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ORIGINAL ARTICLE

The cost and quality of life outcomes in developing a robotic lobectomy program

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Abstract

The use of the robotic platform is increasingly being utilized for lung resections. Our aim was to compare outcomes of thoracoscopic (VATS) versus robotic-assisted thoracoscopic (RATS) lobectomy early in a program's adoption of robotic surgery, including perioperative outcomes, cost, and long-term quality of life. A prospective database was retrospectively reviewed for all patients undergoing minimally invasive lobectomy by either VATS or RATS techniques from 2010 to 2012. Patients' operative, post-operative complications, cost (operating room and hospital) and quality of life were compared between the two resection techniques. Long-term follow-up including assessment using the European Organization for Research and Treatment of Cancer quality of life questionnaire was documented. During the first 25 RATS lobectomies, there were 73 VATS lobectomies performed, for a total of 98 cases. There was no significant difference in cancer stage, operative time, estimated blood loss, lymph node count, or hospital length of stay. The RATS resections had significantly higher operative and total hospital cost ($p < 0.0001$ and $p < 0.05$). At a median of 65-month follow-up, 29 patients (9 robotic; 20 VATS) completed the EORTC questionnaire. The global health status and symptom scale median scores were similar to the general population and did not significantly differ between groups. While transitioning from thoracoscopic to robotic lobectomy incurs increased operative and total hospital cost, equivalent operative outcomes, length of hospitalization, and long-term quality of life can be maintained during this transition. With increasing patient and surgeon interest in robotic resection, it appears both safe and feasible to adopt this approach while maintaining outcomes.

Keywords Minimally invasive surgery · Robotic surgery · Lung cancer · Patient quality of life · Health care costs

Introduction

In 2008, only 1% of hospitals were performing lobectomies with the robot-assisted thoracoscopic (RATS) approach [1, 2]. 3 years later, in 2011, 12% of hospitals were performing lobectomies using the robotic technique. In comparison, the use of video-assisted thoracoscopic (VATS) lobectomy has only increased from 36 to 42% over the same 3-year time period [1]. This increase in utilization of the robotic approach is reflected in the 75% increase in the number of robotic systems installed in the US between 2007 and 2009 alone [3].

Current cost data on robotic techniques indicate that the use of this platform increases the cost of an operation by approximately 13% [3]. It is estimated that this cost may be off-set if there is an associated shorter hospital stay and quicker return to work. High-volume robot programs have shown a decrease in hospital stay, 30-day mortality, and post-operative blood transfusion with RATS compared to VATS and thoracotomy [4].

In the Society of Thoracic Surgeons database, 44% of surgeons are performing lobectomies using the VATS technique [4]. Many of these surgeons may have an interest in initiating a robotic program. The transition from thoracoscopic to robotic lobectomy should be, first and foremost, safe for the patient. Cost effectiveness also should be considered. We hypothesized that the early development a robotic lobectomy

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program, undertaken by experienced thoracoscopic surgeons, could be accomplished without compromise to patient safety and with both moderate cost increases during this early phase, and similar long-term patient outcomes.

Methods

Patients

A new thoracic robotics program was started in 2010 with two VATS-trained surgeons in an academic hospital setting. A prospectively maintained database was retrospectively reviewed from November 2010 to March 2012 for all patients undergoing minimally invasive lobectomy by either VATS (three surgeons, including the two robotic-trained surgeons) or RATS (two surgeons) technique during the initiation of the robotics program. The patient characteristics, operative details, and post-operative outcomes were compared between the two resection techniques. Operative time was defined as the time from procedure start to completion and did not include anesthesia time. This retrospective study was approved by the Institutional Review Board (HUM00061840). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent for surgery was obtained from all patients included in the study.

Surgical approaches

All RATS operations were performed using an Si platform (Intuitive Surgical, Inc., Sunnyvale CA) with port placement as has been described by Cerfolio et al. [5]. Three robotic instruments were routinely used with staplers inserted by the bedside assistant, RAL-3 (Covidien Medtronic, Minneapolis MN) [6]. VATS and RATS operations were performed using variations of the anterior to posterior dissection technique as described by McKenna [7]. Routine instrumentation included electrocautery (Medtronics), tissue graspers, DeBakey forceps and scissors (Scanlan, St. Paul MN).

Cost data

The cost data acquired were for direct fixed and variable cost to the operating room and for the entire hospital stay. These charges represent the facility charges to the patient and do not include the professional component. The OR fixed direct costs include the administrative costs and the pre-paid contract with vendors for maintenance and repair of equipment. The variable costs include the cost of surgical supplies and instruments as well as the nursing and technician labor costs.

Quality of life

Long-term follow-up included assessments using the European Organization for Research and Treatment of Cancer QLQ-30 quality of life questionnaire [8]. Attempts were made to contact all patients; those that were contacted were asked to participate in the questionnaire by telephone.

Statistics

Statistical comparisons between groups were done using the Mann–Whitney *U* test for continuous variables and the chi-square and Fisher's exact tests for nominal data. Statistical analysis was performed using GraphPad Prism version 7 (GraphPad Software, San Diego, California). Statistical significance was set at $p < 0.05$.

Results

There were 98 minimally invasive lobectomies performed sequentially during the study period. This included 73 VATS and 25 RATS resections. There were 47 males and 51 females with a median age of 66. Patient characteristics are compared between the two different resection types in Table 1.

There was no significant difference in cancer stage, estimated blood loss, lymph node count, or hospital length of stay, Table 2. There was a significant difference in operation time, as the robotic resection took an average of 45 min longer with no significant reduction in operative time over the study period. The first 10 robot resections took a median of 233 min (173–349 min) versus the last 10 with a median operative time of 218 min (157–543 min), $p = 0.37$.

There were three (12%) RATS procedures converted to VATS operations and five (20%) RATS converted to open operations. All conversions from RATS to VATS occurred during the first 6 months of the robotic program and all were during right upper lobectomies to improve visualization of pulmonary artery branches. The conversion rate for VATS to open was 12% (9) and did not significantly differ from the RATS to open conversion rate (20%), $p = 0.34$. The robotic to open conversions were for pulmonary artery bleeding in two cases, adhesions impairing visualization in two cases and for calcified lymph nodes around the pulmonary artery making dissection difficult in one case.

The total and operative cost, both fixed and variable, were compared between the VATS and RATS techniques. RATS lobectomy had significantly higher operative and total hospital cost, Table 3.

Table 1 Patient and tumor characteristics compared between the VATS and RATS techniques

	VATS ($n=73$)	Robot ($n=25$)	p value
Age	65	68	0.076
Female, % (n)	52 (38)	52 (13)	> 0.99
Zubrod score	0	1	0.16
ASA	3	3	0.89
Lobe resected			0.69
Left	37 (51%)	11 (44%)	
Upper lobe	20	8	
Lower lobe	17	3	
Right	36 (49%)	14 (56%)	
Upper lobe	18	9	
Middle lobe	7	1	
Lower lobe	11	4	
Histology			0.48
Primary lung cancer	56 (77%)	22 (88%)	
Metastatic disease	11 (15%)	2 (8%)	
Benign	6 (8%)	1 (4%)	
Mass size, cm (range)	1.7 (0.4–9.1)	1.8 (0.9–4.5)	0.56
Stage for primary lung cancer	$n=56$	$n=22$	0.37
	Stage IA 32 (57%)	Stage IA 11 (50%)	
	IB 10 (18%)	IB 7 (32%)	
	IIA 3 (5%)	IIA 2 (9%)	
	IIB 6 (11%)	IIIA 2 (9%)	
	IIIA 5 (9%)		

All values expressed as median

Table 2 Operative and post-operative factors compared between the VATS and RATS techniques

	VATS ($n=73$)	Robot ($n=25$)	p value
Operative time (min)	183	231	0.011
EBL (ml)	100	150	0.14
Total lymph node count (range)	13 (2–38)	11 (2–38)	0.27
Conversion to VATS, % (n)	NA	12 (3)	NA
Conversion to open, % (n)	12 (9)	20 (5)	0.34
Length of hospital stay (days)	4	3	0.36
Chest tube days (range)	3 (1–33)	3 (2–7)	0.54
Post-operative complications	20 (27%)	6 (24%)	0.74
Air leak	6	1	
Pneumonia	2	1	
Atrial fibrillation	9	2	
Pneumothorax	1	1	
Urinary tract infection	0	1	
Other	2	0	

All values expressed as median

NA not applicable, *IQR* interquartile range

The 5-year survival was 74% for both RATS and VATS lobectomies and was not significantly different between the two groups ($p=0.56$), Fig. 1. At a median of 65 months (range 51–71 months) post-operatively, 29 patients completed the EORTC questionnaire. Of those that completed the survey, 31% (9/29) had a RATS resection and 69% (20/29) had a VATS resection. The reason for not completing the survey that the patient was deceased was 14% (14/98), declined to respond 9% (9/98), or could not be reached 47% (46/98). The global health status and symptom scale median scores were similar to the general population and did not significantly differ between groups, Fig. 2.

Discussion

Interest and access to robot thoracic surgery has increased over the last decade. Within the Society of Thoracic surgery database and the National inpatient sample, the robotic lobectomy volume increased from 1% in 2008 and 2009 to nearly 14% in 2014 [1, 2]. This increased interest by surgeons, hospitals and patients has led many surgeons to transition from their standard practice of open or thoracoscopic lobectomy to robotic lobectomy. However, implementation of the robotic technique has been associated with longer

Table 3 Operative and hospital cost compared between the VATS and RATS techniques

	VATS (*n* = 73)	Robot (*n* = 25)	*p* value
OR direct fixed cost	$1561 ± 418	$2416 ± 481	< 0.0001
OR direct variable cost	$3412 ± 1131	$5159 ± 1066	< 0.0001
OR direct fixed + variable cost	$4973 ± 1459	$7575 ± 1486	< 0.0001
OR supply cost	$2804 ± 1327	$5757 ± 1780	< 0.0001
Total direct fixed cost	$3938 ± 2089	$4530 ± 1081	< 0.05
Total direct variable cost	$7143 ± 2292	$8593 ± 2256	< 0.01
Total direct fixed + variable cost	$11,080 ± 3291	$13,122 ± 3277	< 0.05

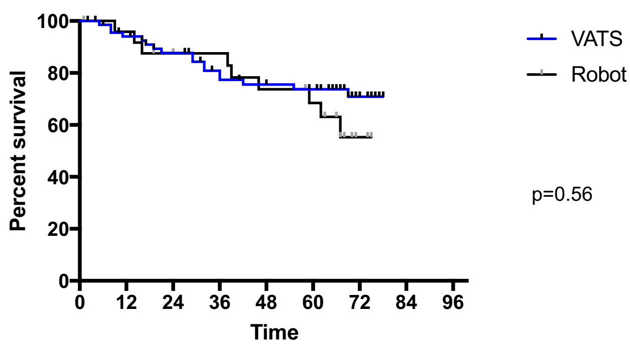

Fig. 1 Overall survival

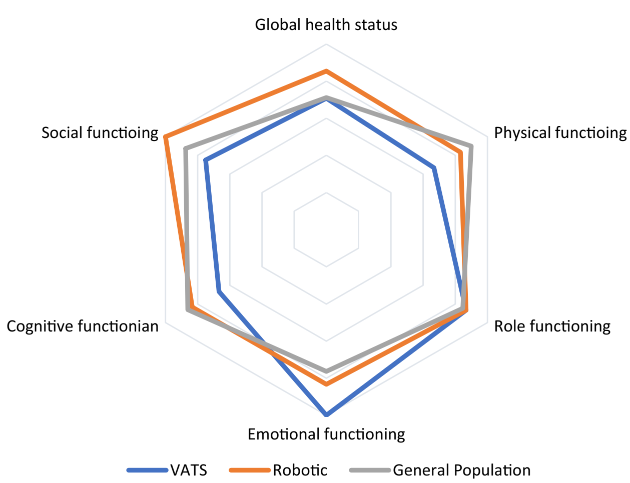

Fig. 2 The EORTC scores are divided into six different domains with a higher score indicating better function in that category. Functioning domains were compared between those who underwent VATS resection or robotic-assisted resection as well as the reference results of the general healthy population

operating times and higher overall operative costs [9–12]. Specifically, RATS lobectomy has been shown to have a higher cost than VATS lobectomy, with both techniques having lower overall cost compared to thoracotomy [9, 10, 12]. The stated benefits of robotic surgery include improved visualization, wristed arm movements and tremor reduction. Specifically, for lung resection, high-volume robotic programs have shown a decrease in hospital lengths of stay, 30-day mortality and post-operative transfusion requirements with the robotic technique compared to VATS and thoracotomy [4].

During the initiation of a robotic lobectomy program at our institution, we found an increased operative and total hospital cost, increased operative times, but equivalent operative outcomes, length of hospitalization, and long-term quality of life. Our data are in accordance with previously published data. Some studies suggest that the increase in operative time is due to the initial learning curve [2, 13, 14]. In our series, we saw a non-significant trend in the reduction in the RATS operative times comparing the first 10 to the last 10 cases. The operative time did not decrease significantly and could be attributed to too few cases for the lobectomy learning curve and our goal of resident participation as surgeons even early in our experience [15]. Even during the robotic cases, the lobectomies in our series were performed by a single surgeon with a thoracic learner (resident or fellow) at a dual console and a surgical assistant at bedside. Integrating residents into robotics cases is essential as the robotic volume in thoracic surgery continues to increase. Most thoracic surgeons finishing training should be skilled to perform a robotic lobectomy. In previous work at our institution, we looked at our thoracic robotic experience and proposed operative skill guidelines to assist in training residents and fellows to be proficient in the robotic technique [15]. It has also been previously shown that resident involvement in robotic cases does not negatively impact patient outcomes [15, 16].

Importantly for patient outcomes, with regard to robotic resection and oncologic outcomes, Cerfolio and colleagues found that even during the initial experience, the robotic technique achieves appropriate oncologic outcomes with the ability to achieve a R0 resection and complete mediastinal lymphadenectomy [17]. In our series, 80% of cases were performed for primary lung cancer, 28% of which were robotic. In our limited series, there was no difference in survival based on surgical technique. The sample size limits our ability to make oncologic conclusions from our data.

While transition from thoracoscopic to robotic lobectomy incurs increased operative and total hospital cost, equivalent operative outcomes, length of hospitalization and long-term quality of life can be maintained during this transition. With increasing patient and surgeon interest in robotic resection, it appears both safe and feasible to transition while maintaining outcomes. Additionally, this safe transition occurred in the context of a thoracic surgery residency with a resident or fellow participating in all cases.

Compliance with ethical standards

Conflict of interest Drs. Reddy and Lin have received compensation serving as robotic educators and as speakers for Intuitive Surgical, Inc. Drs. Worrell, Dedhia, Gilbert, James, and Chang have no financial disclosures.

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