Initial Multicenter Community Robotic Lobectomy Experience: Comparisons to a National Database

R. Douglas Adams, MD,* William D. Bolton, MD, James E. Stephenson, MD, Gavin Henry, MD, E. Todd Robbins, MD, and Eric Sommers, MD

Division of Thoracic Surgery, Owensboro Medical Health System, Owensboro, Kentucky; Division of Thoracic Surgery, Greenville Memorial Hospital, Greenville, South Carolina; Department of Surgery, Saint Agnes Hospital, Baltimore, Maryland; Division of Thoracic Surgery, Baptist Memorial Hospital, Memphis, Tennessee; and Department of Surgery, Tampa General Hospital, Tampa, Florida

Background. **In pulmonary lobectomy, video-assisted thoracoscopic surgery (VATS) offers advantages compared with open thoracotomy. However, various issues have limited its adoption, especially in community settings. Single surgeon studies suggest that completely portal robotic lobectomy (CPRL) may address such limitations. This multicenter study evaluates early CPRL experience in 6 community cardiothoracic surgeons' practices.**

Methods. **Perioperative data from each surgeon's initial 20, consecutive and unselected cases of CPRL were retrospectively gathered (total n = 120) and compared with the 2009 and 2010 Society of Thoracic Surgeons database for VATS (n = 4,612) and open (n = 5,913) lobectomy. The χ^2 and *t* test procedures were used and significance was defined at the 95% confidence level ($p < 0.05$).**

Results. **One hundred sixteen lobectomies (96.7%) were completed robotically with a conversion rate of 3.3%. Preoperative patient characteristics were comparable across the CPRL, VATS, and open groups. The CPRL was equivalent to VATS on all intraoperative and postoperative outcomes, and resulted in significantly lower postoperative blood transfusion rates (0.9% vs 7.8%; $p = 0.002$), air leaks greater than 5 days (5.2% vs 10.8%; $p = 0.05$), chest tube duration (3.2 days vs 4.8 days; $p < 0.001$), and length of stay (4.7 days vs 7.3 days; $p < 0.001$) when compared with open. For these outcomes, results trended favorably for CPRL over VATS.**

Conclusions. **This early CPRL experience reveals a minimally invasive lobectomy technique that is safe and reproducible in varied practice settings. Outcomes were equivalent between CPRL and VATS, trending in favor of robotics. The CPRL was superior in several measures compared with open. The absence of patient selection and low conversion rates suggest a broad applicability of this technique.**

(Ann Thorac Surg 2014;■:■–■)
© 2014 by The Society of Thoracic Surgeons

Endoscopic pulmonary lobectomy through video-assisted thoracoscopic surgery (VATS) has been shown to be safe and efficacious and to offer patient outcome advantages over open thoracotomy [1–6]. Despite these benefits, adoption of VATS for lobectomy has been limited, particularly among community-based surgeons. Reports from studies of large case series and literature reviews show that between 20% and 39% of patients enjoy the benefits of this minimally invasive offering [7, 8]. Equipment, visualization, personnel, procedural standardization, and training issues, as well as a prolonged learning curve of 40 to 50 cases, are some of the factors contributing to this gap [9–12].

Several studies suggest that completely portal robotic lobectomy (CPRL), a more recent minimally invasive platform, may address some of these drawbacks and reduce the procedural learning curve to approximately 20 cases [13–18]. However, broad, multisurgeon application of such new technology, with inherent differences in training and practice can be problematic. Integration can be especially difficult in the community setting where many lobectomies are performed, but individual surgeon volumes and experience are highly variable.

This multicenter study evaluates the early stage of integration of CPRL into 5 community cardiothoracic practices. Technical feasibility and patient outcomes during adoption are assessed by comparison of perioperative clinical CPRL data with that of the established standard of VATS and open thoracotomy

Accepted for publication Feb 4, 2014.

*Recipient of the 2014 Southern Thoracic Surgical Association Carolyn Reed President's Award.

Presented at the Sixtieth Annual Meeting of the Southern Thoracic Surgical Association, Scottsdale, AZ, Oct 30–Nov 2, 2013.

Address correspondence to Dr Adams, Owensboro Medical Health System, Division of Thoracic Surgery, 1201 Pleasant Valley Rd, Ste 200, Owensboro, KY 42303; e-mail: robert.adams@owensborohealth.org.

The funding for this study was provided by Intuitive Surgical, Inc. Drs Adams, Bolton, and Stephenson disclose financial relationships with Intuitive Surgical.

© 2014 by The Society of Thoracic Surgeons
Published by Elsevier Inc

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2014.02.043

lobectomy recorded in the Society of Thoracic Surgeons (STS) General Thoracic Surgery national database.

Patients and Methods

Institutional Review Board approval was granted at all sites participating in this study. Information about the study subjects was kept confidential and managed according to the requirements of the Health Insurance Portability and Accountability Act of 1996. Access to patient records was limited to the study investigators and investigator-delegated study coordinator. A study specific informed consent waiver for retrospective data collection was granted by the Institutional Review Boards upon approval of the study at each site.

Six board-certified cardiothoracic surgeons in community-based, nonacademic practices (situated in Owensboro, KY; Greenville, SC; Baltimore, MD; Memphis, TN; and Tampa FL) agreed to participate in this study. They were selected on the basis of the following: (1) similarity of training and technique; (2) familiarity of the study designer with volume, training, and technique; and (3) a diversity of prerobotic practice characteristics. Practices included mixed cardiothoracic as well as thoracic patients. All surgeons had experience with VATS and open thoracotomy, but varied in their application. These surgeons had been in practice from 5 to 28 years, during which time their annual lobectomy volume varied from 30 to greater than 100 procedures. Training in the 4-arm CPRL was along a standardized pathway and included on-site and remote robotic instruction, early case proctoring, a graded case assumption, and the availability of “remote” on-going support.

Subsequently, CPRL was offered to all candidates in these practices with pulmonary lesions requiring lobectomy; no selection criteria were used. However, to evaluate feasibility and compare perioperative outcomes, clinical stage T3 and T4 cancer patients were excluded. Each surgeon provided data on his first 20 consecutive CPRL patients (total n = 120), after excluding those with clinical stage T3 or T4 disease (n = 8). These robotic lobectomies were conducted between January 2010 and September 2012. Due to the inherent difficulties in cross-institutional cost comparison, this aspect of robotics was not evaluated.

Surgical Technique

Robotic lobectomies were performed totally endoscopically using the da Vinci Si Surgical System (Intuitive Surgical, Inc, Sunnyvale, CA). The surgeon operates while seated at a console, viewing a three-dimensional, magnified, high-density image of the surgical field. This technology translates a surgeon’s hand and foot pedal movements into real-time movements of the surgical instruments inside the patient, and hand tremors are filtered out.

In this study all procedures were performed utilizing 3 operating arms and 1 camera arm. Port placement (see Fig 1) was based on internal anatomy with the camera (Fig 1b) placed 1 interspace below the oblique fissure at the anteroposterior midpoint of the chest. The anterior (Fig 1a) and posterior (Fig 1c) dissecting arms were placed in interspaces 9 to 10 cm directly anterior (apex of the oblique fissure) and 9 to 10 cm directly posterior (mid-body of the lower lobe) to the camera arm. The third operating arm (Fig 1d) was inserted 2 interspaces above and posterior to the posterior dissecting arm (slightly below the posterior apex of the oblique fissure) with 9 to 10 cm spacing from this posterior dissecting arm. Dissection of the lobe and lymph nodes was carried out with various robotically controlled instruments. A 12- or 15-mm accessory port (Fig 1e), necessary for introduction of staplers in a totally endoscopic procedure, was placed just above the costal margin. Stapling and specimen retrieval, using an endoscopic bag, were performed at this site by a tableside assistant. Carbon dioxide insufflation was employed in all cases with pressures ranging from 8 to 18 mm Hg.

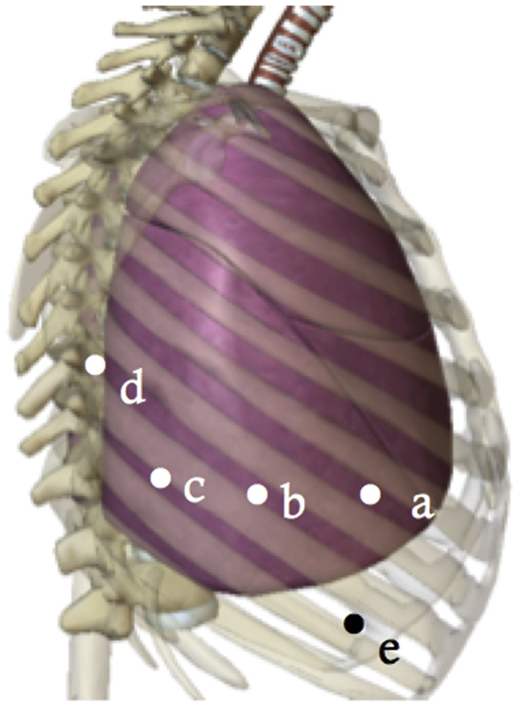

Fig 1. Right side view of port placement for 4 arm CPRL procedure; a = anterior dissecting arm (8-mm port), b = camera arm (12-mm port), c = posterior dissection arm (8-mm port), d = retracting arm (5- or 8-mm port), and e = intercostal accessory port (12- or 15-mm port).

Data Collection

Perioperative data for the robotic lobectomies were retrospectively collected from medical records using a standardized data collection form. A lead study coordinator and a trained nurse assistant completed all data abstraction at the 5 practice sites. Variables and their definitions were comparable with those collected for the STS General Thoracic Surgery national database, version 2.081 [19].

Preoperative patient characteristics collected include age, gender, body mass index, current and past smoking status, forced expiratory volume in 1 second (FEV_1) percent predicted value, diffusing capacity of the lung for carbon monoxide (DLCO) percent predicted value, American Society of Anesthesiologists status, cancer findings, and clinical staging. Clinical staging of lung cancer was done in accordance with the American Joint Committee on Cancer, 7th Edition [20].

Intraoperative variables collected were operative time (minutes from procedure start to procedure end including robotic docking), estimated blood loss, blood transfusion, complications, conversion of robotic procedure to open lobectomy by thoracotomy (and reasons), tumor size and location, pathologic staging, results of lymph node sampling or dissection, and operating room death. Postoperative data and clinically significant complications through 30 days were similar to those collected in the STS database. The outcomes presented in this study include initial ventilatory support greater than 48 hours, blood transfusion, bleeding requiring reoperation, chest tube duration, air leak greater than 5 days, atrial arrhythmia requiring treatment, acute respiratory distress syndrome, pneumonia, reintubation, discharged with chest tube, unexpected admission to the intensive care unit, unexpected return to the operating room, length of hospital stay, and 30-day mortality. As no data on these parameters or even specific conversion rate data were available for the STS patients, data from subjects who underwent conversion were excluded from further analysis of outcomes. There were no mortalities or major morbidity in these patients.

Statistical Analysis

The combined perioperative robotic data were compared with the 2009 and 2010 STS national database for VATS and open lobectomy, excluding the clinical stage T3 and T4 cases. Data were generally described using means and standard deviations for continuous measurements and percentages for discrete (nominal or ordinal) variables. Statistical comparisons between CPRL versus VATS and CPRL versus open thoracotomy patients were done using the t test and χ^2 procedures. When it was determined that variances for the comparisons of continuous data were unequal, Welch-Satterthwaite t test statistics were calculated instead of the Pearson. The Fisher exact test was employed when any of the expected frequencies in a χ^2 table was 5 or less. All tests were 2-sided with criterion for statistical significance at a p value less than 0.05.

Results

The total number of VATS and open thoracotomy procedures available for comparative analysis were 4,612 and 5,913, respectively. As discussed, these lobectomies did not include clinical stage T3 and T4 cancers and were, thus, comparable with the CPRL data.

The patient mix across the 3 surgical groups was similar on age, gender, body mass index, current and past smoking status, DLCO percent predicted value, and clinical tumor stage (Table 1). The FEV_1 percent predicted value was equivalent between the CPRL and open groups, but significantly lower for patients who underwent CPRL compared with VATS. The CPRL group had a significantly higher proportion of patients with ASA status 3 or greater compared with the VATS group.

Of the 120 CPRL surgeries attempted, there were 4 conversions (3.3%) to open thoracotomy. Conversions were undertaken for bleeding (n = 1), patient anatomy (n = 2), and technical issues (n = 1).

Operative time was significantly greater for robotic lobectomy by just over an hour compared with the other approaches (Table 2). Mean estimated blood loss (130 ± 103.4 mL) was low during CPRL and the proportion of intraoperative blood transfusions did not differ between robotic and VATS techniques. Although blood transfusion during surgery was infrequent, a greater percentage of patients who underwent open thoracotomy compared with CPRL procedures received blood transfusions, but this difference was only of borderline statistical significance.

Pathologic tumor stage was comparable between robotic and the other 2 approaches (Table 2). Nodal evaluation included recording both stations and number of nodes collected. The mean number of stations collected was 4.1 (1.5 N1 and 2.6 N2). The mean number of nodes collected was 10.1, ranging from 0 to 35. No comparative data from the STS database were available. The only operating rooms deaths occurred during open thoracotomy.

Postoperative complications and outcomes were generally similar between CPRL and VATS patients (Table 3). Hospital length of stay was an exception where duration was 1.4 days less in patients who had the robotic procedure, but the difference was of borderline statistical significance. Comparisons between robotic and open approaches showed that incidence of air leak greater than 5 days was 2 times greater in the thoracotomy cohort, and blood transfusion was required significantly more often in thoracotomy patients. Chest tube duration was 1.6 days longer and hospital stay 2.6 days longer, in the group that underwent open compared with CPRL surgery.

Comment

These data on early experience with CPRL reveal a totally endoscopic, minimally invasive lobectomy technique that is safe and reproducible in varied community practice settings. From a results standpoint, CPRL demonstrated statistically equivalent clinical outcomes when compared with the established minimally invasive platform of VATS. In several areas such as rate of postoperative blood transfusion, duration of chest tube, prolonged air leak, and hospital length of stay, trends favored CPRL but did not achieve statistical significance. For these outcomes, CPRL was superior to lobectomy by open thoracotomy.

Advantages of the robotic platform and completely portal technique that may account for these results in our surgeons' early experience include precision instrumentation, three-dimensional visualization of anatomic structures, and procedural standardization, all aspects of

Table 1. Preoperative Patient Characteristics

Variable[a]	CPRL (n = 120)	VATS (n = 4,612)	Open (n = 5,913)	*p* Value[b]	*p* Value[c]
Age (years)	64.6 ± 10.5	66.2 ± 11.3	65.0 ± 12.1	0.13	0.66
Sex				0.41	0.71
Male	58 (48.3)	2,053 (44.5)	2,961 (50.1)		
Female	62 (51.7)	2,559 (55.5)	2,952 (49.9)		
Body mass index (kg/m^2)	27.1 ± 5.5	27.3 ± 5.9	27.9 ± 6.6	0.60	0.11
Current smoker	34 (28.3)	1,069 (23.2)	1,521 (25.7)	0.19	0.52
Ever smoked	102 (85.0)	3,683 (79.9)	4,804 (81.2)	0.16	0.30
FEV_1 % predicted[d]	79.1 ± 19.0	84.1 ± 21.1	80.4 ± 20.2	0.03	0.56
N	90	4,241	5,325		
DLCO % predicted[e]	73.1 ± 28.8	76.1 ± 22.2	73.6 ± 21.8	0.39	0.89
N	70	3,497	3,987		
Clinical tumor stage[f]				0.24	0.42
T1a	51 (46.4)	1,861 (49.0)	1,861 (39.0)		
T1b	24 (21.8)	947 (24.9)	1,060 (22.2)		
T2a	27 (24.5)	844 (22.2)	1,428 (29.9)		
T2b	8 (7.3)	144 (3.8)	419 (8.8)		
ASA status[g]				0.006	0.04
1, 2	12 (10.0)	1023 (22.2)	969 (16.4)		
3	98 (81.7)	3280 (71.1)	4201 (71.0)		
4, 5	10 (8.3)	309 (6.7)	743 (12.6)		

[a] Categoric data are shown as n (%); continuous variables are shown as mean ± standard deviation. [b] Between CPRL and VATS. [c] Between CPRL and open. [d] Among patients who had the FEV_1 test performed. [e] Among patients who had the DLCO test performed. [f] Total sample size available for analysis of this parameter excludes >10% subjects with missing data. [g] Status 1 and 5 ranged from 0% to 0.6% across procedures, so these were combined with scores 2 and 4, respectively.

ASA = American Society of Anesthesiologists; CPRL = completely portal robotic lobectomy; DLCO = diffusing capacity of the lung for carbon monoxide; FEV_1 = forced expiratory volume in 1 second; VATS = video assisted thoracoscopic surgery.

VATS procedures that are cited as potential barriers to adoption [12, 21, 22].

Further, the very low incidence of conversion to open thoracotomy (4 of 120 = 3.3%) suggests a broad applicability of this totally endoscopic, robotic platform. The VATS conversion rates have been noted to vary from 2.5% [6] in the hands of a confirmed expert to 24% in other series, with a median of 8.1% [23]. The range of reported conversion rates for robotic procedures is similar, 1.5% to 19.2% (mean of 9.4%), where the lowest rate is also that of an acknowledged expert in the field [24].

Studies comparing clinical outcomes of robotic lobectomy to either VATS or open thoracotomy procedures have found results similar to those in the present study. Louie and colleagues [14] compared clinical outcomes from their initial robotic lung resection surgeries with outcomes from VATS lobectomy by experienced VATS surgeons and found similar blood loss, minor and major

Table 2. Intraoperative Parameters

Parameter[a]	CPRL (n = 116)	VATS (n = 4,612)	Open (n = 5,913)	*p* Value[b]	*p* Value[c]
Operative time (min)	241.5 ± 64.9	179.8 ± 78.3	175.5 ± 84.2	<0.001	<0.001
Blood transfusion	1 (0.9)	62 (1.4)	281 (5.0)	1.0	0.07
Pathologic tumor stage[d]				0.43	0.17
T1a	40 (39.2)	1,493 (39.9)	1,428 (30.4)		
T1b	17 (16.7)	779 (20.8)	913 (19.4)		
T2a	34 (33.3)	1,152 (30.8)	1,582 (33.6)		
T2b	4 (3.9)	178 (4.8)	453 (9.6)		
T3 or greater	7 (6.9)	138 (3.7)	329 (7.0)		
Death in operating room	0 (0)	0 (0)	2 (0.0004)	1.0	1.0

[a] Categoric data are shown as n (%); continuous variables are shown as mean ± standard deviation. [b] Between CPRL and VATS. [c] Between CPRL and open. [d] Total sample size available for analysis of this parameter excludes >10% subjects with missing data.

CPRL = completely portal robotic lobectomy; VATS = video assisted thoracoscopic surgery.

ARTICLE IN PRESS

Table 3. Postoperative Complications and Outcomes

Outcome[a]	CPRL (n = 116)	VATS (n = 4,612)	Open (n = 5,913)	*p* Value[b]	*p* Value[c]
Initial vent support >48 hours	0	23 (0.5)	61 (1.0)	1.0	0.63
Air leak >5 days	6 (5.2)	408 (8.9)	634 (10.8)	0.17	0.05
ARDS	2 (1.7)	23 (0.5)	76 (1.3)	0.13	0.66
Atrial arrhythmia requiring treatment	10 (8.6)	426 (9.3)	713 (12.1)	0.81	0.25
Blood transfusion	1 (0.9)	172 (3.8)	458 (7.8)	0.13	0.002
Bleeding requiring reoperation	1 (0.9)	48 (1.0)	66 (1.1)	1.0	1.0
Chest tube duration[d] (days)	3.2 ± 4.0	3.7 ± 8.8	4.8 ± 4.0	0.18	<0.001
N[e]	115	3,975	5,068		
Discharged with chest tube[d]	5 (4.3)	360 (8.2)	409 (7.2)	0.14	0.24
Pneumonia	2 (1.7)	134 (2.9)	299 (5.1)	0.77	0.13
Reintubation	4 (3.4)	103 (2.2)	277 (4.7)	0.34	0.66
Unexpected return to OR	7 (6.0)	146 (3.3)	252 (4.4)	0.10	0.41
Unexpected admission to ICU	6 (5.2)	147 (3.2)	287 (4.9)	0.24	0.90
Mortality at 30 days postoperative	0	40 (1.0)	119 (2.2)	0.63	0.18
N[e]	114	4,140	5,361		
Hospital length of stay (days)	4.7 ± 3.1	5.3 ± 7.1	7.3 ± 7.6	0.07	<0.001

[a] Categoric data are shown as n (%); continuous variables are shown as mean ± standard deviation. [b] Between CPRL and VATS. [c] Between CPRL and open. [d] Among patients with chest tube used. [e] Total sample size available for analysis of this parameter excludes >10% subjects with missing data.

ARDS = acute respiratory distress syndrome; CPRL = completely portal robotic lobectomy; ICU = intensive care unit; OR = operating room; VATS = video assisted thoracoscopic surgery.

morbidity, and intensive care unit and hospital stay between the 2 techniques. In a matched study design, Kent and colleagues [8] found no statistically significant differences between robotic and VATS procedures in mortality, complication rates, and length of hospital stay, but trends favored the robotic approach. Likewise, a 2013 study by Augustin and colleagues [25] did not demonstrate significant differences in outcomes between robotic and VATS lobectomy cases other than change in hemoglobin in the perioperative period.

In a study of propensity-matched patients, Veronesi and colleagues [16] showed that robotic lobectomy was safe, feasible, and associated with a shorter hospital stay when compared with open thoracotomy. In a 2011 study of matched patients, Cerfolio and colleagues [13] demonstrated that robotic compared with open procedures were associated with lower complication rates (27% vs 38%), a trend toward lower mortality (0% vs 3.1%), and shorter hospital stays (2.0 vs 4.0 days), respectively. Also reported were significantly less blood loss (35 mL vs 90 mL) and shorter chest tube duration (1.5 vs 3.0 days). In a recent study of propensity-matched patients who underwent anatomic pulmonary resection [8], findings paralleled those noted above; when compared with open thoracotomy, robotic procedures demonstrated significant reductions in mortality (0.2% vs 2.0%), length of stay (5.9 vs 8.2 days), and overall complication rates (43.8% vs 54.1%).

Operative time was longer for CPRL than both VATS and open thoracotomy by approximately 1 hour. This finding was anticipated given that our study included each surgeon's early experience (first 20 cases) with CPRL. An accurate comparison of operative times between robotic-assisted lobectomy and VATS or open thoracotomy can only be achieved at proficiency with each approach beyond the learning curve. The longer operative time did not appear to have a negative impact on the outcomes in this early, multicenter experience. In their study of the transition from open to robotic lobectomy, Oh and colleagues [26] also reported significantly longer operative time with the robotic procedures. However, they showed that robotic operative time decreased with experience; the latter half of their robotic surgeries were within 20 minutes of the open cases. Other studies [16, 27] have similarly found that operative time diminished significantly with experience. In contrast, Louie and colleagues [14] demonstrated comparable operative times between their initial robotic lobectomy series and VATS by experienced VATS surgeons (213 vs 208 minutes, respectively).

Oncologic soundness, as measured by completeness of resection and lymph node evaluation, appeared favorable with completely portal robotic resection. In this evaluation of early experience with CPRL, average total number of lymph node stations sampled or dissected was 4.1 and the average number of total lymph nodes resected was 9.4. These values are consistent with literature-defined norms for this aspect of anatomic lobectomy.

Limitations of this study include the retrospective, nonmatched nature of the comparisons in addition to the relatively small size of the CPRL cohort compared with the VATS and open thoracotomy lobectomy cohorts from the 2009 and 2010 STS General Thoracic Surgery database. The methodologic significance of the voluntary nature of the STS database and difficulties with its quality control and standardization cannot be assessed.

ARTICLE IN PRESS

In conclusion, this study demonstrated successful, safe, and effective application of a totally endoscopic, completely portal robotic lobectomy technique in a variety of community practice settings. Perhaps most powerfully are the varied backgrounds that these surgeons brought to the effort. Clinical background, surgical volume, team composition, and many other variables differed significantly among the surgeons; yet, each was able to successfully incorporate the technology into his practice. Completely portal robotic lobectomy appears to be a minimally invasive platform with which community surgeons can generate outcomes equivalent to VATS and, in some cases, statistically superior to open techniques. Such outcomes can be accomplished early in a surgeon's experience and in the vast majority of lobectomy candidates with minimal need to convert to thoracotomy. These findings suggest a broad applicability of the technology with a relative ease of adoption and therefore a greater proportion of patients undergoing a successful minimally invasive procedure. While it is assumed that reduction in surgical time should accompany increasing facility and experience with the technology, larger and longer prospective comparative studies are warranted to further evaluate CPRL on this and other issues.

The funding for this study was provided by Intuitive Surgical, Inc. The authors would like to acknowledge Shawn Sams, RN, BSN, for her assistance with data collection, Cindy Bornander, PhD, for data analysis, and Ali Andreasen, MD and Helen Hubert, MPH, PhD, for their support with manuscript preparation.

References

1. Paul S, Sedrakyan A, Chiu YL, et al. Outcomes after lobectomy using thoracoscopy vs thoracotomy: a comparative effectiveness analysis utilizing the Nationwide Inpatient Sample database. Eur J Cardiothoracic Surg 2013;43:813–7.
2. Cao C, Manganas C, Ang SC, Yan TD. A meta-analysis of unmatched and matched patients comparing video-assisted thoracoscopic lobectomy and conventional open lobectomy. Ann Cardiothorac Surg 2012;1:16–23.
3. Paul S, Altorki NK, Sheng S, et al. Thoracoscopic lobectomy is associated with lower morbidity than open lobectomy: a propensity-matched analysis from the STS database. J Thorac Cardiovasc Surg 2010;139:366–78.
4. Scott WJ, Allen MS, Darling G, et al. Video-assisted thoracic surgery versus open lobectomy for lung cancer: A secondary analysis of data from the American College of Surgeons Oncology Group Z0030 randomized clinical trial. J Thorac Cardiovasc Surg 2010;139:976–83.
5. Swanson SJ, Herndon JE II, D'Amico TA, et al. Video-assisted thoracic surgery lobectomy: Report of CALGB 39802-a prospective, multi-institution feasibility study. J Clin Oncol 2007;25:4993–7.
6. McKenna RJ, Houck W, Fuller CB. Video-assisted thoracic surgery lobectomy: experience with 1100 cases. Ann Thorac Surg 2006;81:421–6.
7. Boffa DJ, Allen MS, Grab JD, Gaissert HA, Harpole DH, Wright CD. Data from The Society of Thoracic Surgeons General Thoracic Surgery Database: the surgical management of primary lung tumors. J Thorac Cardiovasc Surg 2008;135:247–54.
8. Kent M, Wang T, Whyte R, Curran T, Flores R, Gangadharan S. Open, video-assisted thoracic surgery, and robotic lobectomy: review of a national database. Ann Thorac Surg 2013;96:1–9.
9. Hansen JH, Peterson RH, Christensen M. Video-assisted thoracoscopic (VATS) lobectomy using a standardized anterior approach. Surg Endosc 2011;25:1263–9.
10. Ferguson J, Walker W. Developing a VATS lobectomy programme—can VATS lobectomy be taught? Eur J Cardiothorac Surg 2006;29:806–9.
11. McKenna RJ Jr. Complications and learning curves for video-assisted thoracic surgery lobectomy. Thorac Surg Clin 2008;18:275–80.
12. Petersen RH, Hansen JH. Learning curve associated with VATS lobectomy. Ann Cardiothorac Surg 2012;1:47–50.
13. Cerfolio RJ, Bryant AS, Skylizard L, Minnich DJ. Initial consecutive experience of completely portal robotic pulmonary resection with 4 arms. J Thorac Cardiovasc Surg 2011;142:740–6.
14. Louie BE, Farivar AS, Aye RW, Vallières E. Early experience with robotic lung resection results in similar operative outcomes and morbidity when compared with matched video-assisted thoracoscopic surgery cases. Ann Thorac Surg 2012;93:1598–604.
15. Dylewski MR, Ohaeto AC, Pereira JF. Pulmonary resection using a total endoscopic robotic video-assisted approach. Semin Thorac Cardiovasc Surg 2011;23:6–42.
16. Veronesi GGD, Maisonneuve P, Melfi F, et al. Four-arm robotic lobectomy for the treatment of early-stage lung cancer. J Thorac Cardiovasc Surg 2010;140:19–25.
17. Jang HJ, Lee HS, Park SY, Zo JI. Comparison of the early robot-assisted lobectomy experience to video-assisted thoracic surgery lobectomy for lung cancer: a single-institution case series matching study. Innovations (Phila) 2011;6:305–10.
18. Park BJ, Melfi F, Mussi A, et al. Robotic lobectomy for non-small cell lung cancer (NSCLC): long-term oncologic results. J Thorac Cardiovasc Surg 2012;143:383–9.
19. The Society of Thoracic Surgeons General Thoracic Surgery Database Data Collection Form, Version 2.081. Available at http://www.sts.org/sites/default/files/documents/pdf/ndb2010/GeneralThoracicDCFV2_081_Annotated.pdf. Accessed September 30, 2013.
20. Edge SB, Byrd DR, Compton CC, Fritz AG, Greene FL, Trotti A, eds. AJCC cancer staging manual. 7th ed. New York, NY: Springer; 2010.
21. Zhao H, Liang B, Yang F, Li J, Li Y, Wang J. Video-assisted thoracoscopic surgery lobectomy for lung cancer: the learning curve. World J Surg 2010;34:2368–72.
22. Hanna JM, Berry MF, D'Amico TA. Contraindications of video-assisted thoracoscopic surgical lobectomy and determinants of conversion to open. J Thorac Disease 2013;5(Suppl 3):182–9.
23. Yan TD, Black D, Bannon PG, McCaughan BC. Systematic review and meta-analysis of randomized and non-randomized trials on safety and efficacy of video-assisted thoracic surgery lobectomy for early-stage non-small-cell lung cancer. J Clin Oncol 2009;15:2553–62.
24. Takagi H, Yamamoto H, Goto S, Matsui M, Umemoto T. Perioperative results of robotic lung lobectomy: summary of the literature. Surg Endosc 2012;26:3697–9.
25. Augustin F, Bodner J, Maier H, et al. Robotic-assisted minimally invasive vs thoracoscopic lung lobectomy: comparison of perioperative results in a learning curve setting. Langenbecks Arch Surg 2013;398:895–901.
26. Oh DS, Cho I, Karamian B, Demeester SR, Hagen JA. Early adoption of robotic pulmonary lobectomy: feasibility and initial outcomes. Am Surg 2013;79:1075–80.
27. Cerfolio RJ, Bryant AS, Minnich DJ. Starting a robotic program in general thoracic surgery: why, how, and lessons learned. Ann Thorac Surg 2011;91:1729–37.

DISCUSSION

DR ROBERT CERFOLIO (Birmingham, AL): Doug, congratulations on your presentation. One thing, and my friend, Dr Howington, is coming behind me, is I do agree with him that length of stay, chest tube management, that's all culture. My thoracotomies don't get epidurals, don't go to the ICU [intensive care unit], get their tubes out early by POD [postoperative day] 1 or 2 go home in 3 days. So that doesn't impress me. But the blood loss in robotics is almost always less, in every paper less. And forget the statistics, just look at the videos and see how the operation is being done. It's not blunt and using a sucker and sweeping; it's meticulous dissection with a bipolar. So, will you comment on that first.

And my second question is about mortality, the operative technique, because you did a lot of VATS lobes and you are now doing robotics. I continue to see a lower mortality with robotic lobe compared to VATS lobe; is that real or just center excellence we are seeing.

DR ADAMS: I did all 3 techniques.

DR CERFOLIO: What made you switch?

DR ADAMS: Our experience with VATS, which preceded robotics by about 2 years, was a very frustrating experience for a number of reasons. Technical for sure and some of our limitation may have been the operating room personnel. Also, we never appreciated a significant outcomes difference between that and a muscle-sparing thoracotomy, and, quite honestly, it was just easier to do the thoracotomy.

DR CERFOLIO: But to be fair to the world experts like guys behind me who are going to say a VATS [video-assisted thoracic surgery] lobectomy is great and in many hands it's true, but I think it's more difficult to learn.

The second thing is mortality. The first time I saw this, I said, well, maybe it doesn't matter. But now I see report after report after report, when you look at RATS [robot-assisted thoracic surgery], a word that should be abandoned, that is what Dr Howington talked about in the last question, that is not a CPRL-4 [completely portal robotic lobectomy]. That's the big difference. And I want to make a point on that. A CPRL-4 is a completely portal robotic operation. There is no access port, there is no cold ambient air, which is supposed to be 72 degrees and it's often 68 degrees in the operating room interfacing on a lung that is 98 degrees. And so although the morbidity is the same, that ability to do a completely portal I'm convinced is the advantage of the robot, where I can pump in warm humidified air. If patients get pneumonia, they don't die, if patients get bowel problems, they don't die, because they have less third spacing. We are putting in warm humidified air and they don't get that third spacing.

Will you comment on the difference between a CPRL-4 and a RATS so when Dr Howington's papers come out we can say, great, but it doesn't matter; we don't do RATS, we do CPRL-4?

DR ADAMS: I will comment on three aspects. First of all, blood loss. We have gathered the data on these surgeons over the course of the last 2 years, and I can tell you that although it is low in this initial series (median of 100c), it decreases even further in the second, that will be presented at the STS; you will see a difference as we move through the learning curve.

As far as mortality, our own hospital mortality with muscle-sparing thoracotomy in evaluating over 300 patients preceding this robotic series was 3%; within expected norms for open thoracotomy. Our practice mortality with robotics since we started in 2009 has been one 30-day mortality in the course of 200+ patients, less than 0.5%. Further, anecdotally, the breadth of patients on whom we are operating is considerably broader as we are offering resection to less physiologically ideal patients.

And thirdly, as far as the technique, one of the things that impressed me most about Dr Swanson's 2007 paper was that it took a myriad of techniques that had been presented from 1992 forward and standardized it. It emphasized that there is a lot value in terms of maintaining a purely endoscopic approach. That's where many of the advantage[s] come in. I would echo that. Robotics is a totally endoscopic procedure that is highly transferrable and highly reproducible.

DR JOHN A. HOWINGTON (Evanston, IL): First off, Cerf, I've got to correct you. You are insufflating CO_2, not air. Otherwise your patients would blow up with sub Q air.

First, a caution. I think to say with any platform, RATS, VATS, whatever, that 20 cases is your learning curve is a mistake. You don't have surgeons thinking that 5 different lobes, anatomic variability. We saw that yesterday. So a caution to people that think that I'm an expert after I have done 20 cases.

DR ADAMS: Agreed, absolutely.

DR HOWINGTON: And because you limited it to the first 20 cases, I can tell you that I was so nervous and so cautious in my first 20 I didn't get into any trouble. Once I got confident, cocky, that's when I got in trouble.

Second, blood loss. Again, it's culture and what we choose to do. If you looked at the videos that Seth showed or the video from David Jones, you can do an energy-based dissection and it can be bloodless; it can be 20 milliliters. And that's anesthesia calling it. They put it into the computer now. So that's not a category.

What is, and I will give you credit, we have failed as VATS surgeons, and I have been involved with teaching courses, of transferring that knowledge. And I will give you that; you have been able to transfer the knowledge better than we have. But in my mind, it's not VATS versus RATS. It's doing minimally invasive rather than open thoracotomy. Quit cutting people in half to take a T1a lesion out.

Thank you.

DR ALLAN PICKENS (Atlanta, GA): I would like to add a comment from the podium. Don't you think that the advancements in minimally invasive thoracic surgery that were made with thoracoscopy have aided in the propagation of robotic procedures? When you talk about the penetrance of robotics into the community being much easier than thoracoscopy, a lot of the tools that you are using in robotics were developed for thoracoscopy. As we compare these 2 techniques, we must recognize that thoracoscopy paved the way for robotic thoracic surgery.

DR ADAMS: I would agree to some degree with that. I think the wristed instrumentation is obviously significantly different than at least the thoracoscopic instruments I had, as is the visualization, the ability to magnify the field, zoom in, etc. Robotics is a natural technologic extension of a minimally invasive video-assisted platform. That's the overarching point that I think myself and other individuals involved in teaching this are trying

ARTICLE IN PRESS

to make; this is the next logical technologic step, enhancing technology if you will, to facilitate a broader application of endoscopic lobectomy by a greater number of surgeons.

DR PICKENS: I agree with your comments; however, I still think placing staplers, having specialty staplers to get around vessels, and other tools for minimally invasive thoracic surgery were developed with thoracoscopy. If robotic thoracic surgery was introduced back in the 1990s when thoracoscopy hit the market, I think it would have the same slow progression into practice.

DR ADAMS: Fair enough.

DR PICKENS: That's my only point for making the comment.

DR JOSHUA ROBERT SONETT (New York, NY): The same idea. John was right. The big paradigm was going from open to minimally invasive, and, to me, whether it's minimally invasive, thoracoscopic, if you do it well, or robotic, either way you have to invest the time. Now, for a while people were not investing the time, just like a new computer program, be it Apple or PC. You have to invest the time to get good at it, and you showed a good teaching program when you invested the time in teaching.

I would also say that the data that everybody is propagating about the penetrance of minimally invasive lobectomy is wrong now, just like the mediastinoscopy data that Cerf showed was wrong; everybody is saying 20% of mediastinoscopies didn't get any nodes and stuff. Now I'd say the STS database, if you look at it now, 70% of early stage tumors, stage I tumors, are done thoracoscopically.

So, please, don't propagate this business that it's 20 or 30% anymore. If you go out there in the community, or certainly in the northeast, 70 to at least 80% of the early lung cancers are done thoracoscopically. So the penetrance is much, much higher, because the foot dragging has stopped. I think it's pretty much coming close to the gold standard is some type of minimally invasive lobectomy for early stage lung cancer, and hopefully we will all improve our techniques to keep on getting better.

Thanks.

DR ADAMS: In response to that, I certainly hope so, although the data to support VATS penetration of 70% remains to be published. The point is a minimally invasive approach and I think a rising tide lifts all boats. If robotics simply raises the visibility and the importance of a totally endoscopic approach, thereby pushing the application of that technique, be it robotic or VATS, I think it has accomplished a tremendous amount.