New or enlarging hiatal hernias after thoracic surgery for early lung cancer

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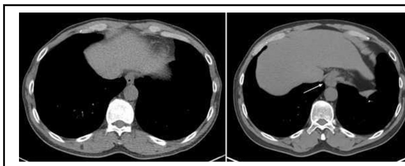
ABSTRACT

Objective: The study objective was to determine the relationship between lung resection and the development of postoperative hiatal hernia.

Methods: Preoperative and postoperative computed tomography imaging from 373 patients from the International Early Lung Cancer Action Program and the Initiative for Early Lung Cancer Research on Treatment were compared at a median of 31.1 months of follow-up after resection of clinical early-stage non–small cell lung cancer. Incidence of new hiatal hernia or changes to preexisting hernias were recorded and evaluated by patient demographics, surgical approach, extent of resection, and resection site.

Results: New hiatal hernias were seen in 9.6% of patients after lung resection (5.6% after wedge or segmentectomy and 12.4% after lobectomy; $P = .047$). The median size of new hernias was 21 mm, and the most commonly associated resection site was the left lower lobe (24.2%; $P = .04$). In patients with preexisting hernias, 53.5% demonstrated a small but significant increase in size from 21 to 22 mm ($P < .0001$). All hernias persisted through the latest postoperative computed tomography scan. When 110 surgical patients without preexisting hernia were matched by sex, age, and smoking to nonoperative controls, the incidence of new hernia at follow-up was significantly higher among those who underwent surgery (17.3% vs 2.7%, $P = .0003$).

Conclusions: Both open and minimally invasive lung resection for clinical early-stage lung cancer are associated with new or enlarging postoperative hiatal hernia, especially after resections involving the left lower lobe. (JTCVS Open 2022;10:415-23)



Preoperative and postoperative CT scans, 52 months apart, showing a new HH (*arrow*).

CENTRAL MESSAGE

Surgery for early lung cancer is associated with new postoperative HH and increased size of preexisting HH. This occurs most commonly after left lower lobe resections.

PERSPECTIVE

There is a significant incidence of new HH after lung resection for early-stage lung cancer. Although the clinical significance of these findings remains unclear, consideration of an existing hernia or reflux may be warranted when planning for elective resection.

See Commentary on page 424.

The anatomic and physiologic sequelae of lung resection on the diaphragmatic hiatus have not been well established. It is plausible that alterations in functional lung volume,[1] decreased diaphragmatic function,[2] or changes in pleural or intrathoracic pressure[3] could enlarge an existing hernia or lead to higher incidence of new postoperative hiatal hernia (HH).

Isolated case reports of new[4,5] or enlarging HHs, documented secondary to complications,[6,7] have been reported after major lung resection and up to 66% of patients with persistent cough after pulmonary resection report simultaneous symptoms of gastroesophageal reflux.[8] Clinically, it might be expected that a new or enlarging HH could compromise pulmonary quality of life in a patient after recent thoracic surgery, while uncontrolled reflux disease can lead to aspiration pneumonitis. Up to 74% of patients with giant HH receive relief from dyspnea after surgical repair even without objective improvement in respiratory function.[9]

Despite these associations, no substantial investigation has been published to explore the existence of a relationship between lung resection and HH, or the potential associated

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Abbreviations and Acronyms

BMI	= body mass index
CT	= computed tomography
HH	= hiatal hernia
I-ELCAP	= International Early Lung Cancer Action Program
IELCART	= Initiative for Early Lung Cancer Research on Treatment
IQR	= interquartile range

clinical relevance. We turned to the Initiative for Early Lung Cancer Research on Treatment (IELCART), a prospectively collected multi-institutional cohort created to answer specific questions about different treatments of early lung cancer,[10] and the International Early Lung Cancer Action Program (I-ELCAP), a prospectively collected cohort of participants enrolled in a multi-institutional, international low-dose computed tomography (CT) screening program for lung cancer.

MATERIALS AND METHODS

Patient Selection and Data Collection

We reviewed all patients with an initial primary non–small cell lung cancer measuring 30 mm or less in maximum diameter on their preoperative CT scan (cT1a-c) enrolled in 2 prospectively collected cohorts: the I-ELCAP[11] and IELCART.[10] The I-ELCAP cohort includes participants in the international multi-institutional screening project who were asymptomatic for lung cancer at the time of enrollment. For this study, we included participants who were later diagnosed with lung cancer and underwent surgical resection between 1996 and 2019 with at least 2 years of follow-up imaging. The IELCART cohort includes patients enrolled in the Mount Sinai Health System (3 hospitals; Icahn, West, and Brooklyn) who underwent surgical resection between 2016 and 2019.[10] Both studies were Health Insurance Portability and Accountability Act compliant and approved by the Institutional Review Board (Western IRB #0325 approved March 25, 2019; Mount Sinai IRB HS #:15-01021 approved February 5, 2021). All patients provided written informed consent. Documentation in the I-ELCAP and IELCART databases included demographic information, body mass index (BMI), smoking history, the presence of 21 preexisting comorbid conditions, and diagnostic workup. When diagnosed with lung cancer, documentation included treatment details including type of surgery, clinical staging, tumor location, pathology results, and survival status. Patients were classified into 4 BMI categories according to the World Health Organization[12] (underweight for BMI <18.5, normal for BMI between 18.5 and 24.9, overweight for BMI between 25.0 and 29.9, and obese if BMI $\geq$30.0).

Preoperative and postoperative CT scans were performed using standard-dose or low-dose setting on multi-slice CT scanners with or without contrast (Figure 1). Axial, coronal, and sagittal images were used to determine the presence, size, and type of hernia. Presence of a hernia was determined by displacement of the gastroesophageal junction above the hiatus or any portion of the stomach above the diaphragm. All preoperative and postoperative CT scans included in this study were reviewed, and findings were documented by experienced chest radiologists (MC 5 years of experience, QC 17 years of experience, YZ 7 years of experience), and AS (fourth-year radiology resident). To minimize potential differences in CT evaluation of findings, a senior radiologist (MC) provided a training session with sample cases to all radiologists to ensure that same measurement approach was used. Upon completion of case review and before analyses, a senior radiologist reviewed all cases with preexisting HH before surgery as well as cases that developed a hernia after surgery. Any disagreement on the presence or size of hernia was jointly reviewed and resolved by 2 senior radiologists (CH, DY, >25 years of experience).

Statistical Analysis

Characteristics and clinical information of the surgical patients were summarized using descriptive statistics, mean ± standard deviation or median (interquartile range [IQR]) for continuous variables, and frequencies and percentages for categorical variables. Comparisons between sublobar resection and lobectomy were examined using the Student *t* test or Mann–Whitney *U* test for continuous variables and using chi-square test or Fisher exact test for categorical variables.

Frequency of preexisting HH before surgery and frequency of newly developed HH after surgery by tumor location were examined using chi-square or Fisher exact test. Among the patients with preexisting HH before surgery, postoperative change in size of HH was assessed using signed-rank test. Follow-up was calculated from the date of surgery to the date of initial detection of hernia on postoperative CT or date of last follow-up CT postsurgery. In addition, missing values of BMI (n = 60) were imputed using Markov chain Monte Carlo method. Univariable and multivariable logistic regression were used to identify risk factors associated with the development of hernia after surgery among patients without preoperative hernia. Factors included sex, age, smoking status (current, former, never smoker), BMI, site of resection (upper/middle vs lower lobe, left vs right lung), extent of surgery (sublobar/lobectomy), and surgical approach (minimally invasive vs thoracotomy) were considered in the model. Variables with *P* less than .10 in the univariable model were selected for multivariable analyses. Odds ratios and 95% confidence intervals were computed.

The I-ELCAP database was queried for participants who underwent surgery for stage I lung cancer. Of these, participants who had CT imaging

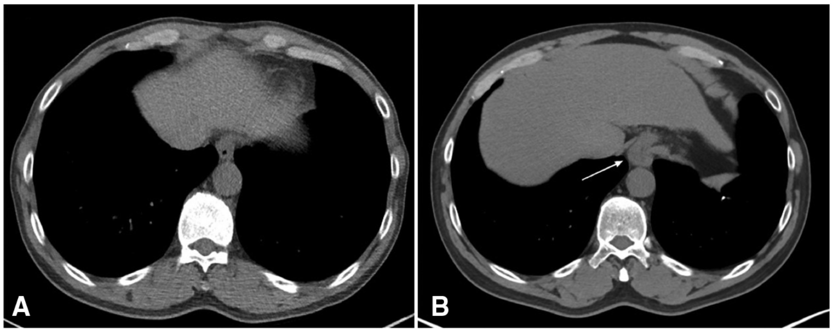

FIGURE 1. Preoperative (A) and postoperative (B) CT scans, 52 months apart, showing a new HH (*arrow*) after wedge resection of a 1-cm left lower lobe adenocarcinoma.

before and after surgery were identified and matched to a control group of screening patients who did not have a diagnosis of lung cancer and did not undergo lung resection. For each surgical patient without preoperative HH, a participant without hernia was matched by age, sex, smoking status, and duration of follow-up was randomly selected from the I-ELCAP database of participants. Among the 136 patients who underwent surgical resection for early stage lung cancer, 126 (92.0%) had no preoperative HH. Nonsurgical screening participants (controls) were identified in 110 (87.3%) of 126 cases. Of these 110 matched pairs, 53.6% were women, 56.4% were former smokers, 41.8% were current smokers, and 1.8% were never smokers. Median age was 63 years (IQR, 58-69). Using the 110 matched pairs, the effect of surgery on the risk of developing HH was assessed using McNemar's test. Statistical analysis was performed using the Statistical Analysis System software v9.4 (SAS Institute).

RESULTS

A total of 373 patients (137 from I-ELCAP and 236 from IELCART) had surgical resection of lung cancers 30 mm or less in maximum diameter with postoperative CT scans ranging 2.1 to 231.6 months after the surgical resection (median 31.1 months; Table 1 and Figure 2). Of all included patients, 221 were women and 152 were men. Median age was 68 years (IQR, 62.0-73.0) and not significantly different between sexes. Sublobar resection was performed in 169 patients (45.2%; wedge in 154, segmentectomy in 15), and 204 patients (54.5%) underwent lobectomy. Median tumor size was 15.3 mm (IQR, 11.0-20.0). Final pathologic stage was Stage IA (T1a-1cN0M0) in 322 patients (86.3%), Stage IB (T2N0M0) in 35 patients (9.4%), Stage II in 15 patients (4.0%), and Stage IV in 1 patient (0.3%).

Among the 373 resections, most (52.8%; n = 197) were performed by a minimally invasive approach (video-assisted thoracoscopy or robot-assisted thoracoscopy), and 47.2% (n = 176) were performed by thoracotomy. Information regarding intraoperative conversion to thoracotomy was only available for the 236 patients in IELCART and occurred in 53 patients (22.5%). Sex and tumor location did not significantly differ by resection approach. Patients undergoing sublobar resection were significantly older (70.0 vs 65.0 years, $P < .0001$), more likely to have some smoking history (84.6% vs 71.5%, $P = .0009$), and more likely to be overweight or obese (65.6% vs 40.6%, $P < .0001$). A total of 67 (18.0%) of the 373 patients had enlarging or developed new HH after surgery. There was no significant difference in patient characteristics, type of surgery, or tumor location among these 67 patients and the remaining 306 patients who did not have enlarging or new HH after surgery (Table 1).

A preoperative HH was identified in 71 (19.0%) of the 373 patients. Preoperative prevalence was higher among those who had sublobar resection than those who had

TABLE 1. Demographic and clinical characteristics of patients

	Enlarging or new hernia n = 67	No enlarging or new hernia n = 306	Total n = 373	*P* value
Gender				
Male	27 (40.3%)	125 (40.8%)	152 (40.8%)	.93
Female	40 (59.7%)	181 (59.2%)	221 (59.2%)	
Age at surgery, median (IQR)	69.0 (64.0-75.0)	67.5 (62.0-73.0)	68.0 (62.0-73.0)	.08
Smoking status				
Current	13 (19.4%)	71 (23.2%)	84 (22.5%)	.76
Former	42 (62.7%)	187 (61.1%)	229 (61.4%)	
Never	12 (17.9%)	48 (15.7%)	60 (16.1%)	
Pack-years of smoking, median (IQR)	42.9 (27.8-65.8)	36.9 (20.3-55.5)	37.5 (21.0-57.0)	.09
BMI categories				.64
<24.9 (underweight/normal)	19 (28.4%)	100 (32.7%)	119 (31.9%)	
≥25.0 (overweight/obese)	35 (52.2%)	159 (52.0%)	194 (52.0%)	
Missing	13 (19.4%)	47 (15.4%)	60 (16.1%)	
Type of surgery				.52
Robotic/VATS	33 (49.3%)	164 (53.6%)	197 (52.8%)	
Thoracotomy	34 (50.7%)	142 (46.4%)	176 (47.2%)	
Tumor location				
RUL	23 (34.3%)	117 (38.2%)	140 (37.5%)	.10
RML	2 (3.0%)	24 (7.8%)	26 (7.0%)	
RLL	11 (16.4%)	60 (19.6%)	71 (19.0%)	
LUL	18 (26.9%)	77 (25.2%)	95 (25.5%)	
LLL	13 (19.4%)	28 (9.2%)	41 (11.0%)	

IQR, Interquartile range; *BMI*, body mass index; *VATS*, video-assisted thoracoscopic surgery; *RUL*, right upper lobe; *RML*, right middle lobe; *RLL*, right lower lobe; *LUL*, left upper lobe; *LLL*, left lower lobe.

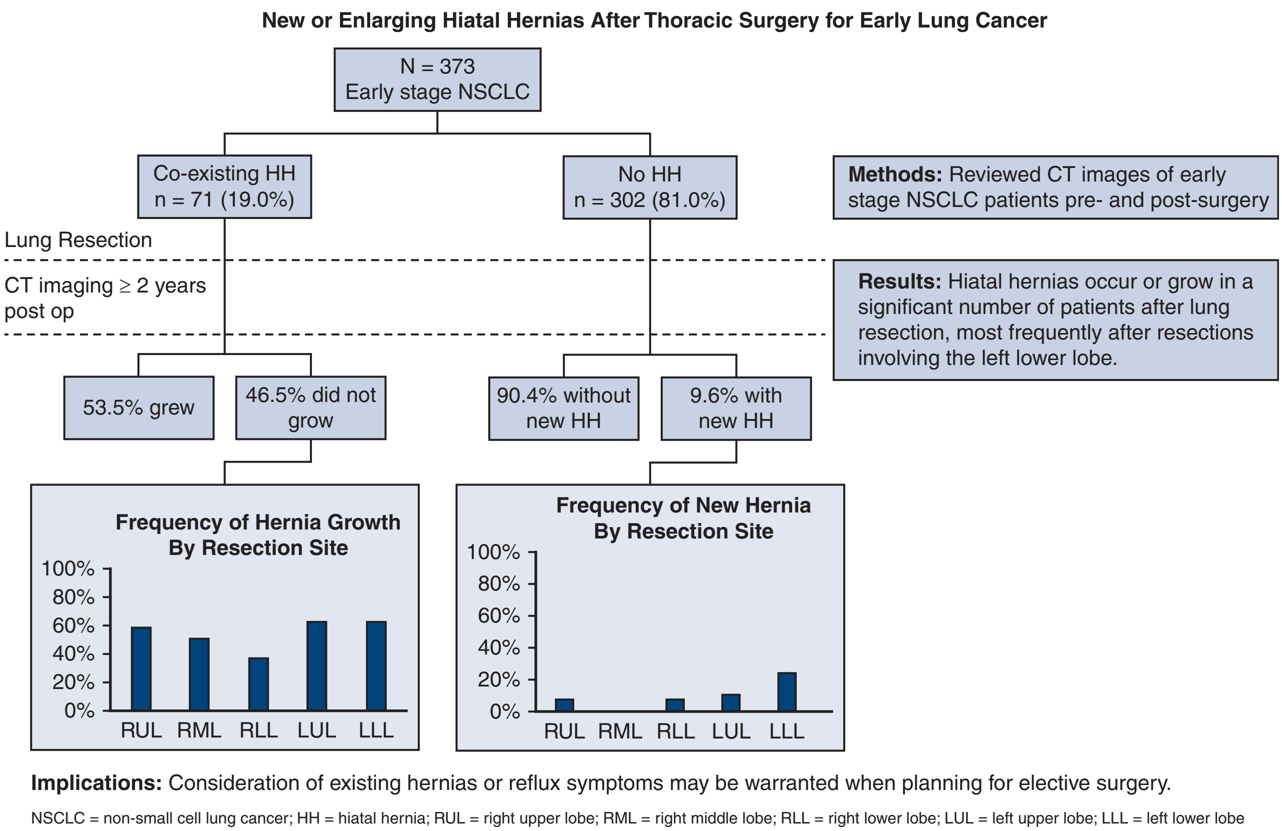

FIGURE 2. HHs occur or grow in a significant number of patients after lung resection, most frequently after resections involving the left lower lobe. Consideration of existing hernias or reflux symptoms may be warranted when planning for elective surgery. *NSCLC*, Non-small cell lung cancer; *HH*, hiatal hernia; *CT*, computed tomography; *RUL*, right upper lobe; *RML*, right middle lobe; *RLL*, right lower lobe; *LUL*, left upper lobe; *LLL*, left lower lobe.

lobectomy (26.0% vs 13.2%, $P = .002$). Median preoperative HH size was 21 mm (IQR, 18-25 mm); most (64; 90.1%) were of the sliding type. The median hernia size significantly ($P < .0001$) increased from 21 to 22 mm on the last follow-up CT scan (Table 2). Increase in size was observed in 38 (53.5%) of the 71 patients, more often among patients who had sublobar resection than those who had lobectomy (59.1% vs 44.4%, $P = .23$). By resection site, a size increase was most frequently seen in the left lower lobe (62.5%) and left upper lobe (62.5%) resections, followed by right upper lobe (58.3%), right middle lobe (50.0%), and right lower lobe (36.8%; $P = .54$).

No preoperative HH was present in 302 (81.0%) of the 373 patients, and median size of the esophageal hiatus was 1.6 cm (IQR, 1.4-1.83). After surgery, 29 (9.6%) developed new HH, 7 (5.6%) in patients after sublobar resection and 22 (12.4%) in patients after lobectomy ($P = .047$). Median postoperative hiatus size was 1.6 cm among the 273 patients who did not develop a postoperative hernia and 1.8 cm among the 29 who developed a hernia; the difference was not statistically significant ($P = .31$). Of the 29 patients with new HH, 28 (96.6%) were of the sliding type and 1 was paraesophageal (3.4%). The median hernia size was 21 mm (IQR, 17-24) (Table 2). Median time from surgery to detection of HH on CT scan was 20.6 months (IQR, 9.3-44.8). All persisted through the latest postoperative CT scan (median 3.7 months, IQR, 0.0-27.0). Median time from surgery to last CT was 28.6 months (IQR, 16.2-42.1) for the 273 patients who did not develop new HH after surgery.

Among the 302 patients without preoperative HH who underwent resection, incidence of new HH was significantly different by site of resection ($P = .04$) (Table 3). New hernias were most frequently seen in patients after resection involving the left lower lobe (24.2% of patients), followed by resections of the left upper lobe (10.1%), right upper lobe (7.8%), and right lower lobe (7.7%). None of the 22 patients with right middle lobe resections developed hernia. Incidence of HH was higher after lobectomy compared with sublobar resection across all sites except the left upper lobe, for which the incidence was about the same for sublobar resection (10.3%) and lobectomy (10.0%). HH was more likely to develop after a lower lobe resection regardless of laterality, but the difference was not statistically significant (Table 3). Overall, HH was more likely to develop after resection of the left

TABLE 2. Prevalence of hiatal hernia on preoperative and postoperative computed tomography

	Sublobar n = 169	Lobectomy n = 204	Total n = 373
Preexisting HH	44 (26.0%)	27 (13.2%)	71 (19.0%)
Median size of HH presurgery (cm)	2.1 (1.8-2.6)	2.0 (1.7-2.3)	2.1 (1.8-2.5)
Median size of HH postsurgery (cm)	2.3 (1.9-2.6)	2.0 (1.6-2.5)	2.2 (1.8-2.5)
Difference (Post-Pre) in cm, median (IQR)	0.19 (-0.11-0.35)	0 (-0.70-0.50)	0.10 (-0.2-0.4)
Signed-rank *P* value	.06	<.0001	<.0001
No preexisting HH	n = 125	n = 177	n = 302
New HH after surgery	7 (5.6%)	22 (12.4%)	29 (9.6%)
Sliding type	7 (100.0%)	21 (95.5%)	28 (96.6%)
Paraesophageal type	0 (0.0%)	1 (4.5%)	1 (3.4%)
Median size of new HH, in cm (IQR)	2.3 (1.9-2.4)	2.1 (1.4-2.4)	2.1 (1.7-2.4)
Median time between presurgery CT and surgery (IQR), mo	1.9 (1.2-3.0)	1.8 (1.2-2.8)	1.8 (1.2-2.8)
Median time between surgery and most recent CT (IQR), mo	25.1 (15.1-35.5)	31.8 (19.0-64.8)	28.8 (16.7-43.0)
Median time between presurgery and most recent CT (IQR), mo	27.9 (18.6-37.5)	34.6 (21.1-72.7)	31.1 (19.3-46.0)

HH, Hiatal hernia; *IQR*, interquartile range; *CT*, computed tomography.

lung (16/112, 14.3%) than the right lung (13/190, 6.8%) ($P = .03$). When stratified by extent of surgery, this difference was only significant among sublobar resections ($P = .04$) but not lobectomies ($P = .20$).

There was a borderline significant difference by surgical technique in that new hernias were more frequent after thoracotomy (13.0%) than after a minimally invasive approach (6.4%; $P = .05$).

TABLE 3. Newly developed hiatal hernia on postoperative computed tomography among the 303 participants with no hiatal hernia before surgery

	Type of surgery by tumor location						
	LLL n (%)	LUL n (%)	RLL n (%)	RML n (%)	RUL n (%)	Total n (%)	*P* value
Sublobar resection	2/14 (14.3%)	4/39 (10.3%)	0/19 (0.0%)	0/4 (0.0%)	1/49 (2.0%)	7/125 (5.6%)	.17
Lobectomy	6/19 (31.6%)	4/40 (10.0%)	4/33 (12.1%)	0/18 (0.0%)	8/67 (11.9%)	22/177 (12.4%)	.08
Total	8/33 (24.2%)	8/79 (10.1%)	4/52 (7.7%)	0/22 (0.0%)	9/116 (7.8%)	29/302 (9.6%)	.04

	Type of surgery by upper/middle or lower lobe			
	Lower n (%)	Upper/Middle n (%)	Total n (%)	*P* value
Sublobar resection	2/33 (6.1%)	5/92 (5.4%)	7/125 (5.6%)	1.00
Lobectomy	10/52 (19.2%)	12/125 (9.6%)	22/177 (12.4%)	.08
Total	12/85 (14.1%)	17/217 (7.8%)	29/302 (9.6%)	.10

	Type of surgery by right or left lung			
	Right n (%)	Left n (%)	Total n (%)	*P* value
Sublobar resection	1/72 (1.4%)	6/53 (11.3%)	7/125 (5.6%)	.04
Lobectomy	12/118 (10.2%)	10/59 (16.9%)	22/177 (12.4%)	.20
Total	13/190 (6.8%)	16/112 (14.3%)	29/302 (9.6%)	.03

	Surgical approach by tumor location						
	LLL n (%)	LUL n (%)	RLL n (%)	RML n (%)	RUL n (%)	Total n (%)	*P* value
VATS/robotic	3/16 (18.8%)	4/47 (8.5%)	0/24 (0.0%)	0/6 (0.0%)	3/63 (4.8%)	10/156 (6.4%)	.18
Thoracotomy	5/17 (29.4%)	4/32 (15.2%)	4/28 (14.3%)	0/16 (0.0%)	6/53 (11.3%)	19/146 (13.0%)	.17
Total	8/33 (24.2%)	8/79 (10.1%)	4/52 (7.7%)	0/22 (0.0%)	9/116 (7.8%)	29/302 (9.6%)	

LLL, Left lower lobe; *LUL*, left upper lobe; *RLL*, right lower lobe; *RML*, right middle lobe; *RUL*, right upper lobe; *VATS*, video-assisted thoracoscopic surgery.

In the univariate logistic regression analysis of 302 patients (29 with new HH, 273 did not develop HH postsurgery), patients with left lung resection were more likely to develop new HH ($P = .04$) (Table 4). Patients who had lobectomy ($P = .05$) and an open resection via thoracotomy ($P = .06$) were at the highest risk of developing new HH, although the difference only reached borderline significance. Results from the multiple logistic regression analysis showed that left lung resection was the only significant risk factor for new HH after controlling for other covariates. Patients with left lung resection were 2.6 times more likely to develop new postoperative hernia compared with those with right lung resection (odds ratio, 2.6, 95% confidence interval, 1.2-5.7) (Table 4).

Among the 302 participants, BMI was missing and imputed in 51 participants (16.9%). A separate logistic regression analysis of the 302 participants was performed using the imputed BMI along with other factors included in the first model. Similar to the results from the prior model, left lung resection was the only significant risk factor for developing new HH after surgery.

Matched Cohort Study in I-ELCAP

Among the 110 matched pairs of surgical patients and nonsurgical participants who did not have preoperative HH, 19 (17.3%) of the 110 surgical patients developed an HH after surgery, whereas only 3 (2.7%) of the 110 matched nonsurgical participants developed an HH. McNemar's test demonstrated that surgery significantly increased the risk of new HH (McNemar's test statistic = 12.8, $P = .0003$).

DISCUSSION

HHs are relatively common in the general population, although cited prevalence has ranged from 10% to 80% of adults in North America.[13] Many HHs are discovered incidentally, and their natural history is not well documented in the literature. Presentation of these hernias can range from asymptomatic to ischemic incarceration requiring emergency treatment, but the more commonly associated symptoms include epigastric discomfort or typical and atypical reflux.[14] While traditional teaching advised the repair of all paraesophageal-type HHs regardless of symptoms, this approach has become less popular as the management of complicated paraesophageal hernias has improved.[15] There are data to suggest that watchful waiting is appropriate in the majority of HH, because few require emergency repair.[16] Despite their high prevalence, the asymptomatic nature of many of these hernias leads to difficulty in following their course, and little research has

TABLE 4. Logistic regression of new hiatal hernia among 302 participants without preexisting hiatal hernia

Parameter	Univariate OR (95% CI)	Univariate *P* value	Multivariable OR (95% CI)	Multivariable *P* value
Gender				
Male	1.12 (0.52-2.41)	.78		
Female	Ref			
Age at surgery (in decade)	0.99 (0.64-1.52)	.95		
Smoking status				
Current	1.45 (0.36-5.92)	.61		
Former	1.56 (0.44-5.54)	.49		
Never	Ref			
BMI categories				
<24.9 (underweight/normal)	Ref			
≥25.0 (preobesity/obese)	0.71 (0.30-1.68)	.44		
Lesions size on CT before surgery (mm)	0.97 (0.91-1.04)	.37		
Lung region				
Upper/middle	0.52 (0.24-1.16)	.10		
Lower	Ref			
Side of lung				
Right	Ref		Ref	
Left	2.27 (1.05-4.92)	.04	2.57 (1.17-5.65)	.02
Type of surgery				
Robotic/VATS	Ref		Ref	
Thoracotomy	2.18 (1.00-5.05)	.06	1.83 (0.77-4.35)	.17
Extent of surgery				
Sublobar resection	Ref		Ref	
Lobectomy	2.39 (0.99-5.79)	.05	2.11 (0.82-5.47)	.12

OR, Odds ratio; *CI*, confidence interval; *BMI*, body mass index; *CT*, computed tomography; *VATS*, video-assisted thoracoscopic surgery.

been done to investigate how they are affected by lung resections, of which thousands are performed annually in the United States for lung cancer alone.[17]

We used the multi-institutional IELCART and I-ELCAP databases to look for new hernias or changes to preexisting HH after lung resections in patients with early-stage lung cancer and found that approximately 10% developed a new hernia. Although our study population consisted of patients in their seventh and eighth decades of life. Despite the most common tumor location being the right upper lobe, a new hernia was most common after resection involving the left lower lobe. Additionally, in patients with a preexisting HH, more than half had an increase in hernia size; the growth was small but significant and again most common after a left lower lobe resection. Although HHs are anatomically a mediastinal structure without laterality, it is possible that the liver may factor into these results. In cases of blunt traumatic diaphragm injury, 70% to 80% of cases occur on the left versus 15% to 24% on the right; this is thought to be due to a protective effect from the liver.[18]

We compared outcomes after sublobar resections and lobectomies because we hypothesized that a larger resection would be associated with new or enlarging hernias. Our results demonstrated that new hernias were more common after lobectomies. One potential explanation is that the removal of an entire lobe leaves behind a larger postresection space in the immediate postoperative period. Although this space often resolves without intervention, the initial absence of positive pressure from the thorax might predispose to herniation from below. This hypothesis is supported by the lack of new HH after right middle lobectomy, which tends to be the smallest lobe. A limitation of our study is that we did not collect information about factors that could intentionally or secondarily affect intrathoracic dead space, such as division of the inferior pulmonary ligament or phrenic nerve paralysis. It is unclear why HH would develop in a delayed fashion (at a median of 20.9 months), although evolving changes in the hiatal anatomy could play a role. Although the change in hernia size was small, the growth was significant and could continue over time. In the last part of our analysis, results from the matched cohort of surgical patients and nonsurgical screening participants suggested that surgery significantly increased risk of hernia.

Study Limitations

Because of the nature of our study and the data available, we did not have information about symptoms to determine the clinical relevance of our findings. Although this is a major limitation, this information is now being collected with the goal of further discussion in another analysis. As such, the current findings are unlikely to significantly change the management of patients with early lung cancer. However, they may become relevant for certain circumstances such as a patient with a large symptomatic hernia who is heavily considering nonoperative cancer treatment. To our knowledge, this is the first article focusing on HH as a potential complication of lung resection in a prospective cohort of patients with early-stage lung cancer.

Even if asymptomatic, HHs are clinically relevant because of their strong correlation with Barrett's esophagus[19] and its predisposition to esophageal adenocarcinoma. The presence and size of a HH are both associated with Barrett's metaplasia,[19] with larger HH having an increased risk of developing high-grade dysplasia or adenocarcinoma.[20] We did not have information about the incidence of Barrett's available for this population.

CONCLUSIONS

The most recently published guidelines from the Society of American Gastrointestinal and Endoscopic Surgeons[21] suggest that HHs should be repaired if symptomatic. Our study did not report patient symptomatology, although the collection of that information is ongoing. Currently, surgical resection is the mainstay of treatment for early-stage lung cancer, and this is unlikely to change in the near future. However, our findings indicate that the incidence of HH development after lung resection is significant and consideration of a patient's existing hernia may be warranted when planning for elective lung resection, such as a focused conversation about the potential exacerbation of reflux symptoms. With the ongoing collection of information regarding the symptoms associated with these HHs, we hope to follow up with the potential clinical implications these changes may have.

Conflict of Interest Statement

D.Y. is a named inventor on a number of patents and patent applications related to the evaluation of chest diseases including measurements of chest nodules; has received financial compensation for the licensing of these patents; and is a consultant and co-owner of Accumetra, a private company developing tools to improve the quality of CT imaging and is on the medical advisory board of Carestream, a company that develops radiography equipment and has consulted for Genentech, AstraZeneca, and Pfizer. C.H. is an inventor of the patents and pending patents owned by Cornell Research Foundation. As of April 2009, she has divested herself of all royalties and other interests arising from these. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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