Robotic lobectomy: an essential addition to the minimally invasive armory

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Received: 17 July 2016; Accepted: 28 July 2016; Published: 09 August 2016.

doi: 10.21037/vats.2016.08.01

View this article at: http://dx.doi.org/10.21037/vats.2016.08.01

As the only robotic system approved by the United States Food and Drug Administration for lung surgery, the Da Vinci System (Intuitive Surgical, Sunnyvale, CA, USA) is gaining popularity worldwide as an important alternative to the conventional minimally invasive surgical approach of video-assisted thoracic surgery (VATS). The robotic system is considered a significant evolution in the development of surgical tools, allowing the surgeon to view the surgical site in three dimensions and perform the operation via a console located near the operating table. The endo-wrist instruments attached to the robotic arms provide a wide range of precision movements with greater dexterity. Moreover, the hand tremor of the surgeon can be filtered out by using a 6-Hz motion filter, which guarantees precise micro-movement around vital structures.

Many researchers believe that the robotic system will reduce the number of procedures needed to master a skill compared with traditional thoracoscopic surgery, especially for experienced VATS surgeons (1). By creating a regression trend-line and defining the learning curve as the change in slope corresponding to the beginning of the plateau, Meyer *et al.* (2) found that the learning curves for robotic assisted lobectomy were 15, 20, and 19 cases for operating time, mortality, and surgeon comfort, respectively. Subsequently, Veronesi *et al.* (3) reported the first study comparing muscle-sparing thoracotomy and robotic assisted lobectomy using propensity score matching. The conversion rate to thoracotomy was 13% with the robotic arm. The two groups had similar postoperative complications and numbers of lymph nodes resected (robotic, 17.5 *vs.* open, 17). The hospital stay was longer with the thoracotomy arm (6 *vs.* 4.5 days) after excluding the initial 18 cases that underwent robotic lobectomy, whereas the robotic (n=36) operating time was approximately 60 minutes longer. The authors also note that the operation duration decreased by 43 minutes after the initial stage, indicating that the surgeons' proficiency led to better performance with the robotic surgery.

Nevertheless, clinicians may be more interested in the technical aspects of the two minimally invasive approaches. The recent *Annals of Thoracic Surgery* article by Louie *et al.* (4) compares VATS and robotic lobectomy for stage I and II lung cancer using the Society of Thoracic Surgeons General Thoracic Surgery Database. The study included 1,220 robotic lobectomies performed from 2009 to 2013 and these patients had more comorbidities (e.g., coronary heart disease, hypertension) compared with the VATS group (n=12,378). Operative measurements were similar, except for the significantly longer operating times needed for robotic lobectomy (186 *vs.* 173 minutes). The postoperative complications and 30-day mortality were equivalent in the two modalities, and concurred with the rate of nodal upstaging defined as clinical N0 to pathological N1. Interestingly, the median postoperative length of hospital stay was 4 days for each group, although a lower proportion of the cases undergoing VATS lobectomy had hospital stays of less than 4 days (39% *vs.* 48%). One possible explanation, as stated by the authors, is that centers with high volumes of robotic surgery would have mature protocols regarding early discharge.

Despite the growing number of studies showing perioperative measurements similar to those of VATS, one of the major concerns preventing widespread adoption of robotic-assisted lobectomy is the lack of adequate long-term survival data. The first large cohort study was that of

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Park *et al.* (5), in which 325 robotic lobectomies achieved a 5-year overall survival (OS) up to 91% for stage IA, and 88% for stage IB, with a median follow-up of 27 months. In a recent study, the same group found that the results of robotic, VATS, and open lobectomy were equivalent from an oncologic perspective (6). The median follow-up time was 52.7 months for all participants and 39.8 months for the robotic approach. The 5-year OS was 77.6%, 73.5%, and 77.9% (P>0.05) for the robotic (n=172), VATS (n=141), and thoracotomy (n=157) patients, respectively. Interestingly, slightly longer disease-free survival (DFS) was observed with the robotic arm (72.7%), as compared with 65.5% and 69.0% in the VATS and open groups, respectively (P=0.047). However, the surgical approach failed to demonstrate a significant association with a better OS and DFS; therefore, the minimally invasive approaches achieved similar survival to thoracotomy in stage I lung cancer following lobectomy. In another study (7), it was also concluded that robotic and VATS approaches had similar R0 resection rates and postoperative survival in comparison with thoracotomy for treating locally advanced lung tumors, although the strength of this result was limited as only 17 robotic procedures were enrolled.

Robotic lung surgery has the advantage of visualizing and dissecting lymph nodes around delicate vessels, resulting in the removal of more lymph nodes stations (6). However, for those who play "devil's advocate" regarding robotic lobectomy, the absence of haptic/tactile feedback raises concerns regarding hemorrhage control, especially when the assistant rather than the surgeon passes the stapler across the pulmonary vessels. The latter for example has been addressed by the industry by providing their robot's own surgeon operated staplers. Nevertheless, clear communication between the surgeon and assistant is vital to avoid iatrogenic accidents, and it has been suggested that a rolled-up sponge be kept ready while working around vascular structures for better control of bleeding (8). Another potential drawback of robotic lobectomy lies in the inability to reduce the working ports needed for the procedure. Although Cerfolio *et al.* (9) has proved the feasibility of positioning four robotic arms along a single rib space, the recent prevalence of single-port VATS (10) has the theoretical merits of minimizing the damage to the intercostal nerves and further reducing the surgical access trauma. Moreover, recent advances in the scope system (11), wrist-like rotational device (e.g., FlexDex; FlexDex, Brighton, MI, USA) (12), and integrated flexible uniportal surgical system (e.g., SPIDER surgical system; TransEnterix, Durham, NC, USA) (13) have contributed to closing the ergonomic gap between VATS and robotic lobectomy. Furthermore, the rapid development of single port robotic surgery may finally provide the answer to single port VATS in terms of single incision access trauma (14).

Cost-efficiency remains another concern that hinders the widespread use of robotic lobectomy. The first findings came from a study conducted in 2008, in which Park and Flores (15) demonstrated that the average cost of a robotic lobectomy was less than that of a thoracotomy due to the shortened hospital stay, but it was still greater than that of VATS. Considering the high purchase and maintenance costs for the robot, and the slightly longer operating time, a robotic lobectomy costs an additional $3,000 to $5,000 per case when compared with VATS alone (16). However, many researchers agree that with the increased experience of the surgical team and modifications of the techniques, the cost of robotic surgery will be decrease gradually.

Despite efforts to promote minimally invasive surgery in recent decades, a thoracotomy was still used in 56.5% of the lung resections performed in the United States in 2010 (17). The camera tremor and reduced dexterity of instrumentation may lower the surgeon's willingness to use the VATS approach. In terms of robotics, Louie *et al.* (4) found that the majority of robotic cases were performed by only 22 groups, and one third of them were done at four centers. Since the current evidence indicates that the robotic approach is equivalent, or at least not inferior, to VATS lobectomy, one may foresee that the true value of robotic surgery is in increasing the proportion of surgeons that use a minimally invasive approach.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the editorial office, *Video-Assisted Thoracic Surgery*. The article did not undergo external peer review.

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/vats.2016.08.01). CSHN serves as an unpaid editorial board member of *Video-Assisted Thoracic Surgery* from Jun 2016 to May 2018. CSHN reports Sponsorship for conference from Intuitive Surgical. ZRZ has no conflicts of interest to declare.

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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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doi: 10.21037/vats.2016.08.01
Cite this article as: Zhao ZR, Ng CS. Robotic lobectomy: an essential addition to the minimally invasive armory. Video-assist Thorac Surg 2016;1:4.