleeding (pulmonary vein) | 5 (1.1%) | 3 (1.2%) | 2 (1.1%) | 0.975 |
| Bleeding (other) | 1 (0.2%) | 1 (0.4%) | 0 (0.0%) | 0.407 |
| Recurrent laryngeal nerve injury | 3 (0.7%) | 3 (1.2%) | 0 (0.0%) | 0.150 |
| Phrenic nerve injury | 1 (0.2%) | 0 (0.0%) | 1 (0.6%) | 0.227 |
| Bronchial injury | 5 (1.1%) | 3 (1.2%) | 2 (1.1%) | 0.975 |
| Diaphragm injury | 1 (0.2%) | 1 (0.4%) | 0 (0.0%) | 0.407 |

### Multivariable Analyses for Length of Stay, Chest Tube Duration, and Postoperative Complications

In multivariable analyses, pre-operative COPD was significantly and independently predictive of increased hospital LOS, increased chest tube duration, and increased postoperative complications. Pre-operative GERD and gender both significantly predicted longer chest tube duration and increased postoperative complications. Pre-operative arrhythmias other than atrial fibrillation (AF) were found to be significantly predictive of postoperative complications, while pre-operative chronic anemia was significantly predictive of decreased postoperative complications. Pre-operative pancreatitis was significantly predictive for longer chest tube duration (**Tables 10–12**).

**Table 5.**
Postoperative Complications

| Complications | Total N = 435 | Lowest Pre-albumin < 15 mg/dL N = 258 | Lowest Pre-albumin ≥ 15 mg/dL N = 177 | *p*-Value |
|---|---|---|---|---|
| Overall postoperative complications | 158 (36.3%) | 114 (44.2%) | 44 (24.9%) | **<0.001** |
| Pulmonary-related complications | | | | |
| Prolonged air leak ≥ 5 days | 88 (20.2%) | 62 (24.0%) | 26 (14.7%) | **0.017** |
| Prolong air leak >7 days w/wo subcutaneous emphysema | 78 (17.9%) | 55 (21.3%) | 23 (13.0%) | **0.026** |
| Pneumonia | 27 (6.2%) | 26 (10.1%) | 1 (0.6%) | **0.000** |
| Chyle leak | 18 (4.1%) | 15 (5.8%) | 3 (1.7%) | **0.034** |
| Mucous plug requiring intervention | 17 (3.9%) | 16 (6.2%) | 1 (0.6%) | **0.003** |
| Respiratory failure | 8 (1.8%) | 7 (2.7%) | 1 (0.6%) | 0.101 |
| Hypoxia | 5 (1.1%) | 4 (1.6%) | 1 (0.6%) | 0.344 |
| Pneumothorax after chest tube removal requiring intervention | 7 (1.6%) | 4 (1.6%) | 3 (1.7%) | 0.906 |
| Aspiration | 6 (1.4%) | 4 (1.6%) | 2 (1.1%) | 0.712 |
| Hemothorax | 4 (0.9%) | 3 (1.2%) | 1 (0.6%) | 0.521 |
| Pulmonary embolism | 2 (0.5%) | 2 (0.8%) | 0 (0.0%) | 0.240 |
| Cardiovascular complications | | | | |
| Atrial fibrillation | 47 (10.8%) | 32 (12.4%) | 15 (8.5%) | 0.195 |
| Other arrythmia requiring intervention | 5 (1.1%) | 3 (1.2%) | 2 (1.1%) | 0.975 |
| Shock/multiorgan system failure | 5 (1.1%) | 4 (1.6%) | 1 (0.6%) | 0.344 |
| Cardiopulmonary arrest | 3 (0.7%) | 3 (1.2%) | 0 (0.0%) | 0.150 |
| Myocardial infarction | 2 (0.5%) | 2 (0.8%) | 0 (0.0%) | 0.240 |
| Cerebrovascular accident | 1 (0.2%) | 1 (0.4%) | 0 (0.0%) | 0.407 |

**Table 6.**
Perioperative Outcomes

| Outcomes | Lowest Pre-albumin < 15 mg/dL N = 258 | Lowest Pre-albumin ≥ 15 mg/dL N = 177 | *p*-value |
|---|---|---|---|
| Skin-to-Skin Duration, min; median (IQR) | 190 (153–241) | 165 (141–203) | **<0.001** |
| EBL, mL; median (IQR) | 200 (100–350) | 150 (50–237) | **<0.001** |
| Postop Complications, n (%) | 114 (44.2%) | 44 (24.9%) | **<0.001** |
| Chest tube duration, days; median (IQR) | 4 (3–7) | 3 (2–4) | **0.001** |
| LOS, days; median (IQR) | 5 (4–8) | 3 (3–5) | **<0.001** |
| In-Hospital Mortality, n (%) | 4 (1.6%) | 2 (1.1%) | 0.712 |

IQR, interquartile range; EBL, estimated blood loss; Postop, postoperative; LOS, length of stay.

**Table 7.**
Univariate Generalized Linear Model Analysis for Hospital Length of Stay

| Variables | b | S.E. (b) | Exp (b) | 95% Wald CI Exp (b) Lower | Upper | *p*-value |
|---|---|---|---|---|---|---|
| Pre-albumin <15mg/dL | 0.477 | 0.0566 | 1.611 | 1.442 | 1.800 | **<0.001** |
| Age | 0.008 | 0.0029 | 1.008 | 1.003 | 1.014 | **0.004** |
| BSA | −0.054 | 0.1167 | 0.947 | 0.754 | 1.190 | 0.641 |
| BMI | −0.006 | 0.0049 | 0.994 | 0.985 | 1.004 | 0.233 |
| Preop CVA | 0.438 | 0.1469 | 1.55 | 1.162 | 2.067 | **0.003** |
| Preop CAD or previous MI | 0.112 | 0.0777 | 1.119 | 0.961 | 1.302 | 0.15 |
| Preop Heart Valvular Disease or Cardiomyopathy | 0.189 | 0.1161 | 1.208 | 0.962 | 1.516 | 0.104 |
| Preop Atrial Fibrillation | 0.159 | 0.1144 | 1.172 | 0.936 | 1.467 | 0.165 |
| Preop Other Arrhythmias | 0.119 | 0.1346 | 1.126 | 0.865 | 1.465 | 0.379 |
| Preop Carotid Stenosis | 0.227 | 0.1315 | 1.255 | 0.969 | 1.624 | 0.084 |
| Preop CHF | −0.130 | 0.2075 | 0.878 | 0.585 | 1.319 | 0.532 |
| Preop Hypertension | 0.142 | 0.0577 | 1.153 | 1.029 | 1.290 | **0.014** |
| Preop Hyperlipidemia | −0.010 | 0.0576 | 0.99 | 0.885 | 1.108 | 0.868 |
| Preop Peripheral Vascular Disease | −0.047 | 0.1482 | 0.954 | 0.713 | 1.275 | 0.75 |
| Preop COPD | 0.300 | 0.0697 | 1.35 | 1.177 | 1.547 | **<0.001** |
| Preop Obstructive Sleep Apnea | −0.014 | 0.1099 | 0.986 | 0.795 | 1.223 | 0.897 |
| Preop Asthma | −0.229 | 0.111 | 0.795 | 0.640 | 0.989 | 0.039 |
| Preop Pneumonia | 0.175 | 0.1017 | 1.191 | 0.976 | 1.455 | 0.085 |
| Preop Pulmonary Fibrosis | −0.256 | 0.277 | 0.774 | 0.450 | 1.331 | 0.354 |
| Preop PE or DVT | 0.174 | 0.1442 | 1.19 | 0.897 | 1.578 | 0.229 |
| Preop Cirrhosis or Liver Failure | −0.277 | 0.4367 | 0.758 | 0.322 | 1.784 | 0.526 |
| Preop Pancreatitis | 0.479 | 0.2523 | 1.614 | 0.985 | 2.649 | 0.058 |
| Preop GERD | 0.063 | 0.073 | 1.065 | 0.923 | 1.229 | 0.388 |
| Preop Kidney Disease | 0.344 | 0.1561 | 1.411 | 1.040 | 1.916 | **0.027** |
| Preop Chronic Anemia | −0.473 | 0.1871 | 0.623 | 0.432 | 0.899 | **0.011** |
| Preop Coagulation, Hemophilia, or Thrombocytopenia | −0.233 | 0.2346 | 0.792 | 0.501 | 1.255 | 0.321 |
| Preop Diabetes Mellitus | 0.077 | 0.0765 | 1.08 | 0.930 | 1.255 | 0.313 |
| Previous Cancers | −0.042 | 0.058 | 0.959 | 0.856 | 1.075 | 0.467 |
| Size of tumor (cm) | 0.031 | 0.0151 | 1.031 | 1.002 | 1.063 | **0.038** |
| Female | −0.159 | 0.0577 | 0.853 | 0.762 | 0.956 | **0.006** |
| Preop FEV1% | −0.006 | 0.0014 | 0.994 | 0.991 | 0.997 | **<0.001** |

b, unstandardized model coefficient; S.E. (b), standard error for model coefficient "b"; Exp (b), exponential of model coefficient "b"; CI, confidence interval; BSA, body surface area; BMI, body mass index; Preop, preoperative; CVA, cerebrovascular accident; CAD/MI, coronary artery disease/myocardial infarction; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; PE, pulmonary embolus; DVT, deep venous thrombosis; GERD, gastroesophageal reflux disease; FEV1%, forced expiratory volume in 1 second as a percent of predicted.

**Table 8.**
Univariate Generalized Linear Model Analysis for Chest Tube Duration

| Variables | b | S.E. (b) | 95% Wald CI Exp (b) | | | |
|---|---|---|---|---|---|---|
| | | | Exp (b) | Lower | Upper | *p*-value |
| Pre-albumin < 15mg/dL | 0.375 | 0.0725 | 1.455 | 1.262 | 1.677 | **<0.001** |
| Age | 0.006 | 0.0038 | 1.006 | 0.998 | 1.013 | 0.133 |
| BSA | −0.050 | 0.1465 | 0.951 | 0.714 | 1.267 | 0.734 |
| BMI | −0.019 | 0.0061 | 0.981 | 0.969 | 0.993 | **0.002** |
| Preop CVA | 0.367 | 0.1825 | 1.443 | 1.010 | 2.065 | **0.044** |
| Preop CAD or previous MI | 0.130 | 0.096 | 1.139 | 0.944 | 1.374 | 0.175 |
| Preop Heart Valvular Disease or Cardiomyopathy | 0.013 | 0.1438 | 1.013 | 0.764 | 1.343 | 0.929 |
| Preop Atrial Fibrillation | 0.152 | 0.1415 | 1.164 | 0.882 | 1.536 | 0.284 |
| Preop Other Arrhythmias | 0.335 | 0.1657 | 1.398 | 1.011 | 1.935 | **0.043** |
| Preop Carotid Stenosis | 0.038 | 0.1629 | 1.039 | 0.755 | 1.429 | 0.816 |
| Preop CHF | −0.070 | 0.2563 | 0.932 | 0.564 | 1.542 | 0.785 |
| Preop Hypertension | 0.117 | 0.0715 | 1.124 | 0.976 | 1.293 | 0.103 |
| Preop Hyperlipidemia | 0.024 | 0.0711 | 1.024 | 0.890 | 1.177 | 0.741 |
| Preop Peripheral Vascular Disease | −0.137 | 0.183 | 0.872 | 0.610 | 1.249 | 0.455 |
| Preop COPD | 0.376 | 0.0861 | 1.456 | 1.230 | 1.725 | **<0.001** |
| Preop Obstructive Sleep Apnea | 0.015 | 0.1357 | 1.015 | 0.778 | 1.324 | 0.912 |
| Preop Asthma | −0.294 | 0.137 | 0.745 | 0.569 | 0.974 | **0.032** |
| Preop Pneumonia | 0.264 | 0.1254 | 1.302 | 1.019 | 1.665 | **0.035** |
| Preop Pulmonary Fibrosis | −0.894 | 0.3407 | 0.409 | 0.210 | 0.798 | **0.009** |
| Preop PE or DVT | −0.026 | 0.1784 | 0.974 | 0.687 | 1.381 | 0.882 |
| Preop Cirrhosis or Liver Failure | −0.667 | 0.5389 | 0.513 | 0.179 | 1.477 | 0.216 |
| Preop Pancreatitis | 0.750 | 0.3107 | 2.117 | 1.151 | 3.892 | 0.016 |
| Preop GERD* | 0.282 | 0.0894 | 1.326 | 1.112 | 1.579 | **0.002** |
| Preop Kidney Disease | 0.093 | 0.1937 | 1.097 | 0.751 | 1.603 | 0.632 |
| Preop Chronic Anemia | −0.675 | 0.2309 | 0.509 | 0.323 | 0.799 | **0.003** |
| Preop Coagulation, Hemophilias, or Thrombocytopenia | −0.538 | 0.2892 | 0.584 | 0.332 | 1.030 | 0.063 |
| Preop Diabetes Mellitus | 0.058 | 0.0946 | 1.06 | 0.880 | 1.275 | 0.541 |
| Previous Cancers | −0.002 | 0.0717 | 0.998 | 0.868 | 1.149 | 0.98 |
| Size of tumor (cm) | 0.018 | 0.0183 | 1.018 | 0.982 | 1.055 | 0.333 |
| Female | −0.307 | 0.0706 | 0.736 | 0.640 | 0.845 | **<0.001** |
| Preop FEV1% | −0.008 | 0.0017 | 0.992 | 0.989 | 0.996 | **<0.001** |

b, unstandardized model coefficient; S.E. (b), standard error for model coefficient "b"; Exp (b), exponential of model coefficient "b"; CI, confidence interval; BSA, body surface area; BMI, body mass index; Preop, preoperative; CVA, cerebrovascular accident; CAD/MI, coronary artery disease/myocardial infarction; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; PE, pulmonary embolus; DVT, deep venous thrombosis; GERD, gastroesophageal reflux disease; FEV1%, forced expiratory volume in 1 second as a percent of predicted.

**Table 9.**
Univariate Logistic Regression Analysis for Postoperative Complications

| Variables | B | S.E. | Wald | *p*-Value | OR | 95% CI for OR Lower | Upper |
|---|---|---|---|---|---|---|---|
| Constant | −0.234 | 0.125 | 3.473 | 0.062 | 0.792 | - | - |
| Pre-albumin < 15mg/dL | −0.873 | 0.214 | 16.564 | **<0.001** | 0.418 | 0.275 | 0.636 |
| Age | 0.026 | 0.010 | 5.960 | **0.015** | 1.026 | 1.005 | 1.047 |
| BSA | 0.597 | 0.387 | 2.380 | 0.123 | 1.817 | 0.851 | 3.881 |
| BMI | 0.000 | 0.017 | 0.000 | 0.998 | 1.000 | 0.968 | 1.033 |
| Preop Cerebrovascular Accident | 0.589 | 0.482 | 1.496 | 0.221 | 1.803 | 0.701 | 4.634 |
| Preop CAD or MI | 0.394 | 0.256 | 2.365 | 0.124 | 1.483 | 0.898 | 2.450 |
| Preop Heart Valvular Disease or Cardiomyopathy | 0.023 | 0.392 | 0.003 | 0.953 | 1.023 | 0.475 | 2.207 |
| Preop Atrial Fibrillation | 0.682 | 0.373 | 3.331 | 0.068 | 1.977 | 0.951 | 4.110 |
| Preop Other Arrhythmias | 0.986 | 0.445 | 4.910 | **0.027** | 2.681 | 1.121 | 6.415 |
| Preop Carotid Stenosis | −0.064 | 0.449 | 0.020 | 0.887 | 0.938 | 0.389 | 2.262 |
| Preop Congestive Heart Failure | −0.697 | 0.808 | 0.744 | 0.388 | 0.498 | 0.102 | 2.427 |
| Preop Hypertension | 0.520 | 0.200 | 6.770 | **0.009** | 1.682 | 1.137 | 2.489 |
| Preop Hyperlipidemia | 0.254 | 0.195 | 1.700 | 0.192 | 1.289 | 0.880 | 1.888 |
| Preop Peripheral Vascular Disease | −0.402 | 0.535 | 0.564 | 0.453 | 0.669 | 0.234 | 1.910 |
| Preop COPD | 0.701 | 0.234 | 9.003 | **0.003** | 2.016 | 1.275 | 3.187 |
| Preop Obstructive Sleep Apnea | 0.359 | 0.360 | 0.997 | 0.318 | 1.433 | 0.707 | 2.901 |
| Preop Asthma | 0.148 | 0.370 | 0.160 | 0.689 | 1.160 | 0.561 | 2.397 |
| Preop Pneumonia | 0.404 | 0.334 | 1.466 | 0.226 | 1.498 | 0.779 | 2.882 |
| Preop Pulmonary Fibrosis | −0.826 | 1.122 | 0.541 | 0.462 | 0.438 | 0.049 | 3.950 |
| Preop Pulmonary Embolus or DVT | 0.484 | 0.470 | 1.059 | 0.303 | 1.622 | 0.646 | 4.077 |
| Preop Cirrhosis or Liver Failure | 0.571 | 1.418 | 0.162 | 0.687 | 1.770 | 0.110 | 28.479 |
| Preop Pancreatitis | 1.279 | 0.872 | 2.153 | 0.142 | 3.593 | 0.651 | 19.828 |
| Preop GERD | 0.598 | 0.240 | 6.205 | **0.013** | 1.819 | 1.136 | 2.912 |
| Preop Kidney Disease | 0.590 | 0.510 | 1.339 | 0.247 | 1.804 | 0.664 | 4.899 |
| Preop Chronic Anemia | −1.763 | 1.053 | 2.801 | **0.094** | 0.172 | 0.022 | 1.352 |
| Preop Coagulation, Hemophilias, or Thrombocytopenia | 0.285 | 0.770 | 0.137 | 0.711 | 1.330 | 0.294 | 6.015 |
| Preop Diabetes Mellitus | 0.377 | 0.252 | 2.228 | 0.136 | 1.458 | 0.889 | 2.391 |
| Previous Cancers | 0.040 | 0.196 | 0.041 | 0.840 | 1.040 | 0.709 | 1.527 |
| Size of tumor (cm) | 0.078 | 0.049 | 2.536 | 0.111 | 1.081 | 0.982 | 1.189 |
| Female | 0.698 | 0.197 | 12.501 | **<0.001** | 2.009 | 1.365 | 2.958 |

B, unstandardized regression weight; S.E, standard error for “b”; OR, odds ratio; CI, confidence interval; Preop, pre-operative; BSA, body surface area; BMI, body mass index; CAD, coronary artery disease; MI, myocardial infarction; COPD, chronic obstructive pulmonary lung disease; DVT, deep vein thrombosis; GERD, gastroesophageal reflux disease.

After controlling for the variables that were found significant in univariate analyses, having lowest postoperative pre-albumin levels below 15 mg/dL remained a significant predictor for hospital LOS ($P < .001$) (**Table 10**), chest tube duration ($P < .001$) (**Table 11**), and postoperative complications ($P < .001$) (**Table 12**). Specifically, the median hospital LOS for patients with lowest pre-albumin less than 15 mg/dL was 1.5 days longer than for patients

**Table 10.**
Multivariable Generalized Linear Model Analysis for Hospital Length of Stay

| | | | 95% Wald CI Exp (b) | | | |
|---|---|---|---|---|---|---|
| **Variables** | **b** | **S.E. (b)** | **Exp (b)** | **Lower** | **Upper** | ***p*-value** |
| Intercept | 1.34 | 0.345 | 3.819 | 1.943 | 7.516 | **<0.001** |
| Pre-albumin < 15mg/dL | 0.43 | 0.055 | 1.542 | 1.384 | 1.719 | **<0.001** |
| Age | 0.01 | 0.003 | 1.007 | 1.002 | 1.013 | **0.007** |
| Preop CVA | 0.24 | 0.140 | 1.275 | 0.969 | 1.031 | 0.082 |
| Preop COPD | 0.22 | 0.068 | 1.24 | 1.085 | 0.921 | **0.002** |
| Preop Kidney Disease | 0.27 | 0.142 | 1.311 | 0.992 | 1.008 | 0.057 |
| Preop Chronic Anemia | −0.68 | 0.170 | 0.509 | 0.365 | 2.740 | **<0.001** |
| Preop FEV1% | 0.00 | 0.001 | 0.996 | 0.993 | 0.999 | **0.005** |

b, unstandardized model coefficient; S.E. (b), standard error for model coefficient "b"; Exp (b), exponential of model coefficient "b"; CI, confidence interval; Preop, pre-operative; CVA, cerebrovascular accident; COPD, chronic obstructive pulmonary lung disease; FEV1%, forced expiratory volume in 1 second as a percent of predicted.

**Table 11.**
Multivariable Generalized Linear Model Analysis for Chest Tube Duration

| | | | 95% Wald CI Exp (b) | | | |
|---|---|---|---|---|---|---|
| **Variables** | **b** | **S.E. (b)** | **Exp (b)** | **Lower** | **Upper** | ***p*-value** |
| Intercept | 1.582 | 0.474 | 4.865 | 1.923 | 12.305 | 0.001 |
| Pre-albumin < 15mg/dL | 0.314 | 0.070 | 1.369 | 1.195 | 1.570 | <0.001 |
| Female | −0.300 | 0.069 | 0.741 | 0.647 | 0.849 | < 0.001 |
| BMI | −0.012 | 0.006 | 0.988 | 0.977 | 0.999 | 0.036 |
| Preop Other Arrhythmias | 0.467 | 0.152 | 1.595 | 1.184 | 2.151 | 0.002 |
| Preop COPD | 0.248 | 0.086 | 1.281 | 1.083 | 1.517 | 0.004 |
| Preop Asthma | −0.334 | 0.128 | 0.716 | 0.557 | 0.920 | 0.009 |
| Preop Pulmonary Fibrosis | −0.658 | 0.322 | 0.518 | 0.276 | 0.973 | 0.041 |
| Preop GERD | 0.300 | 0.085 | 1.35 | 1.145 | 1.594 | <0.001 |
| Preop Chronic Anemia | −0.703 | 0.216 | 0.495 | 0.324 | 0.755 | 0.001 |
| Preop FEV1% | −0.004 | 0.002 | 0.996 | 0.993 | 1.000 | 0.045 |

b, unstandardized model coefficient; S.E. (b), standard error for model coefficient "b"; Exp (b), exponential of model coefficient "b"; CI, confidence interval; Preop, pre-operative; CVA, cerebrovascular accident; COPD, chronic obstructive pulmonary lung disease, FEV1%, forced expiratory volume in 1 second as a percent of predicted.

with lowest pre-albumin greater than or equal to 15 mg/dL, while the median chest tube duration was 1.37 times higher. Patients with lowest pre-albumin less than 15 mg/dL had a 55% higher chance of developing postoperative complications than patients with lowest pre-albumin greater than or equal to 15 mg/dL.

## Survival Analysis

Patients with lowest postoperative pre-albumin below 15 mg/dL had significantly lower 1-year overall survival (OS) (OS; hazard ratio [HR]:0.421, 95% CI: 0.215–0.825, $P = .012$), 3-year OS (HR:0.493, 95% CI: 0.319–

**Table 12.**
Multivariable Logistic Regression Analysis for Postoperative Complications

| Variables | B | S.E. | Wald | *p*-Value | OR | 95% CI OR | |
|---|---|---|---|---|---|---|---|
| Pre-albumin 15mg/dL | −0.879 | 0.224 | 15.411 | <0.001 | 0.415 | 0.268 | 0.644 |
| Female | 0.708 | 0.215 | 10.887 | 0.001 | 2.030 | 1.333 | 3.090 |
| Preop COPD | 0.620 | 0.253 | 6.028 | 0.014 | 1.859 | 1.133 | 3.050 |
| Preop Other Arrhythmias | 1.270 | 0.476 | 7.114 | 0.008 | 3.561 | 1.400 | 9.056 |
| Preop GERD | 0.561 | 0.261 | 4.623 | 0.032 | 1.752 | 1.051 | 2.921 |
| Preop Chronic Anemia | −2.571 | 1.116 | 5.310 | 0.021 | 0.076 | 0.009 | 0.681 |
| Constant | −0.824 | 0.186 | 19.567 | <0.001 | 0.439 | — | — |

b, unstandardized regression weight; S.E., standard error for "b"; OR, odds ratio; CI, confidence interval; Preop, pre-operative; COPD, chronic obstructive pulmonary lung disease; GERD, gastroesophageal reflux disease.

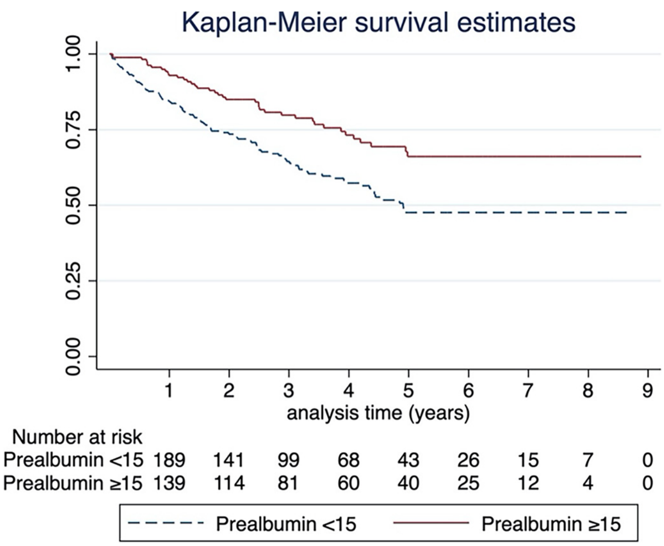


**Figure 1.** Kaplan-Meier Survival Curves Based on Lowest Postoperative Pre-albumin Level.

0.762, *P* = .001), and 5-year OS (HR:0.524, 95% CI: 0.361–0.761, *P* = .001) compared to patients with lowest postoperative pre-albumin at or above 15 mg/dL (**Figure 1**).

In univariate Cox regression analyses, pre-albumin, age, gender, size of tumor, and pre-operative CVA, coronary artery disease or myocardial infarction, atrial fibrillation, COPD, pulmonary fibrosis, pulmonary embolism or deep vein thrombosis, and diabetes mellitus were significant predictors of OS (**Table 13**). Patients with lowest pre-albumin greater than or equal to 15 mg/dL were 48% less likely to die than patients with lowest pre-albumin less than 15 mg/dL (HR:0.524, 95% CI: 0.361–0.761, *P* = .001).

In a multivariable analysis controlled for age, gender, preop CVA, pre-op atrial fibrillation, pre-op pulmonary fibrosis, and size of tumor, lowest postoperative pre-albumin remained a significant predictor of survival. Specifically, patients with lowest postoperative pre-albumin equal to or above 15 mg/dL at any time point in the study period were 35% less likely to die than patients with lowest pre-albumin below 15 mg/dL (HR: 0.652, 95% CI: 0.438, 0.969, *P* = .034) (**Table 14**).

## DISCUSSION

Our results suggest that perioperative nutrition status, as measured by postoperative pre-albumin, plays an important role in predicting chest tube duration, hospital LOS, postoperative complications, and long-term survival in lung cancer patients following RAVT pulmonary lobectomy. Specifically, in this study we identified that patients who dropped below 15 mg/dL of pre-albumin during their hospital stay were at increased risk for longer chest tube duration and hospital LOS, higher rates of postoperative complications, and worse overall survival. Patients with improved pre-operative nutritional status have been shown to have less significant drops in albumin levels in the postoperative period.[14] By extension, we would predict that patients who have less significant drops in pre-albumin levels during the postoperative period are the patients with higher pre-operative pre-albumin levels. Studies have shown that perioperative interventions for improving nutritional status in lung cancer patients undergoing surgical resection via various modalities are associated with decreased hospital LOS and chest tube duration, reduced number of postoperative complications, decreased cost of patient care,

**Table 13.**
Univariate Cox Regression Analysis for Survival

| Variables | B | SE | Wald | *p*-Value | HR | 95.0% CI | |
|---|---|---|---|---|---|---|---|
| Pre-albumin < 15mg/dL | −0.646 | 0.19 | 11.514 | **0.001** | 0.524 | 0.361 | 0.761 |
| Age | 0.032 | 0.009 | 13.553 | **<0.001** | 1.033 | 1.015 | 1.050 |
| BSA | 0.357 | 0.317 | 1.272 | 0.259 | 1.429 | 0.768 | 2.659 |
| BMI | −0.005 | 0.015 | 0.111 | 0.739 | 0.995 | 0.967 | 1.024 |
| Preop CVA | 0.862 | 0.329 | 6.887 | **0.009** | 2.368 | 1.244 | 4.508 |
| Preop CAD or MI | 0.565 | 0.196 | 8.335 | **0.004** | 1.760 | 1.199 | 2.583 |
| Preop Heart Valvular Disease/Cardiomyopathy | 0.167 | 0.301 | 0.309 | 0.578 | 1.182 | 0.655 | 2.132 |
| Preop Atrial Fibrillation | 0.722 | 0.273 | 7.007 | **0.008** | 2.059 | 1.206 | 3.516 |
| Preop Other Arrhythmias | 0.002 | 0.363 | 0.000 | 0.995 | 1.002 | 0.492 | 2.043 |
| Preop Carotid Stenosis | 0.224 | 0.327 | 0.469 | 0.493 | 1.252 | 0.659 | 2.378 |
| Preop CHF | 0.814 | 0.508 | 2.570 | 0.109 | 2.256 | 0.834 | 6.100 |
| Preop Hypertension | 0.431 | 0.168 | 6.549 | **0.010** | 1.539 | 1.106 | 2.140 |
| Preop Hyperlipidemia | 0.306 | 0.164 | 3.493 | 0.062 | 1.358 | 0.985 | 1.871 |
| Preop Peripheral Vascular Disease | 0.634 | 0.344 | 3.388 | 0.066 | 1.884 | 0.960 | 3.700 |
| Preop COPD | 0.437 | 0.190 | 5.301 | **0.021** | 1.547 | 1.067 | 2.244 |
| Preop OSA | 0.067 | 0.328 | 0.041 | 0.839 | 1.069 | 0.562 | 2.031 |
| Preop Asthma | −0.109 | 0.327 | 0.111 | 0.739 | 0.897 | 0.472 | 1.703 |
| Preop Pneumonia | 0.017 | 0.290 | 0.004 | 0.953 | 1.017 | 0.576 | 1.797 |
| Preop Pulmonary Fibrosis | 1.722 | 0.512 | 11.296 | **0.001** | 5.593 | 2.050 | 15.264 |
| Preop PE or DVT | 0.742 | 0.328 | 5.112 | **0.024** | 2.099 | 1.104 | 3.992 |
| Preop Cirrhosis or Liver Failure | 0.072 | 1.004 | 0.005 | 0.943 | 1.075 | 0.150 | 7.690 |
| Preop Pancreatitis | 0.936 | 0.584 | 2.566 | 0.109 | 2.549 | 0.811 | 8.007 |
| Preop GERD* | 0.146 | 0.201 | 0.522 | 0.470 | 1.157 | 0.779 | 1.717 |
| Preop Kidney Disease | 0.712 | 0.389 | 3.357 | 0.067 | 2.038 | 0.952 | 4.365 |
| Preop Chronic Anemia | 0.094 | 0.584 | 0.026 | 0.873 | 1.098 | 0.350 | 3.448 |
| Preop Coagulation, Hemophilias, or Thrombocytopenia | −3.019 | 3.962 | 0.581 | 0.446 | 0.049 | 0.000 | 115.034 |
| Preop Diabetes Mellitus | 0.397 | 0.195 | 4.145 | **0.042** | 1.487 | 1.015 | 2.178 |
| Previous Cancers | −0.102 | 0.164 | 0.387 | 0.534 | 0.903 | 0.655 | 1.245 |
| Size of tumor (cm) | 0.186 | 0.031 | 35.757 | **<0.001** | 1.204 | 1.133 | 1.280 |
| Gender | 0.645 | 0.164 | 15.552 | **<0.001** | 1.907 | 1.383 | 2.628 |

b, unstandardized model coefficient; SE, standard error for "b"; HR, hazard ratio; CI, confidence interval; Preop, pre-operative; BSA, body surface area; BMI, body mass index; CVA, cerebrovascular accident; CAD, coronary artery disease; MI, myocardial infarction; CHF, congestive heart failure; COPD, chronic obstructive pulmonary lung disease; PE, pulmonary embolism; DVT, deep vein thrombosis; GERD, gastroesophageal reflux disease.

improved lung function, and improved morbidity and mortality.[14–17]

In our analysis of OS at 1, 3, and 5 years postoperatively, low postoperative pre-albumin and, thus, poor nutritional status was significantly predictive of decreased survival. Specifically, in our study patients with adequate nutrition were 35% less likely to die compared to patients with poor nutrition (lowest pre-albumin less than 15 mg/dL). This finding is consistent with literature that has identified poor nutrition to be independently associated with decreased OS following thoracotomy and lobectomy.[5]

**Table 14.**
Multivariable Cox Regression Analysis for Survival

| Parameters | B | SE | Wald | $p$-Value | HR | 95.0% CI | |
|---|---|---|---|---|---|---|---|
| Pre-albumin < 15mg/dL | −0.428 | 0.202 | 4.482 | 0.034 | 0.652 | 0.438 | 0.969 |
| Age | 0.022 | 0.010 | 5.069 | 0.024 | 1.022 | 1.003 | 1.042 |
| Female | 0.442 | 0.181 | 5.987 | 0.014 | 1.555 | 1.092 | 2.216 |
| Preop CVA | 0.876 | 0.343 | 6.527 | 0.011 | 2.402 | 1.226 | 4.706 |
| Preop Atrial Fibrillation | 0.677 | 0.301 | 5.036 | 0.025 | 1.967 | 1.089 | 3.552 |
| Preop Pulmonary Fibrosis | 1.252 | 0.526 | 5.661 | 0.017 | 3.498 | 1.247 | 9.811 |
| Size of tumor (cm) | 0.193 | 0.034 | 32.891 | < 0.001 | 1.212 | 1.135 | 1.295 |

B, unstandardized model coefficient; SE, standard error for "b"; HR, hazard ratio; CI, confidence interval; Preop, pre-operative; CVA, cerebrovascular accident.

Although there are currently no published guidelines for nutritional intervention in lung cancer patients undergoing MIS, our findings implicate that adequate nutritional status in the perioperative period is associated with improved OS and decreased hospital LOS and postoperative complications, and possibly by extension decreased hospital costs.

Malnutrition is associated with an increased inflammatory state,[18] which in turn produces poor wound healing and a weakened immune response. Malnutrition is one of the most common causes for immunodeficiency worldwide.[19] C-reactive protein (CRP), a marker for inflammation, has been found to be independently and significantly correlated with pre-albumin levels,[20] also supporting the relationship between malnutrition and inflammation. Inflammatory states are associated with increased production of cytokines, including IL-6, a cytokine that has been identified as an independent predictor for poor prognosis in lung cancer patients.[18]

Increased skin-to-skin duration and EBL was significantly predicted by larger tumor size, and, in our study, patients with poor nutrition had significantly larger tumor sizes. The relationship between malnutrition and inflammation could also help explain the increased skin-to-skin duration, EBL, chest tube duration, and hospital LOS as well as higher rates of postoperative complications in patients in the poor nutrition group for our study. Significant increases in complications, such as pneumonia and prolonged air leaks, in the low pre-albumin group could be explained by weakness of expiratory muscles, decreased chest wall expansion, and poor wound healing that have been observed in malnourished patients.[21,22]

Pre-operative pancreatitis was observed to significantly predict increased chest tube duration. Chronic pancreatitis (CP) is associated with malnourishment due to lack of pancreatic enzymes needed for adequate digestion and absorptions of carbohydrates and lipids, including fat-soluble vitamins. Due to this lack of digestion, CP patients often suffer from steatorrhea and chronic diarrhea.[23] It has also been found that 30%–50% of patients with CP have increased resting energy expenditure,[23] which has been reported as a poor prognostic indicator in patients with lung cancer.[24] The association between pancreatitis, nutritional status, and resting energy expenditure could account for some of our findings in this study.

Our study had an interesting finding in that pre-operative chronic anemia was significantly and inversely predictive postoperative complications. Although pre-operative anemia has been associated with decreased survival following lung cancer resection,[25] it is possible that our patient population received transfusions or additional care that was not analyzed in our study. We did not include measurements of postoperative anemia or whether these patients received interventions due to their pre-operative anemia that resulted in better outcomes.

Limitations of our study include that it is retrospective and that the procedures were performed by one surgeon and at a single institution. Our study was also limited by the lack of comparison of pre-operative pre-albumin values because only one patient in the study group had this value measured pre-operatively. Additionally, the lowest pre-albumin was not a standardized measure among the patients with respect to when the value was measured postoperatively. The lowest value could have occurred at different time points for different patients (i.e. within first 48 hours postoperatively or closer to discharge). The dichotomous grouping of patients above and below a pre-albumin level of 15 mg/dL is based on this value being the lower limit of the normal range for serum pre-albumin levels at our institution's clinical laboratory, which allowed comparison of patients with normal pre-albumin levels and those with below-normal pre-albumin levels. While this dichotomy may not have allowed analysis of outcomes between modestly malnourished patients and severely malnourished patients, subgrouping patients in future investigations will allow analyzing differences between modestly malnourished patients (e.g. pre-albumin = 10 to 14.9) and severely malnourished patients (e.g. pre-albumin ≤ 10) and their respective associations with postoperative risks.

## CONCLUSION

In our study, we found that pre-albumin that dropped below 15 mg/dL during the postoperative period (including within 48 hours after surgery) independently predicted a longer hospital LOS and worse OS. Additionally, low pre-albumin and, thus, poor nutritional status significantly predicted greater EBL, longer skin-to-skin operative time, chest tube duration, and number of postoperative complications. Addressing the nutritional status in patients undergoing RAVT pulmonary lobectomy could result in decreased hospital costs and better patient outcomes. Therefore, the recommendation of nutritionally supplementing patients in the perioperative period, whether pre- or postoperatively, should be evaluated further.

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