Review Article on Robotic Surgery

What happens while learning robotic lobectomy for lung cancer?

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Abstract: A surgeon needs to perform a sufficient number of procedures to achieve a level of proficiency. Learning curves demonstrate ongoing improvement in efficiency over the course of a surgeon's carrier. When the surgeon learns the procedure, this means that he has the ability to perform that procedure safely and effectively. The instruction of the da Vinci Surgical System (Initiative Surgical, Sunnyvale, CA, USA) provoked the need for preparing surgeons for complex robotic skills. As low as 5 repetitions are enough to achieve proficiency on basic robotic skills. Robotic-assisted thoracic surgery (RATS) has a steep learning curve compared to video-assisted thoracic surgery (VATS), and it was proposed that 15 to 20 operations are required to establish a learning curve for RATS anatomical pulmonary resections. Based on several studies, one can conclude that after learning, there is a tendency to toward shorter operative times, a decrease in conversion, morbidity and mortality rates, as well as an increase in the number of resected lymph nodes. Our clinical experience on 129 patients undergoing RATS anatomic pulmonary resections over a period of 5-year demonstrated that the learning curve could be established after 14th operation, and the acquired surgical skills and developing experience let surgeon to obtain shorter operative times, operate larger tumors with more advanced stages, have an increased the number of the dissected lymph nodes.

Keywords: Robotic-assisted thoracic surgery (RATS); lung cancer; learning curve; pulmonary resection

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Introduction

The evaluation of proficiency in specific types of operation is a complex and difficult task. It is quite known that if a person is engaged in a repetitive task, his performance improves over time (1). Learning curves for some procedures demonstrate ongoing improvement in efficiency over the course of a surgeon's carrier (2). Learning curve of the robotic-assisted thoracic surgery (RATS) anatomic pulmonary resections have been studied several times (3-7). Besides defining the learning curve, some of these studies briefly investigated the effects of learning on RATS lung cancer surgery.

The aim of this paper is to review the outcomes of learning curve in performing RATS anatomic pulmonary resections for primary lung cancer with regard to patient selection, perioperative events, and postoperative results, and add personal opinions based on our clinical results.

Specific descriptions about learning

A surgeon needs to perform a sufficient number of procedures to achieve a level of proficiency, which is characterized by terms "efficiency" and "consistency". Both terms are the reflections of the developing competence, which comes from performing a sufficient number of procedures independently. Progressing to proficiency necessitates substantial additional operative experience, and requires a qualitative leap in knowledge and performance (8).

A competent surgeon indicates that the surgeon has the ability to perform a procedure safely and effectively. Greater expertise shows that the surgeon has gained additional experience; he knows how to avoid common errors, and has resiliency in case of unexpected events during the operation. Compared to a "competent" surgeon, a "proficient" surgeon will demonstrate efficiency and consistency, in addition to safety and efficacy (9).

Definitions of the learning curve in RATS in general, and in RATS anatomic pulmonary resections for primary lung cancer

There has been an increase in the need for preparing surgeons for complex robotic skills with the instruction of the da Vinci Surgical System (Initiative Surgical, Sunnyvale, CA, USA). Special skills are required to perform robotic-assisted surgery, including EndoWrist instrument manipulation and clutching, 3D visualization of the surgical filed, and camera control; and special training helps to develop and deepen these skills (10). Currently, three robotic training platforms are available: the Robotic Surgical Simulator (Simulated Surgical Systems, Williamsville, NY, USA), the da Vinci Trainer (Mimic Technologies, Seattle, WA, USA), and the da Vinci Surgical Skills Simulator (dVSS, Intuitive Surgical) (11).

Walliczek *et al*. (11) performed a prospective training study using 40 novices who had no experience in endoscopic surgery, to test the effect of training frequency on the learning curve on the dVSS (Intuitive Surgical). Participants performed Match Board, Ring and Rail, and Needle Targeting exercises, with different frequencies over 4 weeks. The authors assumed that total frequency of repetitions of each exercise is crucial for improvement of technical performance. They concluded that five repetitions in a population of robotic novices seemed to be sufficient to achieve the proficiency level. One should remember that this study is based on basic robotic skills, and is not performed in livings (animals or humans).

Video-assisted thoracic surgery (VATS) lobectomy is another minimally invasive approach, and as the same as RATS, it necessitates a number of operation to become competent. Li *et al*. (9) demonstrated that between 100 and 200 cases are required to achieve efficiency, and consistency requires even more cases. Learning curve of VATS thymectomy is also studied. Toker *et al*. (1) used cumulative summation model to evaluate the learning curve for VATS thymectomy, and concluded that a thoracic surgeon could have a high success rate in VATS thymectomy after 60 operations.

It is a common proposal that RATS has a steep learning curve compared to VATS, and can be adopted rapidly by surgeons experienced in VATS (12-14). Jang *et al*. (12) concluded that the outcomes of RATS lobectomy in terms of operative times, intraoperative blood loss, and length of stay were similar to those with VATS lobectomy when the surgeon had an experience of 2 years in VATS lobectomy. Several authors proposed that 15 to 20 operations are required to establish a learning curve for RATS anatomical pulmonary resections (3-5), however, these suggestions have been made according to researchers' personal preferences.

Contrary to the abovementioned studies, two studies gave a specific description of the learning curve using statististical methods (6,7). Both authors constructed a scatter plot to evaluate the relationship of operative times with the extent of experience, and they defined the overall learning curve as the mean ± SD of the sum of the individual learning curves. On the basis of their use of this method, Meyer *et al*. (6) reported that the learning curve could be completed in 15 operations, whereas in our previous study we proposed that the completion of the RATS learning curve could be established after 14 operations (7).

In addition to a competent surgeon and a cumulative number of the cases, two factors also affect the learning curve of a surgeon. The first one is the selection of ideal candidates for surgery. As suggested by Gharagozloo *et al*. (4), patients with minimal comorbidities, a reasonable body habitus, better pulmonary reserves (FEV1 greater than 1 L), and appropriate disease characteristics, such as clinical T1a tumors improves learning. Administrating RATS to the patients with early-stage non-small cell lung cancer, no previous thoracotomy, no neoadjuvant therapy, a body mass index less than 40 kg/m^2, a lesion diameter less than 5 cm, no requirement for extended or sleeve resection are also other positive points to obtain better results and become competent (5,15).

The second factor is the presence of a dedicated team. The table-assistant must understand the steps of the operation and have manual dexterity necessary to rapidly intervene in case of an emergency situation. The operating surgeon ideally, should remain at the console throughout the operation, have a certain trust to the table surgeon to let him to tie sutures, fire staplers, and assist as needed (15). The anesthesia team must be experienced in the management of double-lumen airway, and prepared to conversion to open approach, if necessary (16). Nurses and scrub technicians should be experienced in the setup of the robot, patient positioning, and instrumentation (15).

Outcomes of learning in RATS anatomic pulmonary resections for primary lung cancer

As the level of proficiency and confidence increased, most authors reported a tendency to toward shorter operative times (4-6), although some others demonstrated similar results (15,17). Conversion rate also decreased with greater experience (5,17). Cao *et al*. (14) showed the importance performing more operations to develop consistency; they showed that lower conversion rates and shorter operating times mostly occurred in specialized center having more than 30 cases.

Velez-Cubian *et al*. (17) concluded that the greater experience had no negative effect on morbidity, but mortality appeared to improve with experience. Contrary to this, Meyer *et al*. (6) showed significant decrease in morbidity. Several authors also demonstrated significant decreases in terms of hospital stay with greater experience (4-6,17). In terms of lymph node dissection, Veronesi *et al*. (5) reported that there were no significant differences comparing early and experienced group of patients.

Clinical experiences in robotic thoracic surgery and outcomes of "learning"

RATS program using da Vinci Robotic System (Intuitive Surgical, Inc., Mountain View, CA, USA) was established at our institution in October 2011. From that date to December 2016, a total of 250 operations have been performed by a single surgeon (A.T.) for pulmonary and mediastinal pathologies. In our previous study, we demonstrated that RATS learning curve could be established after 14 operations (7). We investigated the effects of learning on patient selection, perioperative events, and postoperative results in patients undergoing anatomic pulmonary resection for primary lung cancer (n=129). The first 14 patients were selected as learning period (GI), and the following 115 patients as experienced period (GII).

Both groups were similar in terms of age, gender, lesion location, neoadjuvant treatment, comorbidity rates, and pulmonary reserves. As intraoperative parameters, there were similarities in the conversion to thoracotomy, blood transfusion, and tumor subgroups between the groups. Our study revealed that, with the growing experience the operative times (docking, console, and total) decreased ($P<0.05$), the rate of lobectomy increased (43% *vs*. 72%, $P=0.03$), larger tumors could be resected (23 *vs*. 29 mm, $P=0.04$), and the rate of patients undergoing resection due to non-T1a tumors increased (35% *vs*. 68%, $P=0.02$). There were also significant differences in terms of the dissected lymph nodes. Significantly more lymph nodes (overall, N1-level, and N2-level) were dissected in the GII group ($P<0.05$), though this increase did not significantly affect the upstaging in term of N-status. Finally, both groups were equal regarding to postoperative outcomes, such as length of hospital stay, morbidity and mortality rates.

In short, our clinical experience demonstrated that learning curve has no negative effect on conversion rate, need for blood transfusion, upstaging, or length of stay in RATS. However, the acquired surgical skills and developing experience let us to obtain shorter operative times, operate larger tumors with more advanced stages, have an increased the number of the dissected lymph nodes.

Conclusions

RATS has a steep learning curve compared to VATS, and it was proposed that 15 to 20 operations are required to establish a learning curve for RATS anatomical pulmonary resections. Our clinical experience on 129 patients undergoing RATS anatomic pulmonary resections over a period of 5-year demonstrated that the learning curve could be established after 14th operation. We concluded that learning curve has no negative effect on conversion rate, need for blood transfusion, upstaging, or length of stay in RATS. Our another conclusion was that the developing experience let surgeon to obtain shorter operative times, operate larger tumors with more advanced stages, have an increased the number of the dissected lymph nodes.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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