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Robotic Surgery for Lung Cancer

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1. Introduction

Lung cancer is the leading cause of cancer related deaths in developed countries.

Although the best strategy for reducing lung cancer mortality is tobacco cessation, patients harboring lung cancer need specific treatment.

Surgical treatment is the best choice for localized early tumors, without local or distant malignant spread. Pulmonary lobectomy can be performed by open thoracotomy or by minimally invasive techniques as video-assisted thoracic (VATS) or robotic assisted surgery. VATS lobectomy is a safe, efficient, well accepted and widespread technique among thoracic surgeons, but standard VATS forceps have rigid extremities and do not mimics wrist angulated movements. Furthermore, traditional VATS video-imaging is a simple two dimensional image.

Robotic surgery is performed with telemanipulated flexible effector instruments; some of them can give surgeons tactile feedback; and under three-dimensional (3-D) video-imaging. Hilar pulmonary dissection for lung cancer can be performed by robotic devices in an efficient and safe way. Scientifically speaking, oncological results need further studies including longer postoperative follow-up to allow comparisons between VATS and robotic techniques; but similarities between these approaches regarding the extension of resected structures as pulmonary parenchyma and lymph nodes suggest that robotic surgery is going to be proved as efficient as VATS for lung cancer.

Learning curve can be one of the biases when comparing results between traditional or VATS lobectomy to robotic surgery.

Costs have been implied as one of the major difficulties in becoming robotic lobectomy more used among thoracic surgeons, but some authors have already studied this issue and concluded that if it is considered the total average costs associated with the resultant hospital stay, "the cost of robotic assistance for VATS is still less than thoracotomy, but greater than VATS alone".

Our nowadays restrict knowledge about robotic lobectomy for lung cancer do not allow us to conclude that it is better, similar or even worse than VATS lobectomy. But we believe that in few years, their advantages are going to be proved, because it allies advantages of both open (precise articulated movements) and VATS (minimally invasive technique);

Source: Robot Surgery, Book edited by: Seung Hyuk Baik,
ISBN 978-953-7619-77-0, pp. 172, January 2010, INTECH, Croatia, downloaded from SCIYO.COM

additionally it fill all the requirements to take part in the modern concept of Fast Track Rehabilitation, also called Enhanced Recovery After Surgery (ERAS).

1.1 Lung cancer surgical treatment

Lung cancer is the leading cause of malignance related mortality in western countries.

They can be divided in two major groups: the small cell and the non small cell lung cancer (NSCLC). In this chapter we are not going to discuss small cell lung cancer because it is considered as a priori spread tumor when diagnosed, and its treatment of choice is based essentially in the systemic therapeutic approaches as chemotherapy, allied or not to radiotherapy.

Although the best therapeutic approach for NSCLC is a multi modality therapy, including radio and chemotherapy, surgical removal remains the cornerstone for early stage carcinomas. The surgery of choice for these patients is the entire lung lobe resection with ipsilateral hilar and mediastinal lymph node dissection.

Lung cancer resection can be performed using several surgical techniques. Location, number and extension of surgical incisions, total or partial muscle sparring techniques, video assisted thoracic surgery (VATS) and the use of robotic devices for camera holding or fine vascular and lymphatic dissections are some of the variables considered when planning lung cancer resection.

1.2 Minimally invasive surgeries

Surgical operations were traditionally performed through open incisions. Following the development of operative and anesthesia techniques and surgical instruments, surgeons has been becoming used in performing minimally invasive procedures. In thoracic surgery, minimally invasive techniques play an important role.

The first phase of minimally invasive techniques in thoracic surgery was based in minithoracotomy, followed by the second phase based in the use of port access instruments Nowadays minimally invasive thoracic surgeries are based on muscle sparring incisions and VATS with or without robotic assistance.

1.3 Opened versus video assisted lung cancer resection

It is impossible to understand robotic assisted surgery for lung cancer without previously knowing about VATS.

Thoracic surgery has being incorporating VATS devices and techniques progressively in routine dissections since the early 1990s (Lewis RJ; 1993; Kirby TJ and Rice TW; 1993; Walker WS et al; 1993 and McKenna RJ; 1994).

Nowadays, VATS can be considered as an indispensable tool in thoracic surgery. It has been proved that well trained surgical teams can perform VATS resections in a manner as safe and efficient as traditional open surgeries (Gossot, 2008). Some years ago, there was a deep discussion about costs, because some surgeons believed that VATS would be an expensive choice for lung cancer resection. Nowadays, if the whole cost of surgical procedure and hospitalization is considered, VATS has been proved as a cost-effective procedure when compared to traditional opened lung cancer lobectomy.

Early stage NSCLC can be safely and efficiently resected by VATS. Both pulmonary lobe and regional lymph nodes can be dissected and resected by VATS following standard oncological requirements.

Despite some obvious advantages of VATS over open surgery, some movements of surgeon fingers, hands and wrists can not be reproduced by traditional VATS forceps extremities. These instruments have limited maneuverability. Another disadvantage is that tridimensional visualization of operative bed is not possible when using traditional VATS image devices; furthermore these cameras must have a human holder, thus having an unsteady platform.

Recovering fine movements of human fingers, hands and wrist and three-dimensional visualization are some of the advantages of allying robotic devices to VATS instruments. One can ask why not using these robotic devices as being mere traditional VATS instruments in routine VATS operations. The answer can be that surgeon hands movements using traditional VATS instruments do not require a console as a stable platform, nor traditional VATS monitor images devices do so. But robotic dissection instruments and image devices can not be maneuvered in the same way as done in traditional VATS.

In robotic assisted vascular and lymph nodal fine dissection, surgeon hands must be kept over a stable console when manipulating robotic instruments, furthermore binocular visualization devices can be easily installed in this stable platform. These binocular image devices could not be installed in a comfortable way in front of both surgeon eyes during traditional VATS phase, because this traditional VATS dissection is performed besides the patient, away from the console. In this case, binocular devices should be set on the surgeon head, a not very comfortable option.

1.4 Robot assisted lung cancer resection definition

What is robotic surgery?

What kind of operation can be considered as robotic surgery?

Can we perform a “pure” robotic lung cancer resection disposing only of our nowadays available technology?

In fact, there are different robotic devices that can be used, each one, in several ways in thoracic surgery. But traditionally, not all these robotic assisted uses are classified by thoracic surgeons as “robotic surgeries”.

In order to exemplify some of the most used robotic devices in thoracic surgery, we can cite the Automated Endoscopic System for Optimal Positioning (AESOP) robotic system and ZEUS of Computer Motion Inc, Goleta, California; and da-Vinci Surgical System of Intuitive Surgical, Sunnyvale, California.

1.5 Camera holding was one of the first and simple tasks of robots in VATS

The simple task consisting in merely hold a VATS camera by robotic arms was one of the first uses of robotic devices by thoracic surgeons. These devices were usually surgeon voice controlled and could target VATS camera to the dissected surgical bed. But the effective dissection was performed using only traditional VATS instruments. These first experiences in the robotic field can not be considered as real “robotic surgeries”. This term has been traditionally applied only in cases were robotic devices are used to both hold camera and dissect anatomic structures.

1.6 Robotic fine dissection in VATS

Robotic dissection has been applied in cardiac surgery since the early 2000s. In 2001, Mohr and colleagues published their experience with 148 coronary artery bypass grafting performed by robotic surgery.

But even nowadays, in the field of general thoracic surgery, a pure robotic lung cancer resection is not possible. Robotic assistance is only one phase of two-phase robotic assisted video assisted thoracic surgery. Robotic assistance is the first phase of fine vascular and lymph nodal dissection, without vascular or bronchial ligation and division.

The second phase is still indispensable, because it comprise all the vascular and bronchial ligature and division. Although small vessels can be coagulated by robotic devices, usual vascular and bronchial ligatures for lung cancer resection still require instruments available in the traditional VATS arsenal, but not yet developed for pure robotic uses. One of the examples is the use of traditional VATS mechanical staplers for arterial, venous and bronchial suture and section.

For these reasons we will define robotic surgery for lung cancer as those two-phase procedures, allying the initial robotic assisted vascular and lymphatic fine dissection followed by traditional VATS ligature, division, resection and specimen removal: the robotic assisted VATS lobectomy. Some authors use the term RATS for robotic assisted thoracic surgery.

1.7 Specific anatomic features of thoracic cavity for VATS/RATS

Before talking about robotic surgery for lung cancer, it would be interesting to describe in a few words why video assisted surgical operations in thoracic cavity have some advantages over abdominal video assisted procedures. It can explain why modern thoracic surgery is almost a synonymous of VATS procedures.

Some disadvantages of traditional VATS are also discussed, but it is briefly discussed as how some of them can be resolved or minimized by robotic solutions.

Special characteristics of thoracic cavity compared to abdominal one for robotic/VATS-surgery are the following:

1. One anatomical advantage thoracic cavity for video assisted surgery is that this cavity, differently of abdominal one, does not require gas insufflations in order to achieve visceral visualization. Lung parenchyma is an elastic structure and collapses spontaneously when chest wall is opened resulting in an induced pneumothorax. It is known that some patients with pneumopathies can not be submitted to the CO₂ body cavity insufflation.
2. Another advantage is that collapsed lung remains almost immobile compared to intestinal segments that slide slowly, but continuously. Visceral contact to camera lens became them dirty and difficult visualization, requiring stopping dissection followed by some maneuvers in order to clean leans; and only after these procedures, lens are ready to allow the surgical team to continue operating in the video assisted operative field.
3. Mediastinal movements secondary to contra lateral pulmonary ventilation follow a stereotyped and predictable rhythm, allowing surgeon to avoid unnecessary contacts between lens camera and mediastinal structures. Some robotic devices can subtract of surgeon visualization some undesirable movements as hands tremor, due to robotic software capacity to filter these undesirable movements; based in this concept, we believe that in the future even these repeated ventilation predictable movements will be subtracted by image robotic devices.
4. One clear disadvantage of thoracic cavity operations is that chest wall is composed by muscles, cartilages and ribs, being these two last structures rigid tissues. Traditional VATS effector instruments have limited manoeuvrability due to the rigid shaft axis

fixed to the chest wall by the entry trocar, moreover they should be manipulated between the upper and lower ribs in narrow intercostals spaces. In conclusion, traditional VATS instruments can not recovery fine human finger, hands and wrist movements in the operative field. This disadvantage can be resolved by robotic flexible instruments, which have seven degrees of freedom in the instrument wrist allied to axial freedom of movements. It allows fine vascular and lymph nodal dissection, as will be discussed later.

5. Another disadvantage of thoracic cavity is related to vascular dissections. The pulmonary hilum is composed by structures that can be distant some centimeters one from another, differently of some compact hila, as the renal hilum for example. In thoracic cavity, endoscopic vascular ligature and division of each individual hilum structure can not be performed as an in block ligature. It means that several individual ligature and division must be performed, requiring a number of endoscopic mechanical stapler charges. In addition, for each one of these vascular and bronchial components, endoscopic staplers must be placed in a special and different angle. Nowadays robotic devices can not resolve this anatomical requirement.
6. Another relative advantage of thoracic cavity for video assistance in surgical procedures is that anatomical lung segmentation follows a stereotyped distribution. Chest tomography can determine the exact position of a lung cancer, allowing its endoscopic removal without the need of tactile exploration in order to find the correct tumor placement. In abdominal video operations, intestinal tumors may be firstly found along the probable visceral segment, which some times means some centimeters of tactile exploration.

1.8 Robotic assisted VATS

As discussed above, nowadays, robotic devices still must be allied to VATS instruments in lung cancer resection; no "pure" robotic lobectomy has been described, mainly due nowadays available robotic instruments features that do not permit large vessel coagulation. Despite this limitation, manual dexterity and visualization provided by robotic devices represent some advantages over pure traditional VATS.

Robotic assistance is applied mainly to hilar and mediastinal lymph nodes and vascular (pulmonary artery and vein) fine dissection. Vascular individual dissection of arterial and venous pulmonary branches is the standard initial phase of lung cancer resection surgery, despite of open, VATS or robotic assisted VATS technique.

Although bronchial dissection is not usually performed with robotic instruments, Ishikawa and colleagues (Ishikawa et al, 2006) performed a robotic bronchial dissection, section and end-to-end anastomosis during a experimental robot-assisted VATS right upper lobectomy followed by bronchoplastie in a cadaver in 2006.

Pure robotic lung cancer lobectomy is not yet possible. Even considering only surgical groups with large experience in the use of robotic devices for lung cancer, all of them describe its use only in the first phase of fine dissection of lymphatic and vascular pulmonary structures. As an example, in 2009, Farid Gharagozloo et cols described their large experience with 100 consecutive cases of robot-assisted lobectomy for early-stage lung cancer resection. In 2008, the group of Dr Bernard J. Park, Raja M. Flores and Valerie W. Rusch described their initial experience with 34 robotic assisted VATS lobectomy, and also consider robotic dissection as only one of the two-phase lobectomy.

These groups reported some advantages and disadvantages of robotic assistance in VATS lobectomy.

1.9 Costs comparison between opened, VATS and robotic assisted VATS

One of the most impeditive reasons for not using robotic systems in lung cancer resection is both the associated cost for incorporating this new technology and the specific cost of instruments that may be used in each surgery.

In 2008, Park BJ and Flores RM (Park BJ a& Flores RM; 2008) compared the financial impact of VATS and robotic assisted VATS for lobectomy to those of traditional open thoracotomy.

Park and Flores concluded that although it was confirmed the hypothesis that pure-VATS is less expensive than robotic assisted VATS, robotic assisted VATS had a smaller financial impact in the overall surgical treatment and hospitalization costs than the traditional open thoracotomy.

Authors explain that pure VATS has an increased cost at the first hospital day, but considering the overall hospitalization, it is still less costly than traditional opened thoracotomy, in contrary of some surgeons believed.

1.10 Advantages of robotic assistance

In a few lines we cite some general advantages of robotic assistance for any type of video surgery. These advantages were also observed in lung cancer resection:

- Three-dimensional, stereoscopic binocular video-imaging is one the advantages over traditional VATS images, which are two-dimensionally displayed in the monitor. Da Vinci Robotic System comprises a 3-D scope with 3-chip cameras allowing surgeon a depth perception and optical resolution.
- Magnified video-imaging up to ten times the actual size. This is one advantage over not video assisted procedures, considering that imaging magnification principles can be applied even in non robotic video devices. It is interesting to discuss that in some lung cancer lobectomy steps, it is important having a panoramic vision of intra thoracic structures. Thus, video devices must have the capacity of affording surgeons both magnified images for fine dissection and panoramic vision of whole thoracic cavity.
- Stable robotic camera-holders are one of the advantages of using robotic platform to support video devices. The scope is held by the central four degree of freedom manipulator. We must consider two different points: the skills of human hands compared to the robotic arms in holding the camera and acquiring the best image of operative bed; and the second point that is the requirement of a human being beside the patient to hold the camera. It is well known that well trained humans can optimally perform camera holding and acquisition of an adequate image for surgeon. But the point is that a robotic camera hold can liberate this assistant to perform other tasks, moreover it is important when considering the voluminous robotic devices that are present besides the patient during robotic phase of lung cancer operation.
- Telemanipulated flexible effector instruments: these nowadays available robotic instruments have facilities that represent a recovery of the human movement's degrees of freedom, which were lost during the pure-VATS era. More than a mere recovery of human movements, these robotic instruments provide greater range of motion than those possible for human hands. They have seven degrees of freedom. Three degrees of freedom are conferred by the robotic arm that allow pitch, yaw and insertion

movements; four additional degrees of freedom are conferred by the mechanical wrist located in the interior of thoracic cavity, allowing internal pitch, internal yaw, rotation and grip.

- Downscaling of surgeon movements: fine dissection of pulmonary artery branches, veins and lymphatic structures is facilitated by downscaling. Robotic system is a transducer of surgeon movements in more fine ones in the instruments extremities.
- Indexing is another advantage of robotic systems over the traditional VATS instruments, and will be discussed later.
- Tremor filter: robotic system software is able to filter surgeon hands tremor due to a transducer that are able to reproduce only the desirable movements in the operative field.

1.11 Disadvantages of robotic assistance

- The learning curve has been cited by several authors as a disadvantage of performing robotic assisted VATS. We disagree, because is a characteristic not only applicable to robotic surgery, but to all the new incorporated technologies, including traditional VATS. Melfi and colleagues (Melfi et al, 2002) reported that they believe that the learning curve was relatively short in their experience with robotic assisted VATS, since the surgeons had a solid background in thoracoscopic surgery.
- Costs were already discussed above.
- Large volume of nowadays hardware is one of the disadvantages of robotic assistance for VATS lobectomy. This is a characteristic that requires surgeon team adaptation, because these robotic components limit the free access to the patient by the surgical assistant, usually used performing lobectomy with less voluminous VATS devices (Loulmet et cols, 1999). As discussed later, these components of robotic systems tend to have a decrease in their volume.
- Collision of robotic arms is one of the disadvantages of robotic assistance. But this trouble can be minimized with the optimal placement of port access. Furthermore, in the future, robotic hardware tends to be miniaturized.
- Some authors believe that one of the disadvantages of robotic assisted VATS lobectomy is that two VATS trained surgeons are required in the operative room. Although it is a irrefutable argument, we believe that even for traditional VATS lobectomy it is a prudent measure having two trained thoracic surgeons, always when possible.
- Tactile feedback systems are only in their early development phase, but some surgeons believe that this disadvantage can be minimized with learning curve progression of the surgical team.
- Dissection of lung parenchyma with the nowadays available fine robotic forceps can result in lung tears and bleeding.

2. Technical features

2.1 Robotic assisted video assisted indication

Nowadays, robotic assistance for VATS lobectomy is only indicated for early stage NSCLC. Some services indicate RATS/VATS only for IA stage, other extend this indication for IB or IIA/IIB stage. These stages include tumors classified as T1 or T2 and N0 or N1.

The most large series of robotic assisted VATS lobectomy for lung cancer was reported by Farid Gharagozloo and his colleagues; they used the following inclusion and exclusion criteria in their experience of 100 consecutive cases:

- Inclusion criteria: clinical stage I and II lung cancer (T1 or T2N0; and T1 or T2N1), predicted ability to achieve resection by lobectomy, and the physiologic state of the patient.
- Exclusion criteria: chest wall invasion, endobronchial tumors visible at bronchoscopy, a central tumor, and induction therapy.

Melfi and colleagues (Melfi et al, 2002) suggest five inclusion criteria for robotic assisted VATS lung cancer resection:

1. Lesions with a longer diameter less than five centimeters
2. Clinical stage I status for primary lung carcinomas
3. Absence of chest wall involvement
4. Absence of pleural symphysis and
5. Complete or near complete interlobar fissures.

There is no reference in the literature of robotic assistance neither for T3/T4 nor for N2 stages.

2.2 The choose of the robotic system

Considering only robotic assisted VATS lobectomy, it means excluding the use of robotic devices only as mere camera holders, available articles describe experience only with the use of da-Vinci Surgical System.

2.3 Da Vinci robotic system (Intuitive Surgical, Mountain View, CA)

We describe the Da Vinci robotic system as an example of robotic system already used for lung cancer robotic assisted VATS.

Da vinci roboti system is an assembly of two groups of devices. The first one is the surgeon's viewing and control master console; the second one is the surgical arm cart were robotic instruments and camera are supported and moved.

- The control console: during the first phase of robotic assisted VATS lobectomy, the surgeon control robotic arms and camera from the console, where one surgeon sits comfortably with both hands supported over a stable platform. The surgeon eyes must be accommodated in front of the visualization eyepieces.
- Console robotic arms control: the console facilities allow the surgeon both the telemanipulation of robotic arms with attached dissection fine instruments as allow the optical devices control.
- Console visualization devices: the console eyepiece provides a stereoscopic binocular 3-D visualization of the surgical field. Furthermore, images of the dissected area are magnified.
- The surgical arm cart: robotic arms with attached instruments and camera are moved by the surgical arm cart. Surgeon control movements from the console are processed (for tremor filtration, indexing and scaling) and reproduced by robotic arms in a real time, with no delay. Processed movements are more precise and accurate than real surgeon hands movements.
- Tremor filter: as discussed above, robotic arms process the real surgeon movements in order to filter hands tremor and only transmit effective movements.
- Indexing: while surgeon is repositioning one instrument in one of the robotic arms, the other one can remain steady in the last position the surgeon moved it.
- Movements scaling: Even after tremor filtration, robotic arms also process the surgeon hands movement to transducer them in a more fine scale in the operative field.

Choosing the surgical team

The minimum surgical team includes two thoracic surgeons with experience in VATS lobectomy and one third assistant. During the robotic dissection phase, one of them maneuvers the robotic arms and video system from the non-sterile console and the other two assistants remain in the sterile operative field besides the patient.

These two assistants must be trained in VATS and opened lobectomy, they may be able to perform all the necessary operative maneuvers during the time needed for the console-based surgeon be able to take part in the operative field. In case of severe bleeding requiring conversion to open surgery, these assistants must perform all the urgency maneuvers immediately.

Patient position

Patient position for RATS lobectomy is the same as that for VATS or opened resection: the lateral decubitus.

Positioning robotic devices in operating room

One of the most important things for robotic dissection phase performance is the determination of the optimal position of robotic devices.

Considering that robotic devices can be sometimes placed in a cranial position, it is very important that surgeons and anesthesiologists must choose together the optimal position for achieving both robotic dissection and anesthetic maneuvers security. Melfi and colleagues (Melfi et al, 2002) suggest that during operation, the main body of the machine should be better placed behind the operative site and that the best position of robotic arms must be established in relation to the side of the lesion.

Robotic arms collision will be discussed below.

Choosing the number, position and length of incisions

One of the incisions can be classified as the main utility incision, also called "service entrance" incision (Melfi et al, 2002).

Utility incision is longer than ordinary ones and is usually used for resected lung specimen removal. Its location is usually chosen based on the resection that is going to be performed. Upper lobe resection requires a more cranial placement and lower or middle lobe operations require a more caudal one.

Other ordinary incisions are used for camera and robotic instruments insertion. It is important to say that compared to traditional VATS lobectomy, trocars must be positioned at a greater distance from each other in order to avoid or at least minimize the risk of robotic arms collision.

When choosing the position and length of incisions, surgeon must consider the angle that will be required for vascular and bronchial mechanical stapling, because small incisions can bleed if staplers are forced through a narrow entry. And not well programmed position of incisions for stapling devices can result in unnecessary prolongation of operative time.

Draping robotic arms and camera

Several components of robotic system must be draped by sterile protectors. In order to avoid bacterial contamination and acquire a high performance skill, the nursing staff must be trained in this task.

Dr Morgan and colleagues described in 2003 (Morgan et al; 2003) that during the initial period of the learning curve with robotic system draping, they had to book the operations later in the day, because sometimes it could took the nurses two hours to drape the robot.

Single-lung ventilation

Single-lung ventilation is required because video assistance for both RATS and VATS requires a pleural space between lung parenchyma and chest wall in order to visualize and manipulate anatomic structures with endoscopic instruments.

In case where the ipsilateral lung parenchyma can not be adequately collapsed, as in some emphysematous patients, lobectomy can be safer and faster performed by opened techniques.

Initial VATS exploration

Before proceeding to robotic fine dissection of vascular and lymphatic structures, an initial VATS exploration is performed with traditional equipment.

This thoracic exploration can recognize situations that would preclude lung cancer lobectomy, as small pleural tumor spread not identified in chest tomography, for example.

It is also used to guide the optimal placement of additional incisions.

Incisions position may avoid robotic arms collision

When choosing additional incisions optimal placement during the initial VATS exploration, surgeons must remember that incisions position may allow free robotic arms movement.

If incisions are placed based only on the optimal position for robotic and VATS dissection, ligature, division and specimens removal, not considering the risk of robotic arms collision, unnecessary time will be add to the surgical procedure in order to resolve or minimize this trouble.

2.4 Robotic assisted mediastinal and hilar lymph node dissection phase

Most used instruments for robotic assistance during dissection phase

Robotic instruments must be personally chosen by the surgeons who will perform the robotic dissection of vascular and lymphatic structures. As in traditional VATS phase, one surgeon can be more familiarized with a specific instrument. For each instrument family, several design and degrees of movement are available. We cite some of the instrument families used for robotic fine dissection phase:

Instruments

- Needle Holders
- Scalpels
- Scissors
- Graspers
- Monopolar cautery instruments
- Bipolar cautery instruments
- Ultrasonic energy instruments
- Specialty instruments
- Clip appliers

Vision equipments

- 2D 5mm endoscope system and accessories
- 3D endoscope system and accessories

Vascular and lymphatic dissection

Lymph nodal dissection: is an important aspect of lung cancer resection. Although there is a wide discussion about the extent of nodal dissection, if node picking have the same

diagnostic and therapeutic results compared to radical dissection, it is a consensus that both hilar and mediastinal lymph nodes must be explored during the surgical treatment of NSCLC.

Lymph nodal dissection is one of the procedures that should be performed during the robotic assisted phase of RATS/VATS lobectomy. It can be done before or after lobe removal, but published articles usually describe it before lobe removal.

Arterial branches: are dissected during the first phase of robotic fine maneuvers. DeBakey forceps and electrocautery are the most used instruments during this vascular dissection.

There is no available robotic instrument for pulmonary artery major branches coagulation or ligation. One can say that if arterial branches were hypothetically dissected until a more distal bifurcation, their caliber would be short enough for coagulation with robotic cauteries or robotic clip applicators. But an excessive distal dissection require a longer operative time, expose vascular and parenchyma tissues to further, and perhaps dangerous, dissection and can cause unnecessary bleeding or alveolar air leak. Furthermore, traditional VATS staplers can be easily used for ligature and section of more proximal segments of the arterial pulmonary tree.

Venous structures: are traditionally dissected with VATS instruments only until its more proximal length. In robotic assisted VATS surgeons prefer keeping this principle, too. At this more proximal segment, pulmonary veins have a large caliber when compared to arterial structures, which are usually dissected more distally until segmental branches. More than a mere larger caliber, venous structures are less elastic and resistant to dissection, being more susceptible to small vascular, but bloody, injure.

As arterial vessels, VATS traditional staplers are used to perform ligature and division of pulmonary veins, as discussed later.

VATS lobectomy phase

As discussed below, robotic assisted VATS lobectomy includes a two-phase procedure, being traditional VATS lobectomy the second phase. In this phase, ligature and division of arterial, venous and bronchial structures are performed.

Individual ligation and division of the hilar structures requires temporary repositioning of instrument arm

During the VATS lobectomy phase, endoscopic staplers are used to perform ligation and division of vascular and bronchial hilar structures. Robotic instrument arm must be temporary repositioned in order to allow staplers introduction. Usually, the arm that must be repositioned depends on the lobe that is going to be resected:

- Upper lobectomy: staplers are usually introduced through the posterior incision.
- Middle lobectomy: staplers are usually introduced through the posterior incision.
- Lower lobectomy: staplers are usually introduced through the anterior incision.

Fissure dissection

Robotic instruments allow a fine dissection of vascular and lymphatic structures, but can perforate lung parenchyma causing minor bleeding and alveolar air leak. For this reason, for fissure completion, surgeons prefer using traditional staplers and VATS instruments.

Traditional VATS instruments are more adequate to dissect lung parenchyma and can be used in order to achieve a faster and safer fissure dissection when compared to robotic fine instruments.

Surgeons can perform fissure dissection before or after vascular ligation, but usually it is dissected last, during the VATS phase.

Resected lobe specimen removal

As discussed above, resected lobe is removed through the main utility incision, because it is the incision with the longer length.

Some surgeons prefer performing a previous traditional VATS wedge resection containing the primary lung tumor in order to reduce the whole lung volume. This simple maneuver is believed to allow the specimen removal through narrower utility incisions. Oncologically speaking, in-bloc resection of anatomical structures harboring a carcinoma is theoretically preferable, but no scientific study has been performed comparing oncological results between these two techniques. Furthermore, some authors believe that extending some few centimeters the length of the utility incision does not add any important morbidity to the surgical procedure.

If extending the utility incision or performing a previous VATS wedge resection is controversial. But authors agree that the use of protective VATS bags is essential for the specimen's removal. More than only protecting chest wall against tumor cell implants, it facilitates specimen sliding through the orifices, requiring minimal chest wall incisions.

3. Other robot platforms not used in lung cancer resection

Robotic assisted VATS lobectomy for lung cancer uses extra cavity and steady platform for camera holding and for robotic arms support. Moreover, instruments axis are rather rigid than flexible. We believe that these three features of nowadays available robotic systems for thoracic surgery will evolve to more miniaturized, flexible, intra cavity (or endoluminal) "intelligent self moving" devices.

We believe that miniaturized robots will probably be controlled from the outside cavity, but the surgeons will be able to move them freely in the intra cavity operative field.

We must ally the concept of Natural Orifice Transluminal Endoscopic Surgery (NOTES) to the available robotic assisted VATS techniques.

Some devices are already used in other surgical procedures, based in technologies that can be incorporated in robotic systems for VATS assistance.

NeoGuide's Endoscopy System: One example of technology that can be incorporated aiming more movement free miniaturized robotic devices is the NeoGuide's Endoscopy System used for colonoscopy. Eickhoff (Eickhoff et al, 2007) and colleagues carried out an initial clinical trial using this device. It consists in a computer-assisted colonoscope, which changes its shape to adjust it to the colonic silhouette directed by a computer algorithm.

Based in the concept of Natural Orifice Transluminal Endoscopic Surgery (NOTES), we can suppose that combined endoscopic and thoracoscopic will be used in the future for bronchial dissection, or even ligation and section of airways structures.

I-SNAKE and CardioArm and Endosamurai: 'I-Snake' is a flexible Imaging-Sensing Navigated and Kinematically Enhanced (i-Snake) Robot equipped with special motors, multiple sensing mechanisms and imaging tools at its 'head'.

The flexible i-Snake robot can act as the surgeon's hands and eyes. It can be guided along intra luminal or intra cavity anatomic structures. CardioArm and endosamurai are other available flexible promising robotic device to be used in body natural or surgeon accessed cavities (Mummadi & Pasricha; 2008).

4. Controversies about robot in lung cancer

Although robotic assistance can increase maneuverability, dexterity and afford a 3-D and magnified visualization, clinical outcomes advantages and costs remain controversial.

It is realized by surgeons who perform robotic assisted VATS lobectomy associated to hilar and mediastinal lymphatic dissection that robotic assistance can add advantages in these procedures when fine dissection is required. In cases where patients have a complete pulmonary fissure, blood vessels are easily visualized and dissected; VATS instruments can perform vascular and bronchial dissection in a fast, efficient and safe manner.

It seems that a sub group of patients with incomplete fissures or with pathologic lymph nodes in the hilum or inter lobar fissure can benefit of robotic assistance for arterial dissection (Farid Gharagozloo et al, 2009).

5. Perspectives

We summarize some items we believe are the most important points to be developed in robotic assisted VATS lung cancer lobectomy:

1. Smaller robots hardware
2. Miniature robots including intra cavity and flexible free devices
3. More advanced devices with better tactile sensation
4. New design of dissecting forceps oriented for lung cancer surgery
5. Collision detection and untangling for surgical robotic manipulators
6. Finally, we believe that learning curve is a fair and severe judge of new incorporated technologies in all human activities.

5.1 Are we in the road until a real pure robotic lung cancer resection?

In conclusion, it is intuitive that continuous technological advances will allow surgeons performing pure robotic lung cancer resection one day.

Robotic systems will confer the capacity to resect lung cancer through even smaller incisions, resulting in lesser chest wall tissue manipulation and less painful procedures. In the other hand it is also clear that analgesic techniques and drugs are being developed as well; and it will be possible to offer patients painless surgical treatment of lung cancer based on these new options.

But the concept of pursuing tissue integrity is one of the surgical science cornerstones and can misbalance the equation in favor of minimally invasive procedure, allying NOTES concepts to robotic assisted lung cancer treatment.

Finally, we believe that best pure robotic lung cancer treatment would be a friendly robot helping humans stop smoking.

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Robot Surgery

Edited by Seung Hyuk Baik

ISBN 978-953-7619-77-0

Hard cover, 172 pages

Publisher InTech

Published online 01, January, 2010

Published in print edition January, 2010

Robotic surgery is still in the early stages even though robotic assisted surgery is increasing continuously. Thus, exact and careful understanding of robotic surgery is necessary because chaos and confusion exist in the early phase of anything. Especially, the confusion may be increased because the robotic equipment, which is used in surgery, is different from the robotic equipment used in the automobile factory. The robots in the automobile factory just follow a program. However, the robot in surgery has to follow the surgeon's hand motions. I am convinced that this In-Tech Robotic Surgery book will play an essential role in giving some solutions to the chaos and confusion of robotic surgery. The In-Tech Surgery book contains 11 chapters and consists of two main sections. The first section explains general concepts and technological aspects of robotic surgery. The second section explains the details of surgery using a robot for each organ system. I hope that all surgeons who are interested in robotic surgery will find the proper knowledge in this book. Moreover, I hope the book will perform as a basic role to create future prospectives. Unfortunately, this book could not cover all areas of robotic assisted surgery such as robotic assisted gastrectomy and pancreaticoduodenectomy. I expect that future editions will cover many more areas of robotic assisted surgery and it can be facilitated by dedicated readers. Finally, I appreciate all authors who sacrificed their time and effort to write this book. I must thank my wife NaYoung for her support and also acknowledge MiSun Park's efforts in helping to complete the book.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Joao-Carlos Das-Neves-Pereira, Marc Riquet, Françoise Le-Pimpec-Barthes, Paulo-Manuel Pego-Fernandes and Fabio Biscegli Jatene (2010). Robotic Surgery for Lung Cancer, Robot Surgery, Seung Hyuk Baik (Ed.), ISBN: 978-953-7619-77-0, InTech, Available from: <http://www.intechopen.com/books/robot-surgery/robotic-surgery-for-lung-cancer>

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