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SURGERY IN LOW AND MIDDLE INCOME COUNTRIES

Building a Large Robotic Thoracic Surgery Program in an Emerging Country: Experience in Brazil

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Abstract

Background In the last decade, robotic video-assisted thoracic surgery (R-VATS) has grown significantly and consolidated as an alternative to video-assisted thoracic surgery. The objective of this study is to present the implementation as well as the experience with R-VATS accumulated by 2 Brazilian groups. We also compared the outcomes of procedures performed during the learning curve and after a more mature experience.

Methods Retrospective cohort study included all R-VATS procedures performed since April 2015 until April 2018. We describe the process of implantation of robotic surgery, highlighting the peculiarities and difficulties found in a developing country. Moreover, we reported our descriptive results and compared the first 60 patients to the subsequent cases.

Results Two hundred and five patients included 101 females/104 males. Mean age was 61.7 years. There were hundred and sixty-four pulmonary resections, 39 resections of mediastinal lesions, 1 diaphragmatic plication, and 1 resection of a hilar tumor. Median operative times were 205 min for lung resections and 129 min for mediastinal. There was no conversion to VATS or thoracotomy or major intraoperative complications. Median length of stay was 3 days for pulmonary resections and 1 day for mediastinal. Postoperative complications occurred in 35 cases (17.0%)—prolonged air leak was the most common (17 cases). One fatality occurred in an elderly patient with pneumonia and sepsis (0.4%). Comparison of the first 60 patients (learning curve) with subsequent 145 patients (consolidated experience) showed significant differences in surgical and ICU time, both favoring consolidated experience.

Conclusions Our results were comparable to the literature. Robotic thoracic surgery can be safely and successfully implemented in tertiary hospitals in emerging countries provided that all stakeholders are involved and compromised with the implementation process.

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Introduction

Minimally invasive thoracic surgery (MIS) is the standard of care for early stages of lung cancer, mediastinal lesions, and diaphragmatic diseases [1, 2]. Currently, MITS is done through video-assisted thoracic surgery (VATS) or robotic video-assisted thoracic surgery (RATS), both with a substantial number of cases and with similar early and long-term results. RATS is still more expensive than VATS, according to several publications [3–6]. However, in our opinion, VATS is the next scale of VATS, which, in fact, did not evolve, significantly in the past decade.

It is recognized that VATS is associated with some technical difficulties like 2D visualization, limited, and contra-intuitive instrumentation, tremor at the tip of the instruments, and bad ergonomics. RATS, on the other hand, has full-HD and 3D magnified visualization, accurate sense of profundity, intuitive manipulation, tremor filtration, great mobility of camera, and instruments not limited by the rigidity of chest wall, and comfortable ergonomics. For all these reasons, despite the lack of definitive evidence of superiority of RATS over VATS, we observe a growing and widespread adoption of RATS in North America, Europe, and Asia [7–9].

RATS was first performed in Latin America in 2010, but has grown very slowly since then, basically due to access barriers. Beginning with relatively small number of robotic platform, and furthermore are concentrated in few private hospitals. Another point is the high cost of materials and irregular availability due to difficulties with import and exchange rate fluctuations. Finally, another challenges are the lack of thoracic proctors and the existence of few services with a large volume of complex thoracic surgeries, making it very difficult to overcome the learning curve. Thus, there are many challenges to build a consolidated robotic program in emerging countries. Nevertheless, more recently, the larger number of da Vinci units and the stronger body of evidence supporting robotic surgery has increased the interest in such technique in our region. Therefore, the objective of this study was to present the processes of implementation of robotic thoracic surgery as well as the experience with RATS accumulated by 2 groups of Brazilian thoracic surgeons. As a secondary endpoint, we compared the outcomes of procedures performed during our learning curve and after a more mature experience.

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Materials and methods

This is a retrospective cohort study in which we included all robotic thoracic procedures performed by 2 groups of Brazilian thoracic surgeons, 1 from Sao Paulo and other from Rio de Janeiro, since the inception of their experience in April 2015 until April 2018. The first author participated in all procedures either in the role of console surgeon or as proctor of other surgeons. All data were extracted from a prospectively maintained database dedicated exclusively to robotic procedures performed by the two groups.

All surgeons involved are board-certified thoracic surgeons both in senior or mid-career positions. As usual in Brazil, they operate in multiple private healthcare institutions. All of them also have appointments at University affiliated public hospitals. Most of them already had consolidated expertise in video-assisted thoracic surgery (VATS) being minimally invasive surgery their preferred approach in more than 80% of their cases of anatomic lung resections.

Development of the robotic program

Our robotic thoracic program started in April 2015 at the Sao Paulo State Cancer Institute—ICESP (University of Sao Paulo). The institution had already started its robotic program 2 years earlier, so nurses, clinical engineers, and anesthesiologists were very familiar with the robot. The da Vinci system and supplies were funded by the Ministry of Health and Ministry of Science and Technology (besides the State Government) as part of a research project aiming to better understand the role of robotic surgery in our country, particularly with regard to costs. Initially, 2 surgeons were qualified for the use of the console and 2 for bedside assistance. We included only oncological lobectomies for tumors smaller than 5 cm and not central. Following our initial experience at University of Sao Paulo, we started performing robotic procedures in several private hospitals in Sao Paulo and later in Rio. All hospitals had an established experience with robotic surgery, but with none or very little experience with robotic thoracic surgery. The robotic programs in the private hospitals started with the 2 surgeons already trained doing their own surgeries. In addition, as these surgeons became proctors in other private hospitals, partnerships were consolidated. In this private setting, the inclusion criteria were broader according to experience, including mediastinal and diaphragmatic surgeries.

Training was a complicated issue. Even though there were some thoracic surgeons in South America certified in robotic surgery, none of them had a mature enough program to mentor new surgeons. After the certification in

Orlando and a brief clinical observership (1 week) in Orlando and Miami, we (SP team) performed the first cases under the supervision of a local general surgeon with large experience in robotic surgery. Using a proctor who was not a thoracic surgeon is not the standard; however, there was no sufficiently trained thoracic surgeon in Latin America at the time, and the high costs prevented a thoracic surgeon from other countries from helping us. Dedicated courses and conferences (particularly those with live procedures) and videos available on the internet were extremely helpful to complement our training.

Surpassing the learning curve was also a very complicated issue. In Brazil, patients are spread over different institutions and individual load of cases tend to be low. If, in one hand, in public institutions number of cases is not a problem, resources and reimbursement are. In private practice, on the other hand, reimbursement is negotiable, but patients are rarer. We were lucky to start our program in a public institution under a research project, so we had funding and cases enough to build on an experience fast. Later, negotiation with private hospitals to charge patients the extra cost of the robot as low as possible, and even waive this payment in some cases, was crucial for increasing the numbers quickly.

After building an initial experience, the first author started to mentor other surgeons. Mentoring helped to increase expertise and fostered the development of a collaborative network on robotic thoracic surgeons.

In Rio de Janeiro, the robotic program started in September 2016, always with the same proctor. Rio surgeons did their certification in USA and Europe. The program is evolving slower than São Paulo's one, because it encompasses only private hospitals. There are no robotic platforms in most public hospitals in Rio, and this fact limits a faster accrual of patients.

Operative technique

In all patients, we followed a standardized protocol that included preoperative work-up, intraoperative strategy, and postoperative management. With regard to the operative technique, all procedures were performed with the da *Vinci Si robotic platform*, under general anesthesia and double-lumen intubation. We routinely use CO_2 insufflation (pressure of 8 mmHg), three robotic arms, and in most cases only two instruments, a Maryland bipolar and either a thoracic grasper or a cadiere.

For anatomic lung resections, we use the 3-arms completely portal robotic lobectomy or segmentectomy technique as proposed by Ninan and Dylewski [10] with some adaptations. All arms were sterile draped, and arm 1 was disabled and stored in the back of the cart. Patients were positioned in lateral decubitus with 2 pads under the axillae; the table was then flexed to spread the intercostal spaces. We performed two 8 mm ports for the instruments (Cadiere and Maryland bipolar forceps—seventh intercostal space anterior and eighth posterior) and two 12 mm ports (1 long for the camera (eighth intercostal space at the middle axillary line) and 1 short for the assistant (tenth intercostal space, close to the diaphragmatic insertion) as previously published [11]. The cart came in from the top of the table. The surgical steps for completing the resection were similar to what was previously proposed by Cerfolio et al. [12, 13].

For the resection of anterior mediastinal lesions, we used the technique proposed by Rueckert [14]. All arms were sterile draped except for arm 3 that was disabled and stored in the back of the cart. Patients were placed in 30° lateral decubitus (right of left), and the ports performed at the fifth intercostal space in the anterior axillary line (camera), fifth intercostal space in the hemiclavicular line, and at the third intercostal space just lateral to the hemiclavicular line. The assistant's port was put in the sixth or seventh intercostal space just lateral to the anterior axillary line. In the left hemithorax, it is necessary to take extra care to avoid putting the port with the heart in the way of the instruments. For lesions in the middle or posterior mediastinum, port placement and docking were similar to those adopted for pulmonary resections. Finally, for lesions below the inferior pulmonary vein and at the diaphragm, we followed the port placement and docking proposed by Cerfolio [12].

Data collection and analysis

For this study, we retrieved data from our database addressing demography, diagnosis, length of operation, ICU, chest tube, and admission time, number of nodes, and number of nodal stations harvested, and morbidity and mortality of patients undergoing robotic surgery. All consecutive cases since the beginning of our program were included.

Categorical variables are expressed as absolute numbers and percentages. Continuous variables with normal distribution are expressed as mean and standard deviation. For comparing the outcomes of procedures performed during the learning curve and those performed in a more mature phase of our experience, we divided the patients into 2 groups, 1 comprising the first thirty patients of both Sao Paulo and Rio groups (Group Learning Curve—60 patients) and the other comprising all remaining 145 patients (Group Consolidated Experience). Continuous variables were compared using Student *t* test. Differences were considered significant when $p < 0.05$.

Results

During April 2015 to April 2018, 205 patients underwent RATS in the hospitals and institutions of the authors. Figure 1 depicts the distribution of the procedures performed. There were 164 lung resections, the majority of them lobectomies (130). Out of the 39 mediastinal procedures, 25 involved the anterior mediastinum being 14 thymic tumors (10 thymomas, 2 thymic carcinoma, 1 thymic carcinoid, 1 thymic sarcoma), 2 intrathoracic goiters, 2 teratomas, 2 lymphomas, 2 thymic cysts, 1 ectopic parathyroid, 1 myasthenia gravis, and 1 metastatic tumor. We also had 1 case of diaphragmatic plication and 1 resection of a hilar tumor (Castleman disease).

The baseline characteristics of patients divided by the type of procedure (lung or mediastinal) are depicted in Table 1. Surgical outcomes also divided by type of procedure are shown in Table 2. No conversions and no major intraoperative accident were observed in our series. It should also be highlighted the low complication rate observed after mediastinal procedures, only 2 cases coursed with complications, 1 patient had bronchospasm that postponed discharge and the other had recurrent laryngeal nerve paralysis and severe diarrhea. One patient coursed with chylothorax more than a month after the procedure and was successfully treated with thoracic duct embolization.

Complications associated with lung resections are detailed in Table 3. Prolonged air leak was the most frequent, occurring in 17 (10.4%) patients; one of them had to undergo a new chest tube insertion, and 7 (4.3%) of them were discharged with chest tube. Chylothorax was also frequently occurring in four patients; three of them had to undergo thoracic duct ligation. One patient had right colon distension (Ogilvie disease) and underwent exploratory laparotomy and right colectomy. Finally, the patient who had myocardial ischemia underwent percutaneous angioplasty with a good outcome. The only fatality in our series occurred on the twelfth postoperative day and was secondary to multiple complications that followed pneumonia in an elderly patient who underwent lobectomy due to lung cancer.

Table 4 shows the results of procedures performed during the learning curve and after a more consolidated experience. While we observed a significant reduction in operation times, no significant difference was detected in postoperative recovery times or in the radicality of the operation, as demonstrated by the number of lymph nodes harvested.

Discussion

Our results demonstrate that it was possible to safely implement robotic thoracic surgery in development countries. Although we lacked specialized proctoring and had limited resources and difficulties in patient accrual early in our series, we experienced no major intraoperative complication or necessity to convert to VATS or open procedure. Morbidity was low since the inception of the program

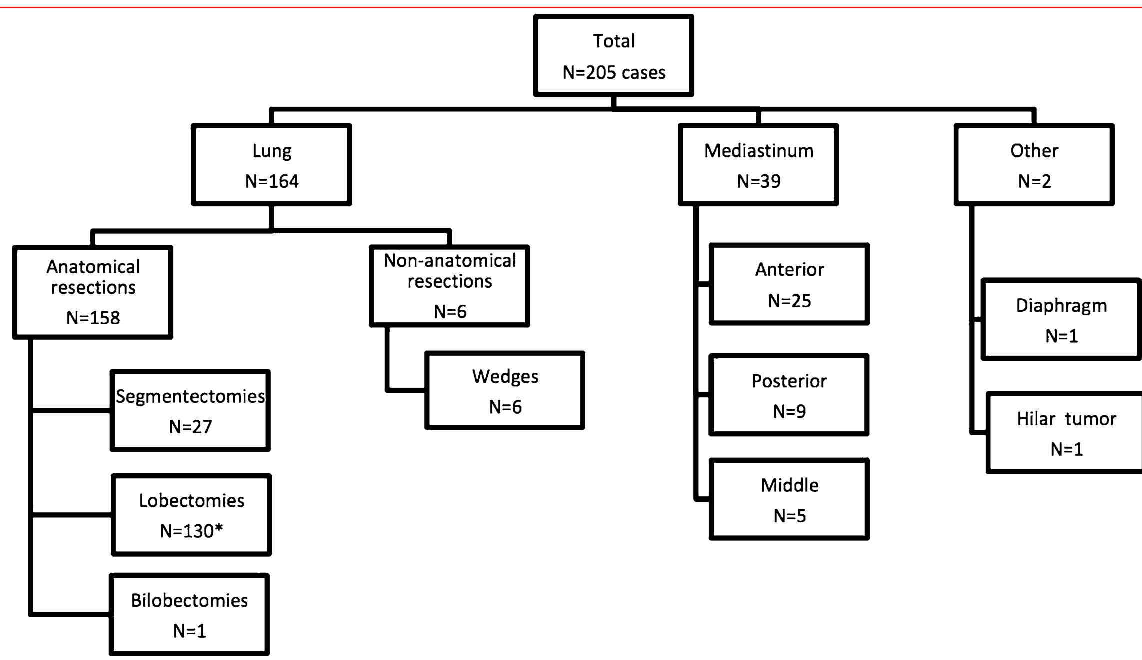

Fig. 1 Procedures performed. *One patient underwent sleeve right upper lobectomy

Table 1 Baseline characteristics of patients

	All procedures $N = 205$	Lung procedures $N = 164$	Mediastinal procedures $N = 39$
Age, mean (SD)	61.7 (13.4)	61.9 (13.1)	61.3 (13.5)
Female gender, *n* (%)	101 (49.3)	77 (46.9)	24 (61.5)
ASA, *n*			
0	5	2	3
1	56	41	15
2	97	79	18
3	23	20	3
FEV1(%), mean (SD)	–	87.6(18.1)	–
Tumor size (mm), mean(SD)	–	25.6(17)	47.4(26.9)
Tumor location in the lung, *n* (%)			
RUL	–	59	–
RML	–	5	–
RLL	–	35	–
LUL	–	31	–
LLL	–	30	–

Table 2 Main surgical outcomes

	Lung procedures $N = 164$	Mediastinal procedures $N = 39$
Total surgery time, min, mean (SD)	205 (80)	129 (55)
Console time, min, mean (SD)	158 (70)	85 (45)
Conversion, *n* (%)	0	0
Severe intraoperative complication, *n* (%)	0	0
ICU stay, days, median (IQ25-75)	0 (0–1)	0 (0–1)
Length of stay, days, median (IQ25-75)	3 (3–6)	1 (1–2)
Mortality, *n* (%)	1 (0.6)	0
Complications, *n* (%)	33 (20.1)	2 (5.1)

Min minutes, *SD* standard deviation, *ICU* intensive care unit

and only 1 fatality was observed. With accumulated experience, operation time decreased significantly.

In this series, we performed a wide range of procedures, and, over time, we increased their complexity. For instance, the first segmentectomy was only performed after case number 60 and the first sleeve resection after case 180. The fact that we neither experienced intraoperative complications nor conversions contrasts with the current literature, where we find a conversion rate of 10% [15]. Patient selection, diligent dissection, and extra care are possible reasons for this finding, but most importantly it highlights the point that robotic thoracic surgery is safe.

Our morbidity and mortality rates for lung resections (20% and 0.6%, respectively) are in line with the modern literature. Most recent series of RATS anatomic lung resections for the treatment of lung cancer or metastatic disease show a mortality rate that varies from 0.2 to 1.3% and a morbidity rate that varies from 34.6 to 43.8% [16–18]. Nevertheless, the complication profile observed in our cases was slightly different from previous publications. Cardiovascular complications were very rare occurring in only 2 patients, 1 had atrial fibrillation (treated with medications) and the other had myocardial ischemia treated with percutaneous stenting. Cerfolio and cols. observed arrhythmia in 7% of their patients submitted to lung resections [15]. The reason for this finding is unclear, but it was already noticed in other Brazilian series of minimally invasive lung surgery [19]. Conversely, chylothorax was a disturbing event observed in four of our patients and it was related to the extensive lymphnodal dissection in right paratracheal stations. After the fourth case, we started using more clips in this region and decreased to -8 cmH_2O

Table 3 Complications observed after lung procedures

	n (%) = 164 (100)
Patients with any complication	33 (20.1)
Patients with 1 complication	25 (15.2)
Patients with 2 complications	5 (3)
Patients with 3 or more complications	3 (2.8)
Type of complication	
Air leak >5 days	17 (10.4)
Chylothorax	4 (2.4)
Pneumonia	4 (2.4)
Pulmonary embolism	4 (2.4)
Atelectasia	2 (1.2)
GI complications	2 (1.2)
Kidney failure	2 (1.2)
Tracheostomy	2 (1.2)
Urinary infection	1 (0.6)
Sepsis	1 (0.6)
Arrhythmia	1 (0.6)
SARA	1 (0.6)
Myocardial ischemia	1 (0.6)

the initial aspiration of the digital postoperative drainage system (our original setup was −20 cmH_2O). After these measures, we have not had any new case of chylothorax.

Prolonged air leak was the most frequent complication in our lung surgery cohort. Indeed, this finding was already reported in other series of lung resection [16–18]. Unfortunately, not only does air leak prolongs length of stay but also can lead to additional procedures such as new chest tube insertions. Hospital discharge with a chest tube is also a very distressing situation for patient and family. Even though our rate of air leak is in line with the current literature [16], our efforts are now invested in reducing such a complication.

Several papers discuss the high cost of robotic surgery [3–6], which is a real concern for hospitals and healthcare managers. However, new evidence has shown that robotic thoracic surgery might be profitable to hospitals, even better than other minimally invasive approaches [5] if procedures and material are standardized. Involvement of hospital managers in this process is critical to reduce costs and attract more patients and health care plans. More experience with the method also increases efficiency reducing costs in a virtuous cycle [20].

Robotic thoracic surgery was successfully implemented by both groups of surgeons, in 2 different large centers, because we invested in an intensive training of all participants and we standardized and systematized all the steps of the operation. We believe that prior knowledge of VATS has facilitated our learning of the robotic technique. However, it is only our impression, since all the surgeons involved already had great experience with VATS preventing us from measure such variable. Moreover, we are able to accumulate a large number of cases fast and, consequently, overcome the learning curve in a short period of time. Our study has limitations, though, and the most significant is its retrospective design. Even though our database is prospectively maintained, a retrospective review of data is prone to several biases. However, we believe our experience could be reproduced in other tertiary institutions in emerging countries, provided they adopt similar policies.

Robotic thoracic surgery can be safely and successfully implemented in tertiary hospitals in emerging countries provided that all stakeholders are involved and compromised with the implementation process. Active case procurement, systematization of procedures, and hospital managers' support are paramount. We believe that with the increasing number of robotic platforms available and free competition in the private health sector, more thoracic surgeons will participate in robotics programs. New surgeons are being trained to teach these new programs. With

Table 4 Comparison of outcomes of lung procedures performed during the learning curve and after a consolidated experience

	Learning curve N = 60	Consolidated experience N = 145	p
Total surgery time, min, mean (SD)	247 (94)	167 (62)	<0.001
Console time, min, mean (SD)	195 (81)	126 (57)	<0.001
ICU time, days, mean (SD)	1.4 (2.1)	0.6 (1.7)	<0.04
Chest tube time, days, mean (SD)	2.9 (3.3)	2.9 (4.3)	NS
Length of stay, days, mean (SD)	4.6 (4.9)	4.8 (5.6)	NS
Lymph nodes stations, n, mean (SD)	5.3 (2)	6 (2)	NS
Lymph nodes resected, n, mean (SD)	11.3 (7)	11 (6)	NS

Min minutes, *SD* standard deviation, *NS* non-significant the consequent increase in the volume of cases and gain in scale, we believe that the cost of robotic surgery will decrease. In addition, new companies promise to enter the market in the coming years, which should also help lower costs. With all this, access to robotic surgery should increase considerably in our country in a few years.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest directly or indirectly related to the manuscript contents.

Informed consent Informed consent was obtained from all individual participants in the study.

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