Robot-Assisted Lobectomy for Non-Small Cell Lung Cancer in China: Initial Experience and Techniques

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ABSTRACT **Objective** To summarize our initial experience in robot-assisted thoracoscopic lobectomy.

Methods Five patients underwent lobectomy using da Vinci S HD Surgical System (Intuitive Surgical, Sunnyvale, California). During the operation, we respectively made four ports over chest wall for positioning robotic endoscope, left and right robotic arms and auxiliary instruments without retracting ribs. The procedure followed sequential anatomy as complete video-assisted thoracoscopic surgery lobectomy did, and lymph node dissection followed international standard.

Results All patients successfully underwent complete robot-assisted thoracoscopic lobectomy. Neither additional incisions nor emergent conversion to a thoracotomy happened. Frozen dissection during lobectomy showed non-small-cell lung cancer in four patients, who afterwards underwent systemic lymph node dissection, while the case left was with tuberculoma and didn't undergo lymph node dissection. Recurrent air leak occurred in one case, so chest tube was kept for drainage, and one week later, the patient was extubated due to improvement. All other patients recovered well postoperatively without obvious postoperative complications.

Conclusion Robot-assisted thoracoscopic surgery is feasible with good operability, clear visual field, reliable action and its supriority of trouble free; exquisite operative skills are required to ensure a stable and safe operation; robot-assisted surgery is efficiency and patients recover well postoperatively.

KeyWords: Robotics; thoracoscopy; minimally invasive; lobectomy

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Video-assisted thoracic lobectomy is currently effective for treating early stage non-small cell lung cancer. It not only causes less bleeding, surgery-related dysfunction and pain, but also supplies shorter hospitalization than thoracotomy. As robot technology entered thoracic surgery field, robotic-assisted lobectomy became possible. On May 11, 2009, Shanghai Lung Tumor Clinical Medical Center introduced robotic-assisted thoracoscopic surgery, including lobectomy, mediastinal tumorectomy, etc. There had been five lobectomy cases, with reports as follows:

Materials and methods

Clinical data

Five patients, three men and two women, were found with solitary pulmonary nodule through health examination. Distribution of lesions was right upper lobe 1, left upper lobe 2, right lower lobe 1 and right middle lobe 1. Preoperative evaluation included electrocardiogram, pulmonary function testing, abdomen B-ultrasound, chest computed tomographic scans, head magnetic resonance imaging and whole body bone scan. No abnormity was found. Functional testing showed operative tolerance. No patients had received thoracic surgery before and none of them was with a malignant tumor history.

Operative technique

Preoperative preparation: scrub nurse prepared all instruments for robot-assisted surgery and dressed robotic arms in sterile garments.

Anaesthesia: general anaesthesia with double lumen tracheal intubation. Single-lung ventilation was strictly established associated with catheterization via the right internal jugular vein.

Position: Patient was placed in a lateral decubitus position at an angle of 90-degree in a Jackknife position with hip bending towards the uninjured side to avoid hindrance to thoracoscopic operation.

Incisions: Four chest wall incisions, including one observation port, two ports for manipulating robotic arms and one auxiliary

Supporting Foundations: None

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port, were made without ribs retraction. The ports were respectively 1cm, 1cm, 2~3cm and 1 cm in length, with the longer port for retrieving specimen. During upper and middle lobectomy, observation port for inserting robotic endoscope was placed in the eighth intercostal space in the midaxillary line towards abdomen. Auxiliary port was placed in the ninth or tenth intercostal space in the posterior axillary line for insertion of assisting instruments (eg. inserting forceps for pulmonary tissue extraction to explore hilum of lung) or automatic stapler. The left robotic arm was placed through the 1cm incision in the seventh intercostal space behind the posterior axillary line. The right robotic arm was placed through the 2~3cm incision in the anterior fifth intercostal space of the anterior axillary line (Figure 1).

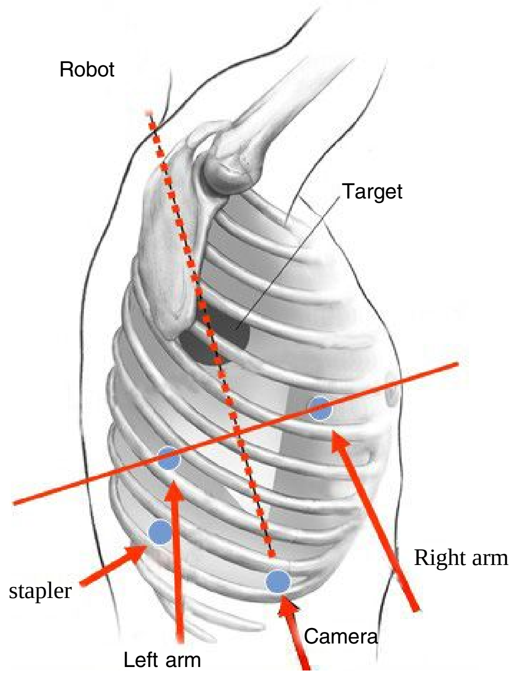

Fig.1 Incisions of robot-assisted lobectomy for non-small cell lung cancer

Position of the robot: After incisions were made, circulating nurse moved robot over the back of patient, making the line between robot centre and chest observation port and the line of patient inclined to one another at an angle of 90 (that is to say, robot was located on the extension line of hilum centre and observation port). Robotic endoscope and robotic arms were introduced to chest cavity with their positions adjusted for manipulation. Robotic instruments included separating forceps, electrotome, scissors, etc, and these instruments were adjusted according to individual necessities.

Anatomical sequence: Surgeon sat at the robotic operating table, while the assistant stood on the operation table to assist in exposing and to manipulate stapler. We followed the complete thoracoscopic lobectomy sequential anatomy adopted by McKenna et al (2), dissected corresponding structures of hilum of lung first, and pulmonary fissure was performed in the final step. At the same time, this sequence was adjusted according to individual anatomic structure. Generally speaking, forceps were used through auxiliary incision to assist in exploring structure of hilum of lung; endoscopic stapler was used for stapling of bronchi, branches of pulmonary veins, pulmonary arties and pulmonary fissure. For ligating and clipping pulmonary arties, Weck Hem-o-lok clips were applied as well. The specimen was retrieved through the longer chest wall port using a specimen bag.

Dissection of lymph nodes: For those suspected to be with non-small-cell lung cancer by frozen dissection, lymph nodes dissection was performed at least according to the IASLC 2005 nodal map, managing surrounding tissues skeletonized.

Hemostasis: After dissection of lymph nodes, we cautiously stopped bleeding. Our experience is after general robotic hemostasis, remove robotic arms to manipulate robotic endoscope manually, and stop bleeding with endoscopic instruments such as Ar-He knife and titanium clips. Hemorrhage over chest wall incision should be noted. After operation, respectively introduce one tube over upper and lower chest for drainage and then close the incisions layer by layer.

Results

No complication was noted in all patients. Patients were with stable vital signs during the whole operation. Mean operative time was 192 minutes and mean intraoperative blood loss was 62ml. No blood transfusion was performed. All patients were successfully extubated in recovery room after operation. Postoperatively, all patients felt pain released and they were up and around on the 2nd postoperative day. Mean drainage time was 6.7 days. Recurrent air leak appeared in 1 case, and after drainage for one week, this case was extubated. Other patients were in stable condition without complications. According to postoperative routine follow up, all patients were with stable vital signs. Lesion nature: non-small-cell lung cancer in 4 cases and tuberculoma in 1 case. Pathologic staging: All of the non-small-cell lung cancer cases were in stage IA or IB.

Discussion

At present, robot-assisted lobectomy is one of the most advanced minimally invasive thoracic surgeries merely conducted in few medical centers in Europe, USA, Japan, Hongkong and Taiwan of China. The da Vinci Surgical Robotic System (Intuitive Surgical, Sunnyvale, California), a FDA (U.S. Food and Drug Administration) authenticated robotic system, is made up of three parts: 1. Surgeon console; 2. "Praying mantis-like" robotic arms chassis, which includes robot optical system and three robotic arms; 3. Electronic communications tower system connecting main console and robotic arms (3). The robotic system our department applied is the newest da Vinci Surgical System modified from the former da Vinvi systems. Auxiliary instruments of da Vinci S Surgical System for thoracoscopic surgery are conveniently attached on collapsible robotic arms, which not only reduces robotic arm external collision, but also extends the robot functional range. Moreover, da Vinci S Surgical System is an ergonomic operating system, it provides a high-definition monitor (4).

Comparing with conventional video-assisted thoracoscopic surgeries, robot-assisted thoracoscopic surgery owns a three-dimensional high-definition dynamic visualization, permitting a clearer and more intuitional vision for surgeons; besides, robotics retains superiorities such as anti-shake arms, fixed endoscope, wide range of motion, high mobility of instruments, which make robot-assisted surgery to be finer. However, one of the significant shortcomings is the lack of haptic feedback (5).

Doctors' rich experience in thoracotomy and complete video-assisted thoracoscopic lobectomy is essential to robot-assisted lobectomy. Though visualization supplied by robotics is superior, the surgeon has to "feel" through visual sense due to lack of haptic feedback, which brings challenge to the surgeon, so that surgeons are required to be skilled in thoracoscopic anatomy. Besides, since preoperative debugging and other procedures are rather elaborate, it's advised to invite correlated technicians from the robot company to assist the operation in the beginning.

Robotic surgery is different from other surgeries, so prediction of a longer operative time is required. Either disharmonious positions between personnel and robot, or improper ports, or inappropriate patient position might lead to a long and frustrating operation. For instance, the first robot-assisted lobectomy our department undertaken, also the first case in China, took 6.5 hours in total. Patients selected should be in good fitness neither with a thoracic surgery history nor with evidence indicating a possibility of pleural adhesion. The tumor should be of peripheral type with 2~3cm in diameter. As the robot-assisted lobectomy cases increase and operation group are better organized, operation will be performed quicker.

Since robot-assisted lobectomy is mainly performed by a single surgeon, theoretically speaking, dependence on the assistant is weakened. However, assistant is still an essential factor to an operation. In video-assisted thoracoscopic lobectomy, pulmonary tissue traction and exposure, the manipulation of automatic stapler are conducted by assistant under the guidance of surgeon; however, during a robot-assisted lobectomy, surgeon stands off the operation table, emergent actions such as establishing additional exposure, stapler application, fast and accurate hemostasis are taken by assistant without surgeon's instruction, which requires the assistant experienced in minimally invasive surgery and being able to conduct thoracotomy. In addition, other assistants are also essential. Skilled instrument nurse and circulating nurse can predict what instruments might be used, and they are experienced in installing and replacing instruments, which can save operative time. In case of accidents, instruments for routine thoracotomy are prepared during operation, and so it is with gauze attached on forceps. A well-organized group benefits an operation to be smoothly undertaken.

Lymph node dissection is an essential factor of surgery for lung cancer. Owning to robotics' better visualization and fine maneuver, mediastinal, aortic-pulmonary arterial, hilar, subcarinal and paratracheal nodal dissection by robotics is safer and more thorough. Though existence of aortic arch brings difficulty to left paratracheal and parabronchial nodal dissection, flexibility of robotics makes it possible to be completed.

According to literature, there are 3~4 incisions in most complete video-assisted thoracoscopic surgery lobectomies, among these incisions, one is for endoscope, the other 2~3 are primary and auxiliary ports. However, since ends of robotic surgical instruments are rather fine, relatively "extensive" common thoracoscopic pulmonary forceps are applied for traction of pulmonary tissues. Moreover, aspirator for aspirating smoke and blood is important as well. So far, stapling of vessels, bronchi and so on still relies on automatic stapler but not corresponding robotic instruments. According to literature, additional 1~3 auxiliary ports are required for assisting the operation besides the observation port and ports for robotic left and right arms. Our initial experience is to establish an auxiliary port behind observation port for insertion of pulmonary forceps, automatic stapler and aspirator, etc. Meanwhile, either aspirator or hem-o-lok clip can be introduced together with robotic right arm through the bigger incision. Left and right arm ports should be more cautiously and exactly positioned than video-assisted thoracoscopic surgery because the distance between the two ports is required to be long enough to avoid robotic arms collision.

In conclusion, our experience has verified that lobectomy and systemic lymph node dissection can be accomplished through robot-assisted thoracoscopic surgery, which treats early stage non-small cell lung cancer normatively and releases patient's suffering maximally. Though robotics is developing, lots of its techniques are still not well developed. As time passes by and technology develops, robotic performance would be further improved after full acknowledgement of robotic performance and proficient cooperation between operator and robots. Robot-assisted minimally invasive thoracic surgery is leading the way of thoracic surgery.

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