Original Article

Social vulnerability is associated with post-operative morbidity following robotic-assisted lung resection

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Background: The social vulnerability index (SVI) is a neighborhood-based metric used to determine an individual's susceptibility to socioeconomic hardship, with high SVI indicating high susceptibility. SVI has previously been associated with surgical outcomes. We aimed to determine if SVI influences morbidity following robotic-assisted lung resection.

Methods: This was a retrospective cohort study at one academic medical center (1/1/2021–11/30/2022). Patients undergoing robotic-assisted lung resection were grouped into low (<75th percentile) and high (≥75th percentile) SVI cohorts. The primary outcome was 30-day overall morbidity; secondary outcomes were individual 30-day post-operative outcomes. Univariate analysis was performed using Chi-squared or Mann-Whitney-*U* tests, and multivariable logistic regression was performed to generate risk-adjusted odds ratios (ORs) of postoperative complications.

Results: We included 320 patients, of which 40 patients (12.5%) in the high-SVI group and 280 (87.5%) in the low-SVI group. High SVI patients were more likely to be non-Caucasian and of Hispanic ethnicity, but there were no other differences in perioperative characteristics (all P>0.05). High SVI patients were more likely to experience a post-operative complication (42.5% *vs.* 24.6%, P=0.017), surgical site infection (SSI) (12.5% *vs.* 4.3%, P=0.047), hemothorax (5.0% *vs.* 0.0%, P=0.015), intensive care need (15.0% *vs.* 4.6%, P=0.021), sepsis (10.0% *vs.* 1.1%, P=0.006) and unplanned reoperation (5.0% *vs.* 0.4%, P=0.042). After risk-adjustment, the association of increased overall morbidity with high SVI persisted (OR =2.53; 95% confidence interval: 1.19–5.35).

Conclusions: High SVI was associated with increased risk-adjusted odds of morbidity after robotic-assisted lung resection. Highly vulnerable patients should be allocated perioperative resources to help mitigate the increased risk of these complications.

Keywords: Social vulnerability index (SVI); social determinants of health; lung surgery; pulmonary resection

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Introduction

Pulmonary resection remains the mainstay of treatment for several pathologies, including early-stage non-small cell lung cancer, severe chronic obstructive pulmonary disease (COPD), diagnosis and treatment of pulmonary nodules, and tissue diagnosis of idiopathic pulmonary fibrosis. Despite improvements in perioperative management, transition to minimally invasive approaches including the rise of robotic-assisted thoracoscopic surgery (RATS) (1), and implementation of enhanced recovery after surgery (ERAS) protocols (2,3), pulmonary resection carries an associated short-term morbidity of 10–50% (4-6). Several studies have provided insight into risk factors associated with worse postoperative outcomes following pulmonary resection, including patient age, gender, body mass index (BMI), smoking status and comorbidities such as COPD (7-10). However sociodemographic factors, and their complex interactions and composite effects have yet to be comprehensively explored outside of access to care (11-13). If clinicians could ascertain which specific factors surrounding sociodemographic status are associated with poor post-operative outcomes, hospitals and providers could anticipate and mitigate these risk factors in order to achieve more equitable surgical care.

Highlight box

Key findings

- Patients' sociodemographic status as measured by the social vulnerability index (SVI) is associated with increased likelihood of developing postoperative complications after lung resection.

What is known and what is new?

- SVI measures social disparity by incorporating 16 socioeconomic and demographic factors measured at the census tract level.
- We found that high SVI patients had significantly higher risk-adjusted odds of postoperative morbidity after lung resection compared to low SVI patients.

What is the implication, and what should change now?

- Recognition of vulnerability can aid in resource allocation in both the pre- and post-operative periods.
- Targeted interventions for these high-risk patients, like supplemented nutrition, mitigation of frailty through pre-habilitation and rehabilitation services, and improving communications and educational materials, may help to mitigate these effects.
- Efforts to allay disparities should also be implemented at levels that supersede individual patients in order to achieve more equitable surgical care.

The social vulnerability index (SVI) is a metric generated by the Centers for Disease Control and Prevention (CDC) that uses 16 neighborhood-based variables to determine susceptibility to external stressors on human health (14). A summary of the variables is shown in *Figure 1*. Scores are updated every two years using census-tract level data and range from 0, indicating low vulnerability, to 100, indicating high vulnerability. SVI was initially designed to understand how a community might respond to natural or man-made disasters. However, several studies in the medical literature have linked high SVI (increased social vulnerability) to poor health outcomes at the patient level. Specific to surgery, high SVI has been associated with increased rates of postoperative adverse outcomes following major surgery, including colectomy (15) and esophagectomy (16), regardless of approach (open versus minimally invasive). However, a comprehensive analysis of 30-day postoperative outcomes following RATS lung resection has not been performed.

The purpose of this study was to determine if there was an association between sociodemographic status as measured by a patient's SVI and odds of complications after robotic-assisted lung resection. We hypothesized that patients with high SVI would have significantly higher risk-adjusted odds of postoperative complications. These findings could help guide both inpatient planning and the perioperative allocation of resources for this potentially high-risk patient population. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1122/rc).

Methods

Study design

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Colorado Multiple Institutional Review Board (COMIRB; IRB Organization No. IORG0000433) and individual consent for this retrospective analysis was waived. This was a retrospective cohort study at the University of Colorado Hospital between January 1, 2021, and November 30, 2022. The University of Colorado Hospital is a quaternary academic referral medical center linked with the University of Colorado School of Medicine. During the study period, there were four operative, board-

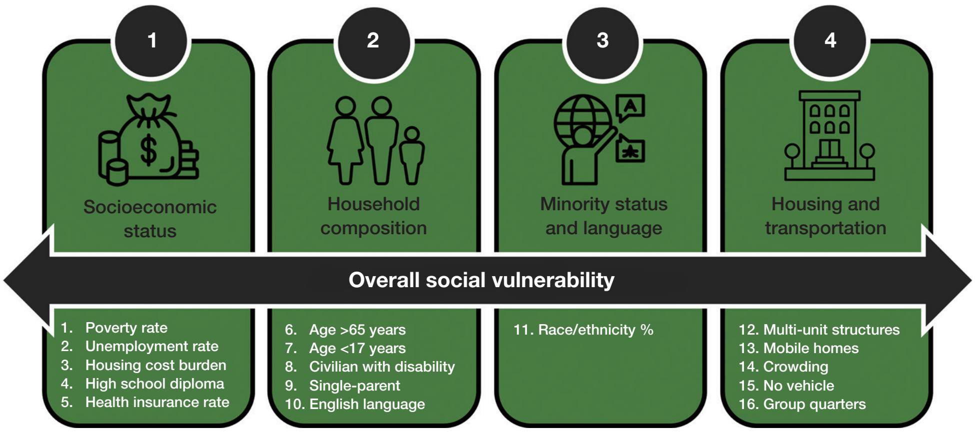

Figure 1 The 16 census tract variables used to calculate SVI, sorted by commonality into four different themes: socioeconomic status, household composition, minority status and language, housing and transportation. SVI, social vulnerability index.

certified thoracic surgeons who all perform lung resections using open, video-assisted thoracoscopic surgery (VATS) or RATS approaches based on patient factors. For the purposes of this study, all patients undergoing robotic-assisted lung resection (lobectomy, segmentectomy or wedge resection) were identified using current procedural terminology (CPT) codes and targeted for inclusion. Patients under 18 years old or whose home address were not documented in the electronic health record (EHR) or able to be geocoded were excluded. Patients' demographic information including age, race/ethnicity, American Society of Anesthesiology physical classification (ASA class), BMI, medical comorbidities, SVI, operative data including surgical procedure performed, indication for surgery, laterality, and operative time (which includes robotic docking time), and rates of postoperative complications were obtained via manual EHR review.

Patients were grouped into low SVI (<75th percentile) and high SVI (≥75th percentile) cohorts, consistent with prior studies (15-18), using the CDC's publicly available interactive SVI tool (https://svi.cdc.gov/map.html) at the census tract level. The primary outcome was 30-day overall postoperative complication, which was defined as the occurrence of any stroke, urinary tract infection, unexpected need for intensive care, readmission, unexpected emergency department (ED) visit, or any respiratory, cardiac, infectious, or renal complication. Secondary outcomes included individual 30-day outcomes, specifically length of stay, mortality, surgical site infection (SSI), postoperative pneumothorax or hemothorax, pleural effusion, pneumonia, need for therapeutic bronchoscopy or reintubation, prolonged ventilator use (>48 hours), prolonged air leak (>5 days), need for upgrade to intensive care status, need for tracheostomy, sepsis/septic shock, deep venous thrombosis (DVT) or pulmonary embolism (PE), arrythmia, cardiac arrest, stroke, conversion to open surgery, and post-discharge ED presentation. Complications were graded using Clavien-Dindo Classification System (19).

Statistical analysis

Bivariate analysis of demographic, perioperative variables and postoperative outcomes of patients with high SVI versus those with low SVI was conducted using the Chi-squared test and Fisher's exact test for categorical variables, and the Wilcoxon-Mann-Whitney test for non-normally-distributed continuous variables, defined by the Shapiro-Wilk Test for Normality. Multivariable analysis evaluating primary and secondary outcomes that were statistically significantly different on bivariate analysis were conducted using a regression model that was adjusted for baseline patient variables including age, sex, race, ethnicity, ASA class, and procedure. All patients were included in multivariable models. Descriptive statistics are presented as absolute numbers and percentages for categorical variables. For continuous variables, statistics are presented as median and interquartile range (IQR). A two-sided P value of <0.05 was considered statistically significant. All analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA) and SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Table 1 Demographic characteristics of the patient cohort stratified by low *vs.* high SVI (n=320)

Demographic characteristic	Low SVI (n=280)	High SVI (n=40)	All (n=320)	P value
Age (years)	67 [60–73]	68 [60–72]	67 [60–73]	0.966
Sex				0.431
Male	101 (36.1)	17 (42.5)	118 (36.9)	
Female	179 (63.9)	23 (57.5)	202 (63.1)	
Race				<0.001*
White	263 (93.9)	29 (72.5)	292 (91.3)	
Non-White	17 (6.1)	11 (27.5)	28 (8.8)	
Ethnicity				<0.001*
Hispanic	9 (3.2)	9 (22.5)	18 (5.6)	
Non-Hispanic	271 (96.8)	31 (77.5)	302 (94.4)	
ASA class				0.175
II	54 (19.3)	3 (7.5)	57 (17.8)	
III	222 (79.3)	36 (90.0)	258 (80.6)	
IV	4 (1.4)	1 (2.5)	5 (1.6)	
Comorbidities				
Any comorbidity	139 (49.6)	25 (62.5)	164 (51.3)	0.128
Stroke or TIA	9 (3.2)	2 (5.0)	11 (3.4)	0.634
Hypertension	104 (37.1)	18 (45.0)	122 (38.1)	0.385
Coronary artery disease	18 (6.4)	3 (7.5)	21 (6.6)	0.735
Congestive heart failure	3 (1.1)	0 (0.0)	3 (0.9)	>0.99
COPD	16 (5.7)	6 (15.0)	22 (6.9)	0.042*
Diabetes mellitus	30 (10.7)	8 (20.0)	38 (11.9)	0.113
Chronic kidney disease	17 (6.1)	4 (10.0)	21 (6.6)	0.314
Liver disease	8 (2.9)	0 (0.0)	8 (2.5)	0.602
BMI (kg/m^2)	25.6 [22.3–29.6]	25.1 [22.7–29.0]	35.6 [22.3–29.4]	0.866

Data are presented as median [interquartile range] or n (%). *, significant P values. SVI, social vulnerability index; ASA, American Society of Anesthesiologists; TIA, transient ischemic attack; COPD, chronic obstructive pulmonary disease; BMI, body mass index.

Results

Patient characteristics

There were a total of 347 patients targeted for inclusion; of these, 27 (7.8%) were excluded due to inability to obtain SVI, leaving a total of 320 patients in the analytic cohort. In the study cohort, 40 patients (12.5%) were allocated to the high SVI group. A summary of patient demographics and medical history is shown in *Table 1*. The median (IQR) age was 67 (IQR, 60–73) years. The majority were women (63.1%), White (91.3%) and non-Hispanic (94.4%). Patients in the high SVI group were significantly more likely to be non-White (27.5% *vs.* 6.1%, P<0.001) and of Hispanic ethnicity (22.5% *vs.* 3.2%, P<0.001) than those in the low SVI group. Patients in the high SVI group were more likely to have COPD (15.0% *vs.* 5.7%, P=0.042), however there were no differences in the presence of other major comorbidities, ASA class or BMI (all P>0.05).

Table 2 Operative characteristics of the patient cohort stratified by low *vs.* high SVI

Operative characteristics	Low SVI (n=280)	High SVI (n=40)	All (n=320)	P value
Procedure				0.112
RATS lobectomy	179 (63.9)	28 (70.0)	207 (64.7)	
RATS segmentectomy	49 (17.5)	2 (5.0)	51 (15.9)	
RATS wedge	52 (18.6)	10 (25.0)	62 (19.4)	
Indication				0.423
Bronchiectasis	5 (1.8)	1 (2.5)	6 (1.9)	
Bullous disease	7 (2.5)	0 (0.0)	7 (2.2)	
Interstitial lung disease	11 (3.9)	2 (5.0)	13 (4.1)	
MAC/NTMB	49 (17.5)	3 (7.5)	52 (16.3)	
Mass/nodule	208 (74.3)	34 (85.0)	242 (75.6)	
Laterality				0.293
Bilateral	1 (0.4)	0 (0.0)	1 (0.3)	
Left	98 (35.0)	19 (47.5)	117 (36.6)	
Right	181 (64.6)	21 (52.5)	202 (63.1)	
Case time (minutes)	177 [133–230]	183 [123–252]	179 [133–236]	0.237

Data are presented as median [interquartile range] or n (%). SVI, social vulnerability index; RATS, robotic-assisted thoracoscopic surgery; MAC/NTMB, mycobacterium avium complex/nontuberculous mycobacteria.

Operative characteristics

A summary of operative characteristics is shown in *Table 2*. The majority of operations performed were lobectomies (64.7%), followed by wedge resection (19.4%) and segmentectomies (15.9%). Operations were performed for the resection of a mass or nodule (75.6%), mycobacterium avium complex/nontuberculous mycobacteria (MAC/NTMB)-associated bronchiectasis (16.3%), interstitial lung disease (4.1%), bullous disease (2.2%) or bronchiectasis (1.9%). There were no differences in operative characteristics between groups.

Outcomes

A summary of 30-day outcomes is shown in *Table 3*, with associated Clavien-Dindo classification. Overall morbidity was 26.9%, with the most frequent complication being prolonged air leak (11.3%) (of which none were discharged with portable drain), followed by unanticipated need for intensive care (5.9%) and superficial SSI (5.3%). On unadjusted analysis, high SVI was associated with increased rates of several complications including superficial SSI (12.5% *vs.* 4.3%, P=0.047), hemothorax (5.0% *vs.* 0.0%, P=0.015), unanticipated need for intensive care (15.0% *vs.* 4.6%, P=0.021), sepsis (10.0% *vs.* 1.1%, P=0.006), return to operating room (5.0% *vs.* 0.4%, P=0.042) and all cause morbidity (42.5% *vs.* 24.6%, P=0.017). There were no occurrences of reintubation, prolonged ventilator use, tracheostomy, DVT/PE, myocardial infarction or stoke in either group. Complications in the high SVI group trended towards increased severity on Clavien-Dindo classification, however this did not reach significance {2 [2–3] *vs.* 2 [1–3], P=0.186}. Following adjustment for preoperative variables, this finding of increased morbidity persisted [odds ratio (OR) =2.53; 95% confidence interval: 1.19–5.35; P=0.015]. Risk-adjusted predictors of overall morbidity are shown in *Table 4*, the only significant predictors were high SVI (compared to low SVI) and lobectomy (compared to wedge resection). Index length of stay was not significantly different between high and low SVI groups (P=0.434), similarly the rates of ED presentation and readmission were not significantly different (P=0.573 and P=1.00, respectively). Table S1 summarizes a sub-group analysis of outcomes by procedure.

Discussion

In a single-institution retrospective cohort study, we

Table 3 Unadjusted rates of 30-day outcomes by group

Outcome	Low SVI (n=280)	High SVI (n=40)	All (n=320)	P value
Index length of stay (days)	3 [2–5]	3 [2–6]	3 [2–5]	0.434
Superficial SSI	12 (4.3)	5 (12.5)	17 (5.3)	0.047*
Clavien-Dindo grade II	12 (100.0)	5 (100.0)	17 (100.0)	>0.99
Deep SSI	1 (0.4)	0 (0.0)	1 (0.3)	>0.99
Clavien-Dindo grade II	1 (100.0)	–	1 (100.0)	–
Pneumothorax	12 (4.3)	3 (7.5)	15 (4.7)	0.414
Clavien-Dindo grade III	12 (100.0)	3 (100.0)	15 (100.0)	>0.99
Hemothorax	0 (0.0)	2 (5.0)	2 (0.6)	0.015*
Clavien-Dindo grade III	–	2 (100.0)	2 (100.0)	–
Pleural effusion	3 (1.1)	0 (0.0)	3 (0.9)	>0.99
Clavien-Dindo grade III	3 (100.0)	–	3 (100.0)	–
Pneumonia	6 (2.1)	1 (2.5)	7 (2.2)	>0.99
Clavien-Dindo grade II	6 (100.0)	1 (100.0)	7 (100.0)	>0.99
Prolonged air leak	30 (10.7)	6 (15.0)	36 (11.3)	0.423
Clavien-Dindo grade I	23 (76.7)	3 (50.0)	26 (72.2)	0.317
Clavien-Dindo grade III	7 (23.3)	3 (50.0)	10 (27.8)	
ICU upgrade	13 (4.6)	6 (15.0)	19 (5.9)	0.021*
Clavien-Dindo grade II	9 (69.2)	3 (50.0)	12 (63.2)	0.873
Clavien-Dindo grade III	2 (15.4)	1 (16.7)	3 (15.8)	–
Clavien-Dindo grade IV	2 (15.4)	2 (33.3)	4 (21.1)	–
Sepsis	3 (1.1)	4 (10.0)	7 (2.2)	0.006*
Clavien-Dindo grade II	1 (33.3)	3 (75.0)	4 (57.1)	0.486
Clavien-Dindo grade IV	2 (66.7)	1 (25.0)	3 (42.9)	–
Septic shock	2 (0.7)	1 (2.5)	3 (0.9)	0.331
Clavien-Dindo grade IV	2 (100.0)	1 (100.0)	3 (100.0)	>0.99
Arrythmia	11 (3.9)	3 (7.5)	14 (4.4)	0.396
Clavien-Dindo grade II	11 (100.0)	3 (100.0)	14 (100.0)	>0.99
Cardiac arrest	1 (0.4)	0 (0.0)	1 (0.3)	>0.99
Clavien-Dindo grade IV	1 (100.0)	–	1 (100.0)	–
Chest tube reinsertion	18 (6.4)	5 (12.5)	23 (7.2)	0.185
Therapeutic bronchoscopy	3 (1.1)	1 (2.5)	4 (1.3)	0.415
Conversion to open	4 (1.4)	2 (5.0)	6 (1.9)	0.165
Return to operating room	1 (0.4)	2 (5.0)	3 (0.9)	0.042*
Any complication	69 (24.6)	17 (42.5)	86 (26.9)	0.017*
Highest Clavien-Dindo grade	2 [1–3]	2 [2–3]	2 [2–3]	0.186

Table 3 (*continued*)

Table 3 (*continued*)

Outcome	Low SVI (n=280)	High SVI (n=40)	All (n=320)	P value
ED presentation	27 (9.6)	5 (12.5)	32 (10.0)	0.573
Readmission	21 (7.5)	3 (7.5)	24 (7.5)	>0.99
30-day mortality	0 (0.0)	0 (0.0)	0 (0.0)	–

Data are presented as median [interquartile range] or n (%). *, significant P values. SVI, social vulnerability index; SSI, surgical site infection; ICU, intensive care unit; ED, emergency department.

Table 4 Risk-adjusted predictors of any complication

Predictor variable	Odds ratio (95% confidence interval)
Increasing age	1.00 (0.98–1.02)
Male *vs.* female sex	0.94 (0.55–1.59)
Non-Hispanic *vs.* Hispanic ethnicity	0.75 (0.25–2.20)
White *vs.* non-White race	1.15 (0.46–2.88)
ASA 4 *vs.* ASA 2	0.74 (0.07–7.81)
ASA 4 *vs.* ASA 3	0.66 (0.07–6.54)
Wedge *vs.* lobectomy	0.47 (0.32–0.99)*
Wedge *vs.* segmentectomy	0.49 (0.19–1.23)
High SVI *vs.* low SVI	2.53 (1.19–5.35)*

*, significant predictors. ASA, American Society of Anesthesiologists; SVI, social vulnerability index.

showed that patients undergoing robotic-assisted lung resection with high SVI have significantly higher odds of 30-day postoperative complications than patients who had lower SVI, including overall morbidity, superficial SSI, postoperative hemothorax, intensive care need, postoperative sepsis, and unplanned reoperation. Highly vulnerable patients remained significantly more likely to experience any 30-day complication after risk-adjustment for perioperative confounders. These findings show that patient sociodemographic status beyond race or socioeconomic status is an independent contributor to poor postoperative outcomes. Interestingly, despite increased complications, we did not note an associated significant difference in hospital length of stay between high and low SVI groups.

Social vulnerability arises from complex political, social and economic structures and resultantly is discussed frequently in the context of ecological models (20). However, there has been growing interest in applying the concept of social vulnerability in the health care setting. In this context, social vulnerability can be defined as the degree to which a persons' overall social circumstances leave them susceptible to further insults, including health adverse events (21). At present, SVI has been identified as an important factor associated with increased risk of postoperative adverse outcomes and 30-day mortality following major surgery, including specific demonstration in colectomy (15) and esophagectomy (16) patients. Two prior studies by Diaz *et al.* (22) and Hyer *et al.* (23) both performed subgroup analyses on patients who underwent lung resection among a larger cohort of other major surgeries and demonstrated that patients with high SVI patients had increased rates of post-operative complications. In a follow up study of lung and colon resection only groups, Diaz *et al.* again reported similar results demonstrating the independent association of social vulnerability and postoperative outcomes, with an effect compounded by residential diversity (24). Notably, in these studies it is not clear the surgical approach, and whether these cohorts included minimally invasive techniques. Our data supports, and confirms these prior findings and builds upon them by demonstrating the specific complications affected by socioeconomic status while using more discrete census-tract level information rather than county level data, while focusing on the RATS approach which is reflective of the modern era of thoracic surgery.

Living under vulnerable conditions, for example social or physical isolation, insecure housing or a high income-to-debt ratio may induce a chronic stress state which blunts a patients' ability to respond to health stressors including surgical stress. At baseline, all patients experience a surgical stress response, which is a well-documented metabolic phenomenon induced by activation of neuroendocrine pathways and inflammatory mediators (25). Patients who have inadequate reserve, such as those highly vulnerable patients living in a state of chronic stress might be unable to respond to these metabolic derangements. Emerging literature suggests that psychological perioperative factors including a patient's psychologic state or personality may directly affect the surgical stress response (26) and that these factors can predict postoperative outcomes with accuracy similar to models using surgical and anesthetic variables (25).

We believe that a patient's SVI might serve as a surrogate for how they will respond to surgical stress and that SVI can be used to guide targeted interventions to mitigate the dysregulation. Preoperatively, SVI could be incorporated into risk stratification. While it is quick to lookup a patient's score manually, SVI could conceivably be written into code in the EHR for automated generation in preoperative clinical visits, and could function similar to other preoperative risk calculators, such as the American College of Surgeons National Surgical Quality Improvement Program's (ACS-NSQIP) Surgical Risk Calculator (27) and the Surgical Risk Preoperative Assessment System (SURPAS) (28). There have been mixed effects on how incorporating a measure of social vulnerability like the SVI affects the predictive modeling of these risk calculators, with some studies suggesting that it improves prediction (29) and others suggesting that the predictor models are not significantly improved by including a socially derived predictor variable (30). SVI could also aid in development of ERAS protocols (2,3), established bundles of proven interventions and post-operative care. Opportunity exists to incorporate SVI as a branch point in determining an automatic referral to a vulnerability-targeted set of discharge services including nutritional and physical therapy rehabilitation services.

Nutritional and pre-habilitation services, among other interventions, could mitigate the deleterious effects of social vulnerability. Social vulnerability has been associated with food insecurity (31), which has been linked to increased risk of readmission following major surgery (32,33). Similarly, extremes of BMI (<18.5 or ≥40 kg/m^2) being linked to higher rates of complications (34,35). This finding is likely mediated through post-operative dysregulation of metabolic pathways that control the absorption of nutrients and subsequent break down leads to generation of energy. As such nutritional status has been identified as potentially modifiable risk factors in patients undergoing surgical treatment. At present, our institution supports universal nutritional optimization prior to anatomic lung resection including providing all patients with an immunonutrition supplement prior to their surgery. However, knowledge of a patient's SVI score could be used for targeted vulnerability-level nutritional interventions including referral to perioperative nutritional services for assessment and intervention. Future studies would be required to determine the efficacy of these interventions on reducing inequities in surgical outcomes.

Since social vulnerability has also been correlated with frailty (36), targeted interventions might focus on perioperative rehabilitation services. It has been well established that rehabilitation following surgery can reduce complications and improves postoperative and functional outcomes. However, surgery-related rehabilitation is rarely actually recognized as an essential part of the continuum of care (37). Beyond post-operative rehabilitation, another emerging idea is pre-habilitation prior to surgery. This has been shown to optimize health outcomes (38), including improving functional capacity (39) and reducing complications in high risk patients (40). Specific to thoracic surgery, pre-habilitation has been shown to prevent functional decline (41) and be as effective as post-operative rehabilitation in returning to functional baseline (42). Improving referral to these services based on SVI scores could be beneficial to patients and reduce postoperative morbidity.

Finally, health literacy is a domain for targeted intervention based on SVI. It has been estimated that over 90 million Americans have inadequate health literacy (43) contributing to inability to understand basic instructions and make appropriate health related decisions (44). Health literacy is critical in the perioperative period, and misinterpretation or misunderstanding of complex preoperative and postoperative instructions can result in negative outcomes (45). Patients with high SVI, which may serve as surrogate marker for low health literacy may benefit from additional time and resources during discharge teaching, including management of incisions or wounds, surgically placed drains, and recognition of potential complications warranting in-person medical evaluation. Increased education efforts in conjunction with arrangement of any necessary home-health need may limit the general anxiety of self-care during recovery from surgery.

There are several important limitations to consider when interpreting the results of the study. Firstly, the single institution and retrospective nature of this study may limit its generalizability to other institutions, patient populations, or geographical regions. Secondly, the study included a relatively small cohort of patients in the high SVI cohort, which may have limited the power to detect differences in the occurrence of more rare postoperative complication. We also hypothesize limited sample size contributes to our observation that despite increased complications in the high SVI group, length of stay did not significantly differ. Given that RATS surgery has relatively short length of stay at baseline, a large sample would be needed to detect differences. Similarly, the small sample size limited our ability to generate risk-adjusted odds ratios for individual complications as the observed rates of these complications did not meet the minimum of 10 outcome events per predictor variable required for appropriate analysis. Sample size was likely limited by our decision to include only RATS lung resections in analysis, however we elected to exclude open and VATS approaches to eliminate the bias of approach as prior studies have demonstrated significant differences in morbidity and mortality by approach, specifically RATS versus open (46), and we feel that focusing on this approach is reflective of the current trend in increase of RATS utilization as a minimally invasive approach to lung resection when compared to VATS (1). Our sample size was able to be increased by the inclusion of RATS wedge resections, which we elected to include due to the fact that the vast majority of our RATS wedge resections are performed for malignant indications. Finally, there was no evaluation of what specific aspect associated with high SVI confers the increased risk of postoperative complications, which makes the efficacy surrounding potential interventions to mitigate these findings speculative. Prior studies have suggested that poor access to medical care or distance to hospital may be contributory, but the study institution is surrounded by areas with high SVI scores in close proximity, which limits our ability to test this hypothesis. Additionally, it should be recognized that we did note an increased rate of COPD in our highly vulnerable population which may have contributed to the observe outcomes despite risk-adjustment for comorbidities.

Conclusions

In conclusion, high SVI was associated with increased odds of postoperative complications after robotic-assisted lung resection even after risk-adjustment for perioperative variables. This high-risk patient population merits significant consideration during the surgical planning for robotic lung resection. Recognition of vulnerability can aid in resource allocation in both the pre- and postoperative periods in an effort to reduce these observed complications. Targeted interventions for these high-risk patients, like supplemented nutrition, mitigation of frailty through pre-habilitation and rehabilitation services, and improving communications and educational materials, may help to mitigate these effects. Efforts to allay disparities should also be implemented at levels that supersede individual patients in order to achieve more equitable surgical care. Future studies should be directed towards elucidating the specific factors of SVI that drive this increase in complication rates so that targeted resources can be directed to this high-risk population to mitigate their risk of complications.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Colorado Multiple Institutional Review Board (COMIRB; IRB

Organization No. IORG0000433) and individual consent for this retrospective analysis was waived.

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Table S1 Subgroup analysis summarizing unadjusted rates of 30-day outcomes by approach and social vulnerability group

30-day outcome	RATS lobectomy (n=207)			RATS segmentectomy (n=51)			RATS wedge (n=62)		
	Low SVI (n=179)	High SVI (n=28)	P value	Low SVI (n=49)	High SVI (n=2)	P value	Low SVI (n=52)	High SVI (n=10)	P value
Superficial SSI	10 (5.6%)	4 (14.3%)	0.103	1 (2.0%)	1 (50.0%)	0.078	1 (1.9%)	0 (0.0%)	0.658
Deep SSI	0 (0.0%)	0 (0.0%)	–	1 (2.0%)	0 (0.0%)	1.000	0 (0.0%)	0 (0.0%)	–
Pneumothorax	9 (5.0%)	3 (10.7%)	0.210	2 (4.1%)	0 (0.0%)	1.000	1 (1.9%)	0 (0.0%)	1.000
Hemothorax	0 (0.0%)	2 (7.1%)	0.018*	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	–
Pleural effusion	1 (0.6%)	0 (0.0%)	1.000	1 (2.0%)	0 (0.0%)	1.000	1 (1.9%)	0 (0.0%)	1.000
Pneumonia	6 (3.4%)	1 (3.6%)	1.000	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	–
Therapeutic bronchoscopy	2 (1.1%)	1 (3.6%)	0.355	1 (2.0%)	0 (0.0%)	1.000	0 (0.0%)	0 (0.0%)	–
Prolonged air leak	23 (12.8%)	6 (21.4%)	0.224	0 (0.0%)	0 (0.0%)	1.000	1 (1.9%)	0 (0.0%)	1.000
ICU upgrade	7 (3.9%)	6 (21.4%)	<0.001*	4 (8.2%)	0 (0.0%)	1.000	2 (3.8%)	0 (0.0%)	1.000
Sepsis	2 (1.1%)	3 (10.7%)	0.019*	1 (2.0%)	1 (50.0%)	0.078	0 (0.0%)	0 (0.0%)	–
Septic shock	2 (1.1%)	1 (3.6%)	0.355	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	–
Arrythmia	5 (2.8%)	3 (10.7%)	0.078	4 (8.2%)	0 (0.0%)	1.000	2 (3.8%)	0 (0.0%)	1.000
Cardiac arrest	1 (0.6%)	0 (0.0%)	1.000	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	–
Conversion to open	4 (2.2%)	2 (7.1%)	0.188	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	–
Return to operating room	0 (0.0%)	2 (7.1%)	0.018*	1 (2.0%)	0 (0.0%)	1.000	0 (0.0%)	0 (0.0%)	–
Any complication	48 (26.8%)	16 (57.1%)	0.001*	14 (28.6%)	1 (50.0%)	0.506	7 (13.5%)	0 (0.0%)	0.586
ED presentation	16 (8.9%)	5 (17.9%)	0.146	0 (0.0%)	0 (0.0%)	1.000	0 (0.0%)	0 (0.0%)	–
Readmission	12 (6.7%)	3 (10.7%)	0.434	7 (14.3%)	0 (0.0%)	1.000	2 (3.8%)	0 (0.0%)	1.000

Data are presented as n (%). *, significant P values. RATS, robotic-assisted thoracoscopic surgery; SVI, social vulnerability index; SSI, surgical site infection; ICU, intensive care unit; ED, emergency department.

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