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CLINICAL STUDY

Starting the first robotic lobectomy program in the Eastern Europe during Coronavirus disease-2019 pandemic

Stolz A, Kolarik J, Vachtenheim J, Svorcova M, Pozniak J, Simonek J, Lischke R

3rd. Department of Surgery, First Faculty of Medicine, Charles University, University Hospital Motol, Prague, Czech Republic. **alan.stolz@fnmotol.cz**

ABSTRACT

BACKGROUND: We report our experience in starting RATS (robotic-assisted thoracic surgery) lobectomy program during COVID-19 pandemic.

METHODS: Data from 20 consecutive cases undergoing RATS lobectomy between August 2020 and April 2021 were prospectively accumulated into our database.

RESULTS: The mean operational time was 235±69 minutes (median 210, range 175 to 370). Conversion-to-open rate was 5 %. One patient was converted to an open procedure during surgery due to surgical bleeding. One patient (5 %), with sever chronic obstructive pulmonary disease (COPD), had prolonged air leak with chest drainage 11 days and conservative treatment. Morbidity rate was 10 % (2 patients). Estimated costs of RATS lobectomy in our department were $9,590 (range $8,250–$12,730). 30-days mortality was 0%.

CONCLUSIONS: Safe robotic surgery is based not only on improved robotic equipment, but also on good technical skills and medical knowledge. It requires training of the entire operating room team. The learning curve is steep, involving port placement, use of the correct robotic arms, availability of the proper instrumentation, and proper patient positioning (*Tab. 2, Ref. 28)*. Text in PDF *www.elis.sk*

KEY WORDS: robotic surgery, lobectomy, complications, COVID-19.

Introduction

Complete surgical resection remains the golden standard for treatment of early-stage non-small cell lung cancer (NSCLC). During last century thoracotomy was a standard approach for the surgical therapy of NSCLC. Video-assisted thoracoscopic surgery (VATS) has emerged as a minimally invasive approach for surgical treatment of NSCLC during last three decades. The first description of VATS lobectomy with hilar dissection for cancer was published in 1992 by Roviaro (1). Several reports concluded that VATS is associated with better quality of life and less postoperative pain than thoracotomy, fewer postoperative complications, shorter hospital stay, smaller surgical incisions, less pain, quicker recovery, and faster return to routine daily activity (2, 3, 4). So, VATS lobectomy was suggested to be preferred surgical approach for lobectomy in early-stage NSCLC. However, VATS also has some limitations, including lack of articulation of the instrument, two-dimensional visualization, and counterintuitive movement of the instrument. Cutting-edge technological approaches such as robotic surgery have helped to overcome some of these limitations. So robotic surgery has become the next level of miniinvasive surgery. The da Vinci platform was the first to be used to undertake a cholecystectomy in Belgium in 1997 (5). Besides da Vinci system, there was also ZEUS platform. Using this system, Carpentier undertook a mitral valve replacement in 1998 (5). Both systems merged in 2003 and as a result, further innovations and improvements were centred on the da Vinci system. The use of robotic surgery in routine clinical practice became established in many surgical fields, including urologic, visceral surgery, gynecology, and thoracic surgery. The first anatomic robotic-assisted thoracic surgery (RATS) was reported in 2002 (6). In recent years, several studies have been published, demonstrating that RATS lobectomy is safe and feasible approach for treatment of NSCLC (1, 7–10). Advantages of RATS, compared with VATS approach, include wider and better movement of instruments, reducing hand tremor, three-dimensional visualization of operation field, and improved ergonomics of surgeon.

In August 2020 we have started our RATS lobectomy program, and it is the only one RATS lobectomy program in the Central and Eastern Europe nowadays on the Da Vinci Xi system. Our initial goal was to analyse the surgical outcomes and initial experience of program with special attention to pitfalls of starting new surgical program during Coronavirus disease-2019 (COVID-19) pandemic, which hit the Czech Republic very hard.

3rd Department of Surgery, First Faculty of Medicine, Charles University, University Hospital Motol, Prague, Czech Republic

Address for correspondence: A. Stolz, MD, PhD, 3rd Department of Surgery, First Faculty of Medicine, Charles University, University Hospital Motol, Prague, V Uvalu 84, CZ-150 00 Prague, Czech Republic
Phone: +420.224434100

Methods

This prospective observational analysis was designed to accumulate peri/postoperative data from 20 consecutive patients

Tab. 1. Preoperative characteristics.

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Age (years) mean±SD	65±9.4
Sex (females)	13 (65%)
BMI (kg/m², mean±SD)	29.9±4.8
FEV1 (%, mean±SD)	95±14.7
Hypertension	13 (65%)
Tumor size (mm, mean±SD)	25±13
Tumor location	
RUL	4 (20%)
RML	6 (30%)
RLL	3 (15%)
LUL	5 (25%)
LLL	2 (10%)

BMI – body mass index, FEV 1 – forced expiratory volume per second, SD – standard deviation, RUL – right upper lobe, RML – right middle lobe, RLL – right lower lobe, LUL – left upper lobe, LLL – left lower lobe

Tab. 2. Peri- and postoperative characteristics.

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Histology	
NSCLC	13 (65%)
Metastasis	4 (20%)
Others	3 (15%)
Operation time, minutes±SD	235±69
Conversion to thoracotomy	1 (5%)
Chest drainage, days±SD	3.3±2.2
Prolonged air leak, n (%)	1 (5%)
Length of postoperative stay, days±SD	4±2.5
30-days mortality	0 %

NSCLC – non-small cell lung cancer, SD – standard deviation

undergoing RATS lobectomy between August 2020 and April 2021. One surgeon (A.S.) operated on first 20 RATS lobectomy patients in the University Hospital Prague, Czech Republic. All patients completed preoperative computed tomography (CT), bronchoscopy, pulmonary function tests (FEV1, FVC, FEV1/FVC). The additional need for positron emission computed tomography (PET-CT), CT-guided core needle biopsy and maximal oxygen uptake (VO2max) testing was decided on an individual basis. The general clinical characteristics such as gender, age, body mass index (BMI), tumor location, tumor size, comorbidity, and clinical stage were recorded before the operation. The pathological stage, chest tube duration, length of stay in hospital, and costs were recorded after operation. The 8th edition of Lung Cancer Stage Classification was applied in this study (11). The outcomes of interest were 30-day mortality, conversion rate to open thoracotomy and postoperative complications, which were recorded and classified according to the Clavien-Dindo Classification System (12).

Prior to the hospital admission all patients had to have a negative PCR COVID test, as all procedures were done during heavy COVID-19 pandemic. All procedures were performed in the lateral decubitus position using da Vinci Xi robotic system (Intuitive Surgical, Inc., Sunnyvale CA). RATS lobectomies were carried out with a 4-armed approach (two 8-mm ports and two 12-mm ports). The 12-mm utility port and CO2 insufflation at 6 mmHg were used. All hilar structures were individually dissected and ligated using stapling devices. Fissures were completed with either an automatic stapling device or sharp dissection, depending on the completeness of the fissure. The utility port incision was enlarged at the end of the procedure to allow for specimen retrieval in the plastic bag. Intercostal bloc using bupivacain 0.5 % 20 ml was administered et the end of surgery. Chest drain 24 Fr was inserted and left on water seal without suction. All patients underwent systemic lymph node sampling or lymph node dissection.

Results

During the study period (August 2020 to April 2021), a total of 20 robotic pulmonary lobectomies were performed. Table 1 shows the general clinicopathological characteristics of the entire cohort. The mean age of the study group was 65±9.4 years (median 68 years, range 43 – 77 years) and 65 % of the patients were female. Adenocarcinoma (7/13, 54 %) was the predominant pathological type of NSCLC. Peri- and postoperative characteristics are listed in Table 2. Pathological stage I accounted for most of the NSCLC cases (11/13, 84 %). The mean tumour diameter was 25±13 mm (median 22 mm, range 9–69 mm). The average total operative time was 235± 69 minutes (median 210, range 175 to 370). One patient (5 %) was converted to an open procedure during surgery due to surgical bleeding. Morbidity rate was 10 % (2 patients). One patient (5 %), with severe COPD, had prolonged air leak with chest drainage 11 days and conservative treatment. Overall 30-days mortality was 0 %.

Discussion

Like other new surgical technologies, the learning process requires time and volume of procedures. How to overcome the learning curve safely and quickly is a key point of consideration by any surgeon planning to adopt RATS program (10). We present results of the first da Vinci Xi pulmonary lobectomy program in the Central and Eastern Europe which runs nowadays. Start of this program was affected by huge COVID-19 pandemic, which had impact on the proctoring of the program and patient's selection.

The COVID-19 pandemic has forced hospitals to progressively reduce surgical volumes to both, minimize disease transmission within the hospital and to preserve human and personal protective equipment and other resources needed to care for COVID-19 patients (13). Hospitals' biggest challenge was to create new intensive care unit (ICU) beds, as the existing system was insufficient to meet new demand, especially in the most affected areas. In response, many hospitals have abruptly reduced or eliminated elective operations. As the COVID-19 burden on a hospital increases, procedures that improve survival may similarly have to be reduced or eliminated. At the beginning of the COVID-19 pandemic, laparoscopy was believed to increase the risk of viral transmission based on the previous reports of viral aerosolization (HPV, HBV, HIV) due to the chimney effect of the smoke that escaped from the trocars. Hence, many surgical societies recommended restricted use of miniinvasive surgery (MIS) and diathermy during the pandemic (14). However, with accumulation of experience and clinical data analysis, it was found that there was no significant perioperative SARS-CoV-2 infection transmission among the patients and healthcare workers with MIS.

As the Czech Republic was hit by COVID-19 pandemic hardly (1,210 new cases per million at one moment, compared to 576 new cases per million in Italy) it was tricky to start RATS program during this time. It was not only about patient's selection and safety of the procedures. But it was also about proctoring the robotic program. Provision of proctorship has made trainees achieve earlier performance of independent robotic cases. This has allowed a conduction of safe surgery with the proctor guiding the trainee throughout the procedure during his early learning curve cases. But during COVID-19 pandemic proctorship in thoracic surgery in the Eastern Europe was reduced as travel among countries was banned, and this putted our start under some pressure, which was very unusual till COVID-19 pandemic.

One of the key points of starting surgical program is to overcome the learning curve safely. Unfortunately, the process by which a surgeon learns a new technique can be subjective and difficult to define. The learning curve for robotic lobectomy has varied in different publications. In a paper by Anderson, the inflection point for decreasing operative time was 45 RATS lobectomies (10). Arnold showed that based on operating time the learning curve for RATS lobectomy was 22 cases, with mastery achieved after 63 lobectomies (16). In his research, operation time after 63 lobectomies was 168 minutes. Yang reported that the learning curve for console operation could be divided into three phases: the learning phase (phase 1, case 1–10), the plateau phase (phase 2, case 11–51), and the mastery phase (phase 3, >51 cases) (15). As predicted, reduced operation time was observed as operation experience accumulated. Although robotics offers excellent 3D imaging and dexterity, there are also a few drawbacks. First, the physical distance to the rest of the team, with the surgeon sitting 4 metres away, poses a challenge to the teamwork. Second, the operator lacks the sensation of tissue manipulation, which is the case for both open and VATS surgery. The third, challenge for the RATS lobectomy learning process is access to the robot and the number of RATS in lobectomy cases.

It is interesting to note the similarities in the adaptation of robotic technology compared to the adaptation of VATS technology. In a survey of international VATS experts, most respondents estimated the initial learning curve for VATS was 50 cases, with the performance of at least 20 cases annually to maintain proficiency (2,17). In considering why, the learning curve for RATS has been consistently demonstrated to be shorter than for VATS, it may be that the transition from performing open surgery to any minimally invasive approach requires more skill acquisition than transitioning from one minimally invasive approach (ie, VATS) to a different minimally invasive approach (ie, RATS) (10).

Among 20 robot-assisted lobectomies performed at our institution, one thoracotomy conversion (5 %) due to pulmonary artery haemorrhage was noted. There was a tear of a small branch of pulmonary artery while dissecting enlarged pulmonary lymph nodes station 12 during right upper lobectomy. Overall blood loss during this surgery was 200 ml, with no need of blood transfusion. Patient was dismissed home on 5th. postoperative day. The 30-day mortality rate was 0 %.

Some studies suggest that the postoperative complication rate of conversion group is comparable with VATS group (8.7 % vs 11.9 % (18)), but some other cohorts hold an opposite viewpoint with lower conversion rate during robotic procedures (6.3 % vs 13.1 % (3), 2.7 % vs 13 % (10), 4.8 % vs 8 % (9), 2.4 % vs 25 % (19)). Tong suggests that preoperative chemotherapy, lesions diameter ≥ 1.4 cm, lymph-node calcification, pleural adhesions, type of resection, location of resection, ipsilateral re-operation, and lower surgical experience could also be independent risk factors of conversion (20).

Management of major perioperative vascular injuries in RATS has been described in many reports (21, 22). Cerfolio and colleagues noted when a major vascular injury occurs, the important strategy consists of four Ps, namely, poise – remain calm, pressure – apply pressure to the bleeding vessel, preparedness – prepare the disaster and give the anaesthesia and nursing team time to prepare after injury, and proximal control of the vessel bleeding (22). To perform these safely and manage the bleeding, one needs to decide whether to continue with robot-assisted surgery or to shift to VATS or open thoracotomy. Louie and Cerfolio described that the decision making on conversion to a thoracotomy consists of many factors, including immediate threat of life, hemodynamic stability, oncological outcomes, and surgical experience. Successful management of intraoperative catastrophes requires strong leadership and effective communication, as well as proficiency, swift action, and engagement from each individual member of the intraoperative team (21, 22). One of the greatest challenges to effective communication during the emergency conversion response is the remote position of the surgeon at the console away from the surgical field and the brief absence of the surgeon from the operating room to scrub before gowning.

There are several reports of operative time for RATS approach ranging between 132 and 293 min (3, 15, 18, 22, 23) and for VATS approach between 120 and 247 minutes (2, 3, 18, 20). Agzarian published a comprehensive systemic review and pooled results of 13 studies demonstrated a mean operative time of 190 minutes (range: 100–241 minutes) (24). A comparative meta-analysis showed a mean longer operative duration of 61.7 minutes and 4.3 minutes for RATS vs. thoracotomy and VATS, respectively. In the study by Anderson robotic-assisted surgery took on average only 8 minutes longer than the thoracoscopic operation (10). This result differs from previous studies, where RATS lobectomy times have been longer than VATS operation times. This difference Anderson explains by the fact that robotic program started after established experience with the VATS program and the surgeons had practice with other minimally invasive procedures.

Both VATS and RATS offer minimally invasive approaches. However, VATS procedure has some limitations, including two-dimensional visualization, lack of articulation of the instrument, and counterintuitive movement of the instrument. Certain disadvantages of robotic surgery must be also considered. The surgeon who controls the robotic instruments at the console has no tactile or force feedback and must perform the surgery based on visual input alone. This limitation may result in various degrees of vascular injury during robotic procedures. Small vascular bleeding can be controlled by compression with sponges; however, if bleeding cannot be controlled, the probability of conversion to thoracotomy is high. Oh et al. presented a study comparing VATS and RATS surgery (3). Compared with VATS, RATS lobectomies were associated with a longer mean operating room time (28-minute difference), comparable intraoperative complication rates (3.2 % vs 3.1 %), but lower postoperative and 30-day complication rates (34.1 % vs 37.6 % and 37.3 % vs 40.5 %, respectively). They also reported that the conversion rate to open in the VATS group was more than twice that in the RATS group (13.1 % vs 6.3 %), and median hospital stay for the VATS group was 1 day longer than that for the RATS group (7.3 % vs 6.9). Jin et al published a single-center, prospective randomized clinical trial to compare the efficacy of RATS and VATS lobectomies (25). The length of hospital stay (4 vs 5 days) and the rate of postoperative complications (14 % vs 18 %), conversion rate (4.5 % vs 5.5 %) were similar in both groups. No perioperative mortality occurred in either group. Number of lymph nodes harvested, lymph nodes stations examined and hospitalization costs ($12,821 vs $8,009) were significantly higher in the RATS group. In the study by Anderson et al was a trend for prolonged air leaks in the VATS group relative to the RATS group (12 % vs 4 %), and arrhythmia developed in 5.3 % of VATS patients and in 4 % of RATS patients (10).

The high cost of robotic surgery has been a main point of criticism since the early adoption of robotic-assisted lung resection and has raised the question of its value. Subramanian found that, on average, RATS was 12 % more costly than open lobectomy (26). Hospitalization costs for patients undergoing RATS lobectomy were significantly more expensive than open lobectomy ($20,377 vs $17,200) and VATS lobectomy ($20,377 vs $17,802). In US database study, Paul et al. estimated costs based on hospital-specific cost-to charge-ratios (27). The median cost of robotic lobectomies was significantly higher more than for VATS procedures ($22,582 vs $17,874). Swanson in the study analysed costs in propensity score-matched patients from a large US multihospital database, again finding that robotic lobectomies were more expensive than VATS lobectomies ($21,833 vs $18,080) (28). The results of the study by Nasir et al showed that robotic lobectomy is profitable (expenses per patients $15 440, profit $ 3 497) for the hospital for patients with Medicare, even in Alabama, where the reimbursement for lobectomy is only $18,937 (7). Novellis in his study found that costs of robotic surgery were higher than for VATS and open surgery, with a profit margin of about 18 % relative to the Region of Lombardy, Italy, health service reimbursement of $12,235 (18). Estimated costs were 82 % of Region of Lombardy lobectomy reimbursement for robotic surgery, 69 % for open surgery, and 68 % for VATS. In the Czech Republic reimbursement for RATS lobectomy is $11,300. Estimated costs of RATS lobectomy in our department were $9,590, so there is a profit about 14%. The future development robotic surgery in general is likely to be enhanced by the arrival of new surgical robots from new manufacturers. Medtronic and Johnson and Johnson are developing surgical robots which will challenge Intuitive Surgical monopoly and hopefully drive costs down.

Summary

There continues to be an increase in the number of RATS lobectomies performed. Together, RATS and VATS now account for more than half of all lobectomies, driving the trend to more minimally invasive lobectomy. RATS and VATS pulmonary lobectomies are equivalent in perioperative and postoperative outcomes. Although use of robotic approach is associated with longer mean operating times, which translated to higher hospital-associated costs, the technical advantages of the robotic surgery may offset these costs in the long term. Prospective, multicentre cost-effectiveness studies are warranted to justify the implementation and continued use of robotics.

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