

Training program in robotic thoracic surgery

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Introduction

Since the introduction of current robotic-assisted surgery into surgical practice in 2000, the number of surgeries performed continues to increase. There are approximately 4,500 robotic platforms fully operational worldwide (*Figure 1*). Approximately half of these are located in the United States. The first reports describing the use of the robotic platform in thoracic surgery occurred in 2003 (1,2). In 2010, the Society of Thoracic Surgeons (STS) database reported that only a small number of lobectomies had been performed with robotic assisted thoracic surgery (RATS). By the end of 2013, 14% of all lobectomies were performed via robotic surgery (3). Oh *et al.* reported that the number of all lobectomies performed with RATS went from 7.6% in 2011 to 17.5% in 2015 (4). In that same year, over 6,000 robotic lobectomies were performed in the United States, and over 8,600 done worldwide (5). During the same period of time, the number of open lobectomies went from 54% to 43%, while the number of VATS lobectomies remained stable at 40%, suggesting an increased adoption of RATS by thoracic surgeons contributed to less open surgery (4). Here we present a pathway for proper adoption of robotic thoracic surgery.

RATS and VATS

Video assisted thoracic surgery (VATS) has been well accepted as a preferred method for surgical management of lung cancer. However, the adoption has been limited in part due to limited training of surgeons as well as technical demand of VATS in complex cases. The robotic platform offers a consistent and reliable high definition three-dimensional view, dashboard display of vital signs

da Vinci system installed base

4,528 worldwide as of March 31, 2018

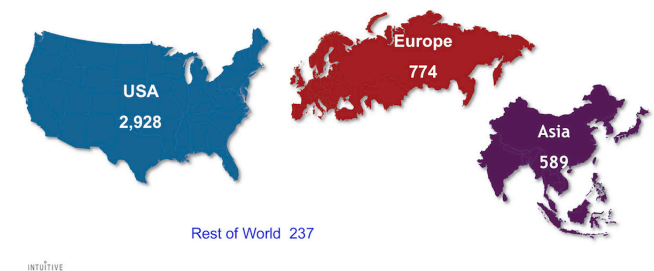


Figure 1 da Vinci robotic platforms installed worldwide in March 2018.

and instruments being used, a teaching console, wristed instruments with a greater degree of freedom enabling the surgeon to control the video-camera as well as multiple instruments simultaneously. Although the number of thoracic robotic surgery continues to increase (6-12), there exist a few limiting factors for safely adapting a RATS approach. One major barrier to adapting robotic surgery is the training of thoracic surgeons and his/her operating room (OR) team, availability of OR time distributed amongst other specialties, training residents, and fellows, as well as the difficulties encountered during the learning curve.

Training

A small number of training centers and proctors are available to teach RATS worldwide and it is encouraged to participate in a live case observation to understand the OR dynamic as well as the robotic techniques to determine if



Figure 2 da Vinci skills simulator.

this approach is feasible for the aspiring surgeon. This often presents a challenge due to the costs and the required time away from the practice. Surgeons in training who decide to pursue robotic thoracic surgery could choose an academic center with an established robotic surgery training program and obtain certification offered by the manufacturer(s). Regardless of training/certification pathway chosen, it should include a few mandatory steps: (I) to obtain a firm knowledge of the robotic platform; (II) to develop the skills necessary to perform robotic surgery in the laboratory; (III) to be proctored by an surgeon with experience in RATS; (IV) to develop a surgical and anesthesia team whose familiarity with thoracic surgery is second to none; and (V) to attain the learning curve within a desirable/established period of time while monitoring patient outcomes

Knowledge of the robotic platform

The first phase of training involves learning the technical aspects of the robotic platform and the basic techniques of instrument control, instrument selection and camera management. This training is facilitated and is standardized by the manufacturer. During this initial step, the surgeon will be familiar with the equipment and the robotic system itself, he/she will know how to set up the operative field and dock the robot to the patient. At the end of the first step, the surgeon should have full knowledge of the robot's operating system, the surgical cart, the surgeon's console,

and visual display. It is paramount to understand monopolar and bipolar energy in the robot since it requires foot and wrist action simultaneously.

Develop skills in the laboratory

It involves robotic technical skills through laboratory simulation, didactic classes, and hands-on courses. The goal is to introduce the neophyte surgeon to a series of training modules and to proceed from a cautionary frame of mind to a faster and precise movement and hand-foot coordination utilizing robotic instruments. The training and simulation modules provide immediate feedback through a scoreboard. A score greater than 90% in each module indicates an adequate level of proficiency for each specific skill set (*Figure 2*). Simulation modules specific to thoracic surgery and pulmonary lobectomy are now available in some centers. Next, hands-on activities in the wet laboratory with either animal or cadaver models coupled with didactic courses will enable the surgeon to use different instruments, to dissect tissues applying monopolar or bipolar energy, and to handle tissue with the robotic instruments/arms as well as endo-suturing.

Although neither robotic nor video-assisted thoracic surgery provides tactile feedback, one would be required to develop visual cues to apply adequate force required to perform the operation without causing trauma to tissues. The application of bipolar energy for dissection requires



Figure 3 How to use robotic thoracic bipolar energy (13).
Available online: <http://www.asvide.com/article/view/28111>

early activation of the energy and pulling the tissue away from the dissection plane. Once these basic skills have been acquired, one should proceed to the third step (*Figure 3*).

Proctored by a surgeon with experience in RATS in the operative room. It is paramount that all staff members involved in the robotic team; surgeon, assistants, anesthesiologist, scrub technicians, and OR circulators should be well acquainted with the scheduled surgical procedure. At first, procedures performed with RATS would take longer than the average time for open or VATS procedures. As the learning curve is attained, communication amongst team members and surgeon's versatility will improve, thus the time for each and every procedure will decrease. It is important to brief and debrief with the anesthesia and OR team to identify areas requiring improvement as well as to streamline the process and improve efficiency.

Develop a surgical and anesthesia team for RATS

The team should be familiar with thoracic surgery. One must never compromise the patient's safety for "efficiency" in the OR. At this stage, the surgeon should focus on the safety of the patient, the surgical technique itself, the positioning of the patient on the table in relation to the anesthesia cart, port placements, docking the robot, placing and exchanging instruments and the strategy for unexpected bleeding requiring conversion to open. The surgical team should incorporate all these during checklist and time-out. It is noteworthy once docking is completed, the anesthesiologist will have limited access to the patient's double-lumen endotracheal tube. Correct placement of the



Figure 4 Robot docked for right upper lobectomy.

ports and trocars should be done with the guidance of a 5 mm thoracoscope. Once desired trocars have been placed, docking is then carried out. When these two steps have been done correctly, there should be no collision of the robotic arms and no limitation of the movements with the instruments (*Figure 4*).

Attain the learning curve within a desirable/established period of time. Whenever unwanted bleeding is encountered, a planned and rehearsed strategy should be implemented without hesitation. Our approach is to have the assistant, at the bedside, apply gentle pressure over the bleeding area with sponged forceps as the surgeon moves swiftly towards the operative table while team members undock the robot and remove the instruments to convert to open thoracotomy. As the number of cases of anatomic pulmonary resections approaches 20, the efficiency of the operation starts to improve significantly (14-16). Each hospital credentialing process for robotic surgery is different, and some require different number of proctored cases from 2 to 5 followed by monitoring of the outcomes in the initial phase of the robotic program implementation. We

PRE-OP Date of Surgery (mm /dd / yy): ____/____/____ Height: _____ Weight: _____ Procedure: Lobectomy Segmentectomy Esophagectomy Thymectomy Staging: T1 T2 T3 T4 / N1 N2 Neoadjuvant therapy? Y / N Chemotherapy Chemoradiation	INTRA-OP Operative Time Skin-to-Skin: _____(minutes) OR Room Time: _____(minutes) (Wheel-in-Wheel-out) Converted to Open? Y / N Estimated Blood Loss: _____(ml) Blood Transfusion? Y / N If so, how much? _____(Units)
POST-OP Opioid Naive pre Surgery? Y / N PACU Stay: _____(Minutes) Pain at PACU Admission: (0 is no pain) 0 1 2 3 4 5 6 7 8 9 10 Pain at PACU Discharge : (0 is no pain) 0 1 2 3 4 5 6 7 8 9 10	POST-OP Pain Meds in PACU (circle) Morphine Fentanyl Hydromorphone Oxycodone Ketamine Pain Meds in PACU: _____(of times given) ICU stay? Y / N If so, how long? _____(days)
General hospital stay: _____(days) Any Post Op Complications? Y / N If so, what are they? _____ _____ _____ _____ _____	Patient Satisfaction: (1 is Unsatisfied) 1 2 3 4 5 6 7 # of Days on Rx Pain Meds: _____(days) # of Days on OTC Pain Meds: _____(days) # of Days on No Pain: _____(days) # of Days to Normal Activity : _____(days) # of Days to Back to Work: _____(days) Work Category: _____
NOTES: _____ _____ _____ _____ _____	

Figure 5 Metrics spreadsheet for RATS. RATS, robotic assisted thoracic surgery.

suggest adopting a quality control and metrics spreadsheet for every RATS procedure from the start (*Figure 5*), and have scheduled, external audits of the program. We would encourage a more direct mentorship program with the proctoring surgeon to discuss troubleshooting, patient selection and technical pearls as the learning curve progresses.

Costs

There are many opportunities to control costs of surgical procedures overall. There are direct and indirect costs. Direct costs are charges related directly to patient care; chest CT scans, X-rays, medications, daily laboratory tests, dietary needs, the daily rate of hospital beds, OR equipment, disposable supplies, OR hourly rate, respiratory

therapists, supplemental oxygen, chest tubes, benefits and salaried personnel who delivered care to the patients in and out of the OR and during hospitalization.

Indirect cost takes into account overhead costs, such as the price of the Robotic system, utilization, annual instruments maintenance contract, time away from clinical duties for personnel and team training, fitting or retrofitting of ORs, amortization of capital equipment and supplies, and the cost of utilities and administrative staff. Profit margin has been defined as the amount of reimbursed money by all payers subtracted by the total expenses of the patient encounter. The total expense is the sum of the direct and indirect costs over time. In 2014, Nasir *et al.* reported a median direct cost of \$9,853, median indirect cost \$5,587, and total expense per patient of \$15,440, median Medicare reimbursement per patient of \$18,937 with a median profit margin per patient of \$3,497 (17). There are, however, local, regional and international variations, which should be taken into consideration when calculating expenses and profitability of RATS procedures. Most of the hospitals will distribute the indirect costs amongst different specialties. We should be mindful of the costs under our control, minimize unnecessary instrument exchanges, supplies and services (i.e., epidural catheters, central lines, etc.) supplies, prevent complications and facilitate appropriate hospital length of stay in order to ameliorate costs.

The introduction of a new modality for performing thoracic surgery will demand time and dedication. As one begins the perform RATS, it is tempting to fall back on the “old ways” whenever difficulties are encountered, may it be in the OR or outside. Another common misconceived idea is that of RATS is just VATS with a three-dimensional view and wristed instruments. In reality, it represents in some ways, a departure from video-assisted surgery into a different approach, which offers many technical improvements and state-of-art optics. It is expected that in the coming months, there are going to be many more improvements within the robotic platforms and compatibility with diagnostic procedures, catheter-based therapy, and radiology as well as distant learning.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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