Evaluation of acute and chronic pain outcomes after robotic, video-assisted thoracoscopic surgery, or open anatomic pulmonary resection

Sebastian T. Kwon, BS,^a Lili Zhao, PhD,^b Rishindra M. Reddy, MD,^a Andrew C. Chang, MD,^a Mark B. Orringer, MD,^a Chad M. Brummett, MD,^c and Jules Lin, MD^a

ABSTRACT

Objectives: Although robotic-assisted thoracic surgery (RATS) provides improved dexterity, the effect of RATS on pain compared with video-assisted thoracoscopic surgery (VATS) or open lobectomy is poorly understood. This study evaluated acute and chronic pain following RATS, VATS, and open anatomic pulmonary resection.

Methods: A retrospective review of 498 patients (502 procedures) who underwent RATS (74), VATS (227), and open (201) anatomic pulmonary resection including lobectomy and segmentectomy from 2010 to 2014 was performed to identify factors related to acute and chronic pain. Acute pain scores were analyzed over the first 9 postoperative days. Chronic pain was assessed using the validated PainDETECT survey.

Results: There were no significant differences in acute or chronic pain between RATS and VATS. There was a significant decrease in acute pain for patients with minimally invasive surgery ($P = .0004$). Chronic numbness was significantly higher after open resection (25.5% vs 11.6%; $P = .0269$) but with no difference in other symptoms of chronic pain. Despite no significant difference in pain scores, 69.2% of patients who received RATS felt the approach affected pain versus 44.2% VATS ($P = .0330$). On multivariable analysis, younger age ($P < .0001$), female gender ($P = .0364$), and baseline narcotic use ($P = .0142$) were associated with acute pain, whereas younger age ($P = .0021$) and major complications ($P = .0003$) were associated with chronic numbness in patients who received MIS.

Conclusions: Although minimally invasive approaches resulted in less acute pain and chronic numbness, there were no significant differences between RATS and VATS. In contrast, more RATS patients believed the approach affected their pain, suggesting a difference between reality and perception. (J Thorac Cardiovasc Surg 2017;154:652-9)

Pain scores were significantly higher after open but not between RATS or VATS lobectomy.

Central Message

Although robotics may provide improved dexterity, there were no differences in acute or chronic pain compared with thoracoscopic lobectomy.

Perspective

RATS lobectomy provides improved dexterity and visualization, but the effect of RATS on pain is poorly understood. Although minimally invasive lobectomy resulted in less acute pain and chronic numbness, there were no differences between RATS and thoracoscopic lobectomy. In contrast, more RATS patients believed the approach affected their pain, suggesting a difference between reality and perception.

See Editorial Commentary page 660.

See Editorial page 649.

From the ^aSection of Thoracic Surgery, Department of Surgery, Departments of ^bBiostatistics and ^cAnesthesiology, University of Michigan Medical School, Ann Arbor, Mich.

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Address for reprints: Jules Lin, MD, Section of Thoracic Surgery, University of Michigan Medical Center, 1500 E Medical Center Drive, 2120TC/5344, Ann Arbor, MI 48109-5344 (E-mail: juleslin@umich.edu).

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Video-assisted thoracoscopic surgery (VATS) is a minimally invasive approach resulting in less tissue trauma, shorter recovery, and improved cosmesis.¹ For early lung cancer, resection is the mainstay of treatment, and VATS lobectomy has become the treatment of choice.²⁻⁴ There is a learning

Scanning this QR code will take you to a supplemental video and table for the article.

Abbreviations and Acronyms

ARDS	= acute respiratory distress syndrome
IASP	= International Association for the Study of Pain
IV	= intravenous
LOS	= length of stay
MIS	= minimally invasive surgery
PCA	= patient-controlled analgesia
PD-Q	= PainDETECT questionnaire
POD	= postoperative day
RATS	= robotic-assisted thoracic surgery
STS	= Society of Thoracic Surgeons
VATS	= video-assisted thoracoscopic surgery

curve to performing complex thoracoscopic procedures like lobectomy due to reduced tactile sensation.⁵ By combining 3-dimensional imaging and increased degrees of freedom, robotic surgery addresses some of these disadvantages.^{6,7} Although robotic-assisted thoracic surgery (RATS) may provide advantages in terms of dexterity, one of the disadvantages is a complete lack of tactile feedback, which could lead to tissue damage especially for inexperienced surgeons.⁸ Several studies have shown that RATS lobectomy can be performed safely by experienced thoracic surgeons with no significant difference in morbidity or mortality compared with VATS.⁹⁻¹¹

However, the benefits of RATS compared with VATS lobectomy have not been clearly defined, especially with higher costs and longer operating times.^{10,12} One of the proposed advantages of robotic over thoracoscopic procedures is that the robotic arms rotate around a fulcrum point, which theoretically reduces torque on the chest wall decreasing damage to the intercostal nerves and surrounding tissues leading to reduced pain. Although RATS offers certain advantages for the surgeon, the benefits in terms of acute and chronic pain outcomes is less clear.¹³⁻¹⁵ This study evaluates postoperative acute and chronic pain outcomes after VATS, RATS, and open lobectomy.

MATERIAL AND METHODS

Approval from the University of Michigan Institutional Review Board was obtained. Consent was waived for the retrospective review of perioperative pain scores but was obtained when patients completed chronic pain surveys. Consecutive patients who underwent VATS, RATS, and open lobectomy or segmentectomy between February 2010 and June 2014 were included. Patients who underwent chest wall resection or previous ipsilateral thoracic surgery were excluded. Pre-resection mediastinoscopy and diagnostic wedge resection were not considered previous thoracic operations. Pulmonary resections were performed by 7 surgeons. Two surgeons performed all the RATS procedures but used VATS and RATS interchangeably depending on equipment availability with no preference based on size or location of the lesion. Although an open approach was favored for centrally located tumors, this represents the current practice in most thoracic groups.

VATS procedures were performed with a 3- or 4-port technique with an access incision less than 5 cm and no rib spreading. A 4-arm technique and an additional 12-mm port for the bedside assistant was used for RATS (Video 1). Posterolateral thoracotomies, generally serratus-sparing, were performed through the fifth interspace after shingling the sixth rib to facilitate rib spreading. All VATS and RATS port sites were infiltrated with 1% lidocaine/0.25% bupivacaine with an intercostal nerve block and postoperative patient-controlled analgesia (PCA) transitioned to oral narcotics. Thoracotomy patients underwent epidural or paraspinal catheter placement supplemented with a PCA when needed.

Data Collection

A retrospective review of 498 patients who underwent 502 lobectomies or segmentectomies, including 74 RATS, 227 VATS, and 201 thoracotomies, was performed to identify factors related to postoperative pain (Table 1). Of these patients, 20 underwent thoracoscopic and 8 open segmentectomies. If a minimally invasive procedure was converted to thoracotomy, the patient was classified as having a thoracotomy. The Society of Thoracic Surgeons (STS) institutional database was queried along with the medical record.

To make the results comparable with other studies, standardized assessment tools were used. For acute (<10 days) postoperative pain, visual pain scores, self-reported by the patient to the nurse, were collected.¹⁶ Focusing on the severity, the maximum pain scores from each postoperative day (POD) were taken from all patients and averaged using a generalized mixed model to create a progression of postoperative pain. Chronic pain is defined by the International Association for the Study of Pain (IASP) as having pain at the site of surgery more than 2 months afterward.¹⁷ Symptoms of chronic pain were assessed using the validated PainDETECT questionnaire (PD-Q), which has been used previously to evaluate post-thoracotomy pain.¹⁸⁻²⁰ If a patient failed to respond by mail after 2 attempts, up to 2 phone calls were made to administer a phone survey including questions from the PD-Q (Table E1). In the design stage, we specifically selected 11 variables (Tables 2 and 3) to be included in the survey because they were hypothesized to be potentially important factors for comparing surgical groups. In the analysis, we did not adjust for multiple comparisons because we set up a separate hypothesis for each of the 11 variables before we collected the data. Four patients underwent more than 1 lobectomy during different hospitalizations and had their inpatient courses analyzed separately for acute pain but were evaluated once for chronic pain at the time of the study.

Preoperative characteristics, including age, gender, tumor stage, preoperative narcotic use, and smoking status were collected. Major comorbidities included preoperative chemotherapy or radiation, coronary disease, peripheral vascular disease, cerebrovascular disease, pulmonary hypertension, diabetes, creatinine >1.5, dialysis, chronic obstructive pulmonary

VIDEO 1. This brief video demonstrates the port placement and standard techniques used during a robotic-assisted thoracoscopic right upper lobectomy including the use of the robotic stapler and an intercostal nerve block. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(17\)30216-7/addons](http://www.jtcvsonline.org/article/S0022-5223(17)30216-7/addons).

TABLE 1. Patient characteristics

Characteristic	All (502)	RATS (74)	VATS (227)	Open (201)	P*	P†
Mean age, y (range)	65.7 (18-93)	66.7 (37-91)	65.4 (18-87)	65.7 (20-93)	.9727	.3940
Men	247 (49.2)	28 (37.8)	106 (46.7)	113 (56.2)	.0102	.1834
Any major comorbidities	285 (57.2)	42 (56.8)	109 (48.0)	134 (66.7)	.0003	.1922
Stage I/II	368 (73.3)	59 (79.7)	178 (78.4)	131 (65.2)	<.0001	.3888
Stage III/IV	86 (17.1)	6 (8.1)	11 (4.8)	42 (20.9)		
Not lung primary	48 (9.6)	9 (12.2)	38 (16.7)	28 (13.9)	.6033	.3455
Preoperative chemotherapy	12 (2.4)	0 (0)	0 (0)	12 (6.0)	<.0001	
Postoperative chemotherapy	58 (11.6)	3 (4.1)	24 (10.6)	31 (15.4)	.0267	.0866
Preoperative radiation	12 (2.4)	0 (0)	0 (0)	12 (6.0)	<.0001	
Postoperative radiation	15 (3.0)	0 (0)	4 (1.8)	11 (5.5)	.0075	.5753
Preoperative narcotic use	90 (17.9)	11 (14.9)	30 (13.2)	49 (24.4)	.0021	.7184
Current smoker	22 (4.4)	2 (2.7)	12 (5.3)	8 (4.0)	.7184	.5296
Quit smoking >1 mo	366 (72.9)	54 (73.0)	156 (68.7)	156 (77.6)	.0528	.4884
Never smoker	114 (22.7)	18 (24.3)	59 (26.0)	37 (18.4)	.0603	.7773
Prior thoracic operation	3 (0.6)	0 (0)	0 (0)	3 (1.5)	.0636	
Right side	274 (54.6)	49 (66.2)	120 (52.9)	105 (52.2)	.3897	.0444
OR time, mean	232	233	200	268	<.0001	.0016
Convert to open	55	14 (18.9)	41 (18.1)	-		.8625
Prolonged air leak	36 (7.2)	2 (2.7)	14 (6.2)	20 (10.0)	.0535	.3733
Chest tube (median days)	3.0 (1-49)	3.0 (2-49)	3.0 (1-39)	4.0 (1-41)	.0004	.7508
In-hospital mortality	1 (0.2)	0 (0)	0 (0)	1 (0.5)	.4004	
Epidural	117 (23.3)	1 (1.4)	13 (5.7)	103 (51.2)	<.0001	.2008
Paraspinous catheter	64 (12.7)	0 (0)	0 (0)	64 (15.9)	<.0001	
Median LOS, d (range)	5.0 (2-71)	4.0 (2-53)	4.0 (2-45)	6.0 (2-71)	<.0001	.3807
Mean follow-up, d	828	719	846	853	.5890	.0020
Deceased	116 (23.1)	17 (23.0)	43 (18.9)	56 (27.9)	.0390	.4503

Values are n (%) unless otherwise indicated. Values in bold are significant at $P < .05$. RATS, Robotic-assisted thoracic surgery; VATS, video-assisted thoroscopic surgery; OR, operating room; LOS, length of stay. *Minimally invasive surgery versus Open. †RATS versus VATS.

disease, pulmonary fibrosis, forced expiratory volume in 1 second <50% predicted, diffusion lung capacity for carbon monoxide <40% predicted, and a Zubrod score ≥ 2 . Epidural, paraspinous catheter, PCA, intravenous (IV) narcotics, and oral narcotic doses were recorded. Oral and IV narcotics were converted to morphine equivalents so the dosages could be compared.

Postoperative complications included return to the operating room, air leak, pneumonia, acute respiratory distress syndrome (ARDS), respiratory failure, bronchopleural fistula, pulmonary embolism, pneumothorax, ventilation, reintubation, tracheostomy, atrial or ventricular arrhythmia, myocardial infarction, deep venous thrombosis, empyema, sepsis, postoperative

TABLE 2. Chronic pain open versus MIS

Variables	MIS (112)	Open (55)	P
Pain	26 (23.2)	18 (32.7)	.1966
Burning	5 (4.5)	5 (9.1)	.3001
Tingling	9 (8.0)	6 (10.9)	.5714
Prickling	9 (8.0)	5 (9.1)	.7755
Light touch	10 (8.9)	7 (12.7)	.4301
Numbness	13 (11.6)	14 (25.5)	.0269
Cold	0 (0)	1 (1.8)	.3293
Heat	0 (0)	1 (1.8)	.3293
Have surgery again?	Yes (103 [92.0])	Yes (50 [90.9])	.6632
	No (6 [5.4])	No (2 [3.6])	
	Not sure (3 [2.7])	Not sure (3 [5.5])	
Approach affects pain?	Yes (56 [50.0])	Yes (20 [36.4])	.0040
	No (45 [40.2])	No (18 [32.7])	
	Not sure (11 [9.8])	Not sure (17 [30.9])	
Affect pain how?	Positively (51/55; 92.7%)	Positively (11/19; 57.9%)	.0002
	Negatively (2/55; 3.6%)	Negatively (8/19; 42.1%)	
	Both ways (2/55; 3.6%)	Both ways (0/19; 0%)	

Values are n (%) unless otherwise indicated. Values in bold are significant at $P < .05$. MIS, Minimally invasive surgery.

TABLE 3. Chronic pain RATS versus VATS

Variables	RATS (26)	VATS (86)	P
Pain	9 (34.6)	17 (19.8)	.1831
Burning	2 (7.7)	3 (3.5)	.3288
Tingling	3 (11.5)	6 (7.0)	.4311
Prickling	3 (11.5)	6 (7.0)	.4311
Light touch	5 (19.2)	5 (5.8)	.0504
Numbness	3 (11.5)	10 (11.6)	1.0
Cold	0 (0)	0 (0)	
Heat	0 (0)	0 (0)	
Have surgery again?	Yes (23 [88.5]) No (3 [11.5]) Not sure (0 [0])	Yes (80 [93.0]) No (3 [3.5]) Not sure (3 [3.5])	.2547
Approach affects pain?	Yes (18 [69.2]) No (8 [30.8]) Not sure (0 [0])	Yes (38 [44.2]) No (37 [43.0]) Not sure (11 [12.8])	.0330
Affect pain how?	Positively (15/17; 88.2%) Negatively (1/17; 5.9%) Both ways (1/17; 5.9%)	Positively (36/38; 94.7%) Negatively (1/38; 2.6%) Both ways (1/38; 2.6%)	.1292

Values are n (%) unless otherwise indicated. Values in bold are significant at $P < .05$. RATS, Robotic-assisted thoracic surgery; VATS, video-assisted thoracoscopic surgery.

transfusion, ileus, delirium, and new renal failure. Minor complications were urinary tract infection, urinary retention, and surgical site infection. Respiratory complications included pneumonia, reintubation, respiratory failure, atelectasis, ARDS, mechanical ventilation, and tracheostomy.

Statistical Analysis

A generalized linear mixed model (PROC Glimmix) was used to estimate the longitudinal acute high pain scores using B-splines, and the pain scores were compared among the 3 surgical groups (RATS, VATS, and open).^{21,22} In the model, the group’s main effect creates separate intercepts for each group, and the interaction of the group with the spline effect creates separate trends. This model allows us to compare the pain scores on each POD. The primary analysis for the pain scores was to compare the score trajectories between surgical groups, and there was no nonparametric test to perform this. Two-sample t tests were used to compare acute pain scores,²³ operative time, and length of hospital stay between RATS versus VATS and open versus minimally invasive surgery (MIS) (VATS or RATS). Chi-square or Fisher exact tests were used to evaluate categorical complications.

Multivariable outcomes of interest were acute pain and chronic numbness. A multivariable analysis was performed with the surgical approach as the primary variable. Covariates including age, smoking status, sex, neo-adjuvant chemotherapy, neoadjuvant radiation, any major comorbidity, cancer stage, baseline narcotic use, average morphine used per day, paraspinous catheter, any major complication, epidural, prolonged air leak, acute pain, adjuvant chemotherapy, and adjuvant radiation were evaluated. A stepwise procedure was used to identify the most important factors with a significance level of .15 to select variables for the multivariable model. The surgical approach was always included. Significance was determined if P values were $< .05$. Additionally, propensity score methods were used to compare surgical approaches after adjusting for the previously mentioned covariates. Specifically, we used inverse probability treatment weights and covariate adjustment using propensity scores.²⁴ First, propensity scores were calculated from a logistic regression model with the surgical approach as the outcome and all the previously mentioned covariates as predictors, and then the propensity scores obtained in the first step were used in another logistic regression model with the acute pain or chronic numbness as the outcome and the surgical approach as the predictor. In the first method, each subject was weighted differently using the inverse of the propensity score (with appropriate normalization of the weights), and the propensity

score was included as a covariate in the second method. All analyses were conducted using SAS (version 9.4; SAS Institute, Cary, NC).

RESULTS
Patient Characteristics

The mean operating room time was significantly longer with RATS compared with VATS (233 vs 200 minutes; $P = .0016$) and open versus MIS (268 vs 208 minutes; $P < .0001$) (Table 1). The open group had significantly more men and more advanced cancers compared with MIS with a higher incidence of preoperative and postoperative chemotherapy and radiation. At least 1 major comorbidity was present in 66.7% (134/201) of open patients which was significantly higher ($P = .0003$) than RATS (56.8%) or VATS (48%). Median chest tube duration was longer, more patients used preoperative narcotics, and there was increased use of an epidural or paraspinous catheter.

There was no difference in length of stay (LOS) between RATS and VATS ($P = .3807$) nor was there a difference in intensive care unit admission rates ($P = .7789$). Open patients had a longer LOS (4.83 days MIS vs 7.31 days open; $P < .0001$) and were more likely to be admitted to the intensive care unit (6.0% [18/301] MIS vs 22.9% [46/201] open; $P < .0001$). Rates of pneumonia (3.0% [9/301] MIS vs 7.0% (14/201) open; $P = .0487$) and reintubation (2.0% [6/301] MIS vs 6.0% [12/201] open; $P = .0259$) were also significantly higher after thoracotomy.

Acute Pain

There were no significant differences in acute pain between VATS and RATS (Figure 1). Although the RATS pain course appeared to be slightly decreased, especially in the later PODs, the difference was not significant

RATS Pts	74	74	66	39	20	15	9	5	4
VATS Pts	227	227	205	134	90	52	28	16	14
Open Pts	201	201	199	182	150	111	77	54	41

FIGURE 1. Daily high pain scores were significantly higher after open lobectomy compared with a minimally invasive approach (video-assisted thoracoscopic surgery [VATS] + robotic-assisted thoracic surgery [RATS]), but only after postoperative day (POD) 4. Pain scores were not significantly different between RATS and VATS. The number of patients in the hospital on each POD is included below as well as the lower and upper bound of the 95% confidence interval for the difference between groups. Values in bold are significant at $P < .05$. MIS, Minimally invasive surgery.

	Acute pain score difference between RATS vs VATS		Acute pain score difference between MIS vs open	
	Confidence interval	P	Confidence interval	P
POD1	-1.0491 to 0.3522	.3294	-0.7768 to 0.2096	.2596
POD2	-0.8575 to 0.3002	.3452	-0.6298 to 0.1624	.2474
POD3	-0.9258 to 0.2341	.2423	-0.1411 to 0.6508	.2070
POD4	-1.3696 to 0.2447	.1719	0.3810 to 1.3176	.0004
POD5	-1.6257 to 0.1500	.1033	0.5030 to 1.4892	<.0001
POD6	-2.1261 to 0.4178	.1950	0.1855 to 1.5872	.0132
POD7	-2.4716 to 0.4178	.1634	0.6688 to 2.2302	.0003
POD8	-4.0033 to 1.2640	.3078	1.3177 to 3.9896	.0001
POD9	-5.3282 to 1.6299	.2959	0.8405 to 4.2324	.0034

($P = .6469$). On the other hand, there was a significant decrease in acute pain after MIS compared with thoracotomy starting on POD 4, (Figure 1; $P = .0004$). After excluding patients with an epidural, acute pain scores between MIS and open became significantly different even earlier on POD 2 ($P = .0003$). On univariate analysis, major complications ($P = .0110$) and baseline narcotic use ($P < .0001$) correlated with acute pain, whereas modifier 22, neoadjuvant chemotherapy and radiation, and previous thoracic operations did not. Patients with higher acute pain scores had higher postoperative oxygen requirements ($P < .0001$).

Chronic Pain

Chronic pain surveys were completed by 86.7% (169/195) of patients who were alive and could be contacted at the time of the study (26 RATS, 87 VATS, and 56 open). Most patients (161/169 [95.3%]) completed the validated PainDETECT survey, and 167 patients answered the questions on whether the surgical approach affected their

pain. Eight patients completed the phone survey alone (which also contained the questions from the PainDETECT; Table E1). The differences in chronic pain between MIS and thoracotomy were not significantly different (23.2% [26/112] MIS vs 32.7% [18/55] open; $P = .1966$). However, when evaluating individual symptoms, chronic numbness was significantly more common after open lobectomy (11.6% [13/112] MIS vs 25.5% [14/55] open; $P = .02$). There was also a significant difference in the degree of numbness scored from 0 to 5, with a mean of 1.61 for the MIS patients and 2.23 after thoracotomy ($P = .0264$). Open patients were more likely to have other symptoms of chronic neuropathic pain, including burning, tingling, and pain with light touch, cold, or heat; however, these differences were not significant (Table 2).

Open patients were more likely to experience persistent pain with pain attacks (Pain course 2 on the PD-Q) (2.6% [1/38] MIS vs 27.8% [5/18] open; $P = .0106$), whereas MIS patients experienced pain attacks without pain

TABLE 4. Postoperative outcomes—multivariable analysis (*P* values)

Variables	Acute pain	Chronic numbness
RATS vs VATS variables		
Procedure type	.6787	.2593
Sex	.0364	>.15
Age	<.0001	.0021
Baseline narcotic	.0142	>.15
Major comorbidity	>.15	.1382
Major complication	.0652	.0003
Average morphine/d	.0027	>.15
MIS vs Open variables		
Procedure type	.6316	.0118
Sex	<.0001	>.15
Age	<.0001	.0002
Baseline narcotic	.0008	>.15
Major comorbidity	>.15	.0847
Major complication	.1515	.0105
Average morphine/d	.0001	>.15

Only variables with *P* < .15 are shown. Values in bold are significant at *P* < .05. See [Methods](#) section for a full list of variables. RATS, Robotic-assisted thoracic surgery; VATS, video-assisted thoracoscopic surgery; MIS, minimally invasive surgery.

between, although this was not significant (Pain course 3; 65.8% [25/38] MIS vs 38.9% [7/18] open; *P* = .0837). Younger patients were significantly more likely to have chronic numbness (*P* = .0004). For open patients, 36.4% (20/55) felt the approach affected their pain versus 50.0% (56/112) MIS (*P* = .0040) and were more likely to feel that the approach affected their pain negatively (42.1% [8/19] open vs 3.6% [2/55] MIS; *P* = .0002).

Although RATS patients had a higher rate of chronic neuropathic pain, this was not significant (34.6% [9/26] RATS vs 19.8% [17/86] VATS; *P* = .1831) ([Table 3](#)). However, significantly more RATS patients felt that the approach affected their pain (69.2% [18/26] RATS vs 44.2% [38/86] VATS; *P* = .0330), and most (88.2%; 15/17) thought that the approach affected their pain positively. Of the VATS patients who felt the approach affected their pain, 94.7% (36/38) also felt that the approach affected their pain positively.

Pain Control Modalities

Patients requiring oral or IV narcotics had higher pain scores (5.0961 vs 2.3865; *P* < .0001). Morphine equivalents also positively correlated with pain scores (*P* < .0001). There was no difference in the average morphine equivalents between RATS and VATS patients (*P* = .7552) or MIS and open patients (*P* = .6892). However, when morphine equivalents were separated by postoperative day, after excluding patients with epidurals, open patients used significantly more morphine equivalents from POD3 through POD6 (*P* < .0001, <.0001, .0007, and .0060, respectively). Patients with a paraspinous catheter had significantly higher pain scores (4.5000 vs 5.1307; *P* = .0009).

Multivariable Analysis

For multivariable analysis, outcomes evaluated included median acute pain scores and chronic numbness ([Table 4](#)). For RATS versus VATS, younger age (*P* < .0001), baseline narcotic use (*P* = .0142), increased average morphine per day (*P* = .0027), and female gender (*P* = .0364) were associated with increased acute pain scores, whereas the approach and major complications were not. Chronic numbness was associated with the occurrence of any major complication (*P* = .0003) and younger age (*P* = .0021) but not procedure type or postoperative acute pain score.

Comparing open versus MIS, younger age (*P* < .0001), female gender (*P* < .0001), baseline narcotic use (*P* = .0008), and increased average morphine per day (*P* = .0001) were associated with increased acute pain. Chronic numbness was associated with younger age (.0002), thoracotomy (odds ratio 3.543; 95% confidence interval [CI] 1.323-0.486; *P* = .0118), and any major complication (*P* = .0105). Smoking, neoadjuvant chemotherapy or radiation, stage, paraspinous catheter, epidural, prolonged air leak, acute pain, and adjuvant chemotherapy or radiation were not significant for RATS versus VATS or open versus MIS.

Propensity Scoring

Using 2 propensity scoring methods, RATS versus VATS (*P* = .49 and .31) and open versus MIS (0.72 vs 0.68) were not significantly different for acute pain. For chronic numbness, RATS versus VATS was not significantly different (*P* = 1 and .65), whereas MIS versus open was (*P* < .0001 and 0.0119). The odds ratios were 6.82 (95% CI 2.89-16.1) and 5.16 (95% CI 1.44-18.52) using the 2 propensity scoring methods.

DISCUSSION

This is the first study evaluating acute and chronic pain outcomes after RATS, VATS, and open anatomic lung resections using validated pain assessment tools. Nasir et al²⁵ reported a median pain score of 2/10 in 394 patients undergoing robotic lung resection 3 weeks postoperatively, but no perioperative pain data were provided, and the only comparison group was 41 patients converted to thoracotomy. Although Chiu et al²⁶ found lower pain scores after robotic versus laparoscopic hysterectomy, Park et al²⁷ found no significant difference in a randomized trial of 71 patients undergoing robotic versus laparoscopic right colectomy.

Our results showed no significant difference between VATS and RATS for acute or chronic pain outcomes. However, more RATS patients (69.2%) felt that the robotic approach affected their pain, and 88.2% felt the affect was positive, suggesting a difference between reality and perception likely reflecting successful marketing. When discussing open versus MIS approaches, surgeons often

describe less pain and quicker recovery after MIS, which could affect patients' perspectives. However, no difference in pain was described by our surgeons when counseling patients on VATS versus RATS.

While acute pain data were collected over the initial 9 PODs, many MIS patients were discharged before day 9. With a median LOS of 4 days, the MIS patients still in the hospital likely had complications, such as a prolonged air leak or pneumonia, and MIS patients at home may have had lower pain scores, potentially increasing the difference in acute pain seen between open and MIS.

Female gender was an independent predictor of increased acute pain in VATS versus RATS and open versus MIS patients, suggesting that female patients should be more aggressively treated for acute pain, using narcotic patches or an epidural. Acute pain scores were also higher from POD 3 to 6 after thoracotomy, reflecting discontinuation of most epidurals on POD 3. When indicated, it may be beneficial to keep epidurals until POD 5 to improve pain control and to use adjuvant methods such as narcotic patches once the epidural is removed.

Although previous studies have associated higher postoperative pain with smoking, there was no significant relationship in the current study. However, our institution has a lower percentage of current smokers because patients are strongly encouraged to quit smoking preoperatively to decrease pulmonary complications with only 4.4% of patients smoking at the time of surgery and no significant difference between groups.

Nomori et al²⁸ found no significant difference in chronic pain among VATS, limited thoracotomy, or open thoracotomy. Open thoracotomy was associated with significantly higher acute pain. Maguire et al²⁹ evaluated 600 patients who underwent VATS or thoracotomy and found chronic pain in 57% at 7 to 12 months. Younger age was associated with chronic pain, whereas the approach was not. In a study of 144 VATS patients, Hutter et al³⁰ reported chronic pain in 20.1% with 16.9% experiencing numbness and 8.3% dysesthesia. Grosen et al³¹ evaluated 414 patients undergoing thoracotomy for lung cancer and found chronic pain in 19%.

Our results showed chronic pain in 34.6% after RATS, 19.8% after VATS, and 32.7% after thoracotomy; however, the differences were significant only for chronic numbness in open versus MIS ($P = .0269$). Although neuropathic pain is not uncommon after thoracic surgery, Steegers et al¹⁹ found that only half of chronic pain included a neuropathic component. Numbness is a standard measure of chronic pain on the PainDETECT questionnaire, which has been used previously to evaluate post-thoracotomy pain.^{18,19} Although use of both mailed and phone surveys could introduce variation, the phone survey included the same questions from the PainDETECT, and the vast majority (161/169 [95.3%]) completed the PainDETECT with only 8 patients completing the phone survey alone.

Although thoracotomy was favored for central tumors, which could bias the results, we believe this represents current practice in most thoracic groups. VATS lobectomy has become the standard approach for most lung cancers, and a randomized trial would be impossible. Although thoracotomy was associated with longer operative times, RATS also took significantly longer than VATS with no significant difference in pain outcomes. Although there were differences in cancer stage between open and MIS, we have attempted to control for this by including these variables in our multivariable analysis, and thoracotomy was independently predictive of chronic numbness.

For postoperative complications after MIS, the only significant difference was a higher rate of urinary retention in RATS versus VATS. This was possibly due to significantly longer operating times because the length of anesthesia has been correlated with voiding times.³² Our approach to Foley removal within 24 hours is the same for RATS and VATS. For open patients, urinary retention may not have correlated with procedure length because the Foley remained in place until removal of the epidural. In contrast, pulmonary complications, including pneumonia and reintubation, were significantly more common after thoracotomy, likely related to increased postoperative pain.

With any retrospective study, there are limitations. Chronic pain data were collected at the time of the study instead of specific time points, which could result in recall bias. However, previous studies have used a similar approach including a VATS study by Hutter et al^{17,30} evaluating patients at least 2 months postoperatively, which is the definition of chronic pain used by the IASP.

Although epidurals were routinely used for thoracotomy, they were infrequent after MIS. A prospective study using a standardized pain regimen in all patients would be needed to address this limitation. However, one of the aims was to evaluate pain outcomes in real-life conditions. Although epidurals are standard after thoracotomy,³³ only 10% to 46% received an epidural after VATS.³⁴ In addition, there was no significant difference in pain scores in a randomized trial between epidural and PCA after VATS lobectomy.³⁵

Although epidurals are a potential confounding factor, epidurals would be expected to improve pain in open patients and decrease any differences between the 2 groups. Despite epidurals, there was still a significant difference in acute pain starting on POD 4, consistent with the removal of most epidurals on POD 3. Eliminating epidurals would likely increase the differences in acute pain, and excluding patients with an epidural revealed a significant difference in acute pain scores even earlier on POD 2. In addition, one of the main aims was to compare RATS and VATS, for which the pain control was the same with no epidurals.

Although there was variability in the frequency that scores were recorded, only the maximum score for each day was used to focus on the severity of postoperative

pain. Although there are limitations in a retrospective study in confirming the consistency of pain assessments, the visual pain scale is used widely across specialties and institutions, and the pain assessment was similar between groups because all patients were cared for on the same unit by the same group of thoracic nurses during the same period.

The benefits of RATS lobectomy in terms of acute and chronic pain outcomes is unclear. Results of the current study show that although minimally invasive approaches resulted in less acute pain and chronic numbness, there were no significant differences between RATS and VATS. In contrast, more RATS patients believed the approach affected their pain, suggesting a difference between reality and perception. This study should serve as a basis for future larger, prospective studies evaluating acute and chronic pain outcomes after thoracic surgery.

Conflict of Interest Statement

Dr Reddy and Dr Lin: Intuitive Surgical Site Mentor and Speaker. Dr Brummett: Tonix Pharmaceuticals and Neuros Medical Inc. All other authors have nothing to disclose with regard to commercial support.

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Key Words: acute pain, chronic pain, lobectomy, thoracoscopy, robotic surgery, thoracotomy

TABLE E1. Phone survey**Postoperative pain and patient satisfaction**

1. Over the past week have you had pain related to your surgery? (Y/N)
 - a. If yes, where is the pain located? (surgical site or specific location):
 - b. How would you characterize the pain? (circle all that apply):
 - i. Burning
 - ii. Tingling
 - iii. Prickling
 - iv. Light touching painful
 - v. Numbness
 - vi. Cold is painful
 - vii. Heat is painful
2. From a pain respect alone, would you do the surgery again? (Y/N)
3. Do you feel like the surgical approach (robotic, thoracoscopic, or open surgery) affected your postoperative pain (Y/N)?
 - a. If yes, positively or negatively?