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Thoracoscopic Lobectomy

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The surgical approach in the management of patients with lung cancer is evolving. Conventional surgical approaches utilizing thoracotomy remain the standard for the majority of patients with resectable lung cancer. Minimally invasive procedures, however, may be employed in selected patients with early-stage lung cancer, in order to minimize operative morbidity without sacrificing oncologic efficacy.

Key words: video-assisted thoracic surgery (VATS); lobectomy

DEFINITION

Minimally invasive procedures, utilizing operative telescopes and video technology, are referred to synonymously as thoracoscopic procedures or video-assisted thoracic surgical surgery (VATS). For clarity, the terms "VATS" or "thoracoscopic" refer to *totally thoracoscopic* approaches, where visualization is dependent on video monitors, and rib spreading is avoided. A hybrid procedure, which employs rib-spreading and direct visualization in addition to thoracoscopy, may be referred to as video-assisted thoracotomy. Thoracoscopy has been widely utilized diagnostically in the management of patients with lung cancer. The application of thoracoscopic anatomic resections is comparatively new, but it is increasing internationally.

Thoracoscopic lobectomy is defined as the anatomic resection of an entire lobe of the lung, using a videoscope and an access incision, without the use of a mechanical retractor and without rib-spreading[1-4]. The anatomic resection includes individual dissection and stapling of the involved pulmonary vein, pulmonary artery and bronchus and appropriate management of the mediastinal lymph nodes, as would be performed with thoracotomy. In selected patients, thoracoscopic anatomic segmentectomy may be formed, adhering to the same oncologic principles that guide resection at thoracotomy.

Some surgeons have advocated simultaneous stapling of hilar structures with video-assistance and the avoidance of rib-spreading[5,6]. Such an approach has been termed video-assisted simultaneously-stapled lobectomy. Although this technique has been utilized successfully in selected patients, the reference to "thoracoscopic lobectomy" is limited to anatomic resection with individual vessel ligation. VATS wedge resection describes non-anatomic thoracoscopic resection of a lesion, which is considered useful for diagnostic procedures.

In order to be considered a viable alternative to conventional lobectomy, thoracoscopic lobectomy must be applied with the same oncologic principles: individual vessel ligation, complete anatomic resection with negative margins, complete hilar lymph node dissection, and appropriate management of the mediastinal lymph nodes. Theoretical advantages to minimally invasive resection include reduced surgical trauma, decreased postoperative pain, shorter chest tube duration, shorter length of stay, preserved pulmonary function, faster return to full activity, and superior cosmetic result when compared to lobectomy via open thoracotomy[7-9].

History

The history of minimally-invasive thoracic surgery began in 1910 when Jacobaeus utilized a cystoscope to lyse adhesions in order to collapse the lung in order to treat tuberculosis[10]. This technique was widely applied in the early part of the century but was largely abandoned after streptomycin was introduced in 1945. However, with the emergence of laparoscopic cholecystectomy, minimally invasive approaches were applied more widely. The first descriptions of VATS to perform anatomic lobectomy were published in 1993 by Kirby et al[1] and Walker et al[2].

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The first randomized trial of VATS lobectomy versus the conventional open approach was presented in 1994 and demonstrated no significant benefits for VATS[11]. With more widespread application of technology and refinements in technique, other groups have published series of VATS lobectomy[5,9,12-20] (Table 1).

Indications

In general, the indications for thoracoscopic lobectomy are similar to those for lobectomy using the open approach[18,19]. Thus, the procedure is applied to patients with known or suspected lung cancer (clinical stage I) that appears amenable to complete resection by lobectomy; preoperative staging and patient selection for thoracoscopic lobectomy should be conducted as for conventional thoracotomy. Tumor size may preclude the option of thoracoscopic lobectomy in some patients, as some large specimens may not be amenable to removal without rib spreading; however, no absolute size criteria are used. Although controversial, some have also argued that the thoracoscopic approach may allow recruitment and resection of some patients considered “medically inoperable”, who could not undergo conventional thoracotomy[19-21]. The minimal physiologic requirements for resection have not been agreed upon; however, the selection of patients for thoracoscopic lobectomy must take into account that conversion to thoracotomy may be necessary.

Contraindications

Absolute contraindications to thoracoscopic lobectomy include the inability to achieve complete resection with lobectomy, T3 or T4 tumors, N2 or N3 disease, and inability to achieve single-lung ventilation[19-20]. Relative contraindications include tumors that are visible at bronchoscopy, the presence of hilar lymphadenopathy that would complicate vascular dissection (benign or malignant), prior thoracic irradiation, and the use induction therapy. Prior thoracic surgery, induction therapy, incomplete or absent fissures, and benign mediastinal adenopathy should not be considered contraindications[19-22]. Finally, chest wall involvement would obviate thoracoscopic resection for most patients, but successful en bloc resection via VATS has been reported[23].

Strategy for Thoracoscopic Lobectomy

After bronchoscopy and mediastinoscopy (when indicated), single-lung anesthesia is established using a dual lumen endotracheal tube or bronchial blocker. The patient is positioned in full lateral decubitus position with slight flexion of the table at the level of the hip, which provides splaying of the ribs to improve thoracoscopic access and exposure. Care must be taken to secure and pad the patient such that the risk of neurologic injury is minimized. Once the patient is positioned, the anesthesiologist should reconfirm desired position of the endotracheal tube. Prior to sterile preparation and draping, the chest is marked for the placement of thoracoscopic incisions.

Table 1. Recent series of thoracoscopic lobectomy

Series	N	Conversion Rate (%)	Method	LN Dissection	Mortality (%)	Survival Stage I (%)
Lewis[6]	200	0	SSL	Dissection	0	92(3yr)
Hermansson[13]	30	6.7	SSL	Sampling	0	NA
Solaini[9]	125	10.4	IHD	Sampling	0	90 (3yr)
Brown[12]	105	7.6	IHD	Sampling	0	NA
Kaseda[14]	128	11.7	IHD	Dissection	0.8	94 (4yr)
McKenna[15]	212	7	IHD	Dissection	0.5	76 (4.5yr)
Roviaro[16]	171	19.9	IHD	Sampling	0	91 (1yr)
Walker[17]	150	11.8	IHD	Sampling	2	81 (5yr)
Yim[18]	214	0	IHD	Sampling	0.5	NA
Daniels[19]	110	1.8	IHD	Dissection	3.6	NA
Swanson[20]	97	8.5	IHD	Both	2.1	NA

Abbreviations:
LN: Lymph node
IHD: Individual hilar dissection
SSL: Simultaneously stapled lobectomy
NA: Not assessed

Port placement is a matter of surgeon preference. Most surgeons use 3 or 4 incisions, although lobectomy can usually be accomplished using only 2 incisions[19]. The first incision, a 10 mm port access used predominantly for the thoracoscope, is placed in the 7th or 8th intercostal space in the midaxillary line. The location of this incision is chosen so that it does not compete with the anterior incision, yet still provides anterior and superior visualization of the hilum. A port is used for placement of the telescope, but ports are not used for the other incisions. Prior to making the second incision, evidence that the patient is unresectable should be sought, such as parietal pleural involvement.

The second incision, an anterior access incision (4.5-6.0 cm) for dissection and specimen retrieval, is placed in the 5th or 6th intercostal space, just inferior to the breast. The location of this incision, where the intercostal spaces are the widest, is chosen to provide access for hilar dissection and is usually not dependent on whether the planned procedure is an upper or lower lobectomy. Additional incisions may be employed, either in the axilla or posteriorly, to improve visualization or to provide retraction.

Instrumentation for thoracoscopic lobectomy is critical to successful completion of the procedure. The thoracoscope should be a 30-degree angled scope, to optimize the ability to achieve panoramic visualization during dissection and to minimize competition with the operative instruments. A spectrum of surgical instruments may be employed for dissection, including conventional instruments and dedicated thoracoscopic or laparoscopic instruments. It is especially beneficial to use curved instruments for retraction during dissection, as it will minimize the tendency for instruments to compete or collide with each other. Thoracoscopic (linear) mechanical staplers, such as the EndoGIA (U.S. Surgical, Norwalk, CT), are employed for control of the vessels (2.0 or 2.5 mm staples), bronchus (3.5 or 4.8 mm staples) and fissure.

After the placement of the second incision, the surgeon performs thoracoscopic exploration, which includes confirmation of the location of the tumor, exclusion of the presence of pleural metastases, and division of the pulmonary ligament. If a malignant diagnosis has not been achieved preoperatively, thoracoscopic wedge resection is performed using an automatic stapling device, and the specimen is removed in a protective bag. After frozen section confirms a malignant diagnosis, thoracoscopic lobectomy may then be completed. Mediastinal lymph node dissection may be performed at this point or may be deferred until the lobectomy is completed.

The approach to the staging of mediastinal lymph nodes is controversial. Many advocate systematic sampling of mediastinal lymph nodes because of concerns about the adequacy and safety of formal dissection[24]. Others accomplish mediastinal lymph node dissection by completely resection the mediastinal nodes thoracoscopically, including levels 2, 4, 7, 8, and 9 on the right and levels 5, 6, 7, 8, and 9 on the left[14,19].

Hilar dissection is carried out through the access incision, to achieve visualization and mobilization of the hilar structures. For any anatomic thoracoscopic lobectomy, hilar dissection is begun with mobilization of the pulmonary vein. For upper lobectomy, the lung is reflected posteriorly and inferiorly to facilitate dissection. For lower lobectomy, the lung is retracted superiorly. Moving the thoracoscope to the anterior incision may improve visualization of the superior hilum and may facilitate placement of the linear stapler for upper lobectomy, if introduced through the midaxillary port.

The risk of intraoperative hemorrhage is minimized with careful hilar dissection, which is facilitated with the visual clarity and magnification available with the video thoracoscope. Unexpected bleeding from a major branch of the pulmonary artery or pulmonary vein may occur, however. In most cases, the source of the bleeding is easily identifiable and tamponade is possible, allowing conversion to thoracotomy. In order to minimize the risk of vascular injury, surgeons have employed a variety of techniques to isolate the pulmonary arterial and venous branches, including ligatures to retract the vessels and catheters to guide the stapling devices. These techniques may be helpful in difficult cases, but are not required for the majority of patients.

All lobectomy specimens are removed using a protective specimen bag, to prevent implantation of tumor cells in the incision. The lobectomy specimen and hilum are each inspected to ascertain that anatomic lobectomy has been performed. After retrieval, the hemithorax is irrigated with warm saline, and the bronchial stump is inspected. If an air leak is encountered, repeat stapling or endoscopic suturing may be performed[25].

RESULTS

The safety and efficacy of thoracoscopic lobectomy for patients with early-stage lung cancer has been established. Although there are no prospective, randomized series that compare thoracoscopic lobectomy to conventional approaches, a sufficient number of series have been published, both single-institution and multi-institution experiences, to conclude that thoracoscopic lobectomy is a reasonable strategy for patients with clinical stage I lung cancer[17,14-21].

Daniels and colleagues reported the results of thoracoscopic lobectomy in 110 consecutive patients[19]. The 30-day mortality was 3.6%, with no intraoperative deaths. The conversion rate was 1.8%, and none were emergent. The median chest tube duration was 3 days and median length of stay was 3 days. The Cancer and Leukemia Group B (CALGB) reported on the results of a multi-institutional series of 97 patients who underwent thoracoscopic lobectomy[20]. In this series, the mortality was 2%, the operative time was 130 minutes, and the median length of stay was 3 days. Numerous other series have been published and are summarized in Table 1. In summary, thoracoscopic lobectomy has been demonstrated to be equivalent in terms of safety and oncologic efficacy, as measured by complete resection rate, operative time, extent of lymph node dissection, operative mortality, and short-term survival, when compared to published results for thoracotomy and lobectomy[26-30].

Morbidity and mortality associated with thoracoscopic resection are comparable or lower than expected for conventional thoracotomy and resection. (Table 1) The mortality reported in several recent series ranges from 0-4%. Conversion rates range from 0-20%, and appear to decrease over time with experience.

Persistent air leak, defined as lasting greater than 7 days, is the most common major complication but may be expected to decrease with experience and the use of endoscopic suturing[25,31]. Wound recurrence due to tumor implantation was first described in 1996[32,] but its risk may be minimized by use of specimen bags and copious irrigation. Perhaps the most feared major complication is hemorrhage into a closed chest, but careful hilar dissection has led to only rare cases.

Postoperative Pain

Post-thoracotomy pain is related to rib spreading, which is obviated by the totally thoracoscopic approach. Many groups have analyzed acute pain after VATS. Although Kirby's randomized trial of VATS versus muscle-sparing lobectomy revealed no difference in post-operative pain, many of the VATS patients had undergone rib-spreading during the operation[1]. This study also did not differentiate between acute and more chronic pain. Nomori and colleagues compared a group of age- and sex-matched patients who underwent thoracoscopic lobectomy (n=33) or limited anterior thoracotomy (n=33)[33]. The patients who underwent thoracoscopic lobectomy experienced less pain between postoperative day (POD) 1 and POD 7 ($p < 0.05$ to 0.001) and had lower analgesic requirements up to POD 7 ($p < 0.001$).

Demmy and colleagues reported on their results in a series of patients, who underwent either thoracoscopic lobectomy or conventional thoracotomy[21]. In this series, the percentage of patients reporting severe pain was 6% in those patients after thoracoscopic lobectomy and 65% after thoracotomy. Moreover, the percentage of patients reporting minimal or no pain was 63% in those patients after thoracoscopic lobectomy and 6% after thoracotomy. Other studies analyzing acute pain have concluded that VATS either causes less pain[8,33-35] or lower analgesia requirement[36,37] in the early postoperative period.

Postoperative Pulmonary Function

Many have theorized that smaller incisions and absence of rib spreading may improve lung function in the postoperative period, and several studies have reported pulmonary function test data following thoracoscopic resection. Two studies examined postoperative PaO_2 after both VATS and muscle-sparing thoracotomy and found that VATS patients had better oxygenation during the first postoperative week[35,38]. Others have revealed improvements in early postoperative forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) in the first weeks and months after VATS[8,33,39].

Oncologic Effectiveness

The ultimate acceptance of thoracoscopic lobectomy will be dependent upon its oncologic effectiveness as compared with conventional lobectomy. Although there has been no prospective, randomized trial with sufficient power to assess differences between the operations, the studies performed are sufficient for limited analysis. First, no differences were seen in number of lymph nodes obtained either by dissection or sampling between conventional and VATS lobectomy[21,37,40]. Second, data from existing series reveal survival rates for Stage I patients at least as good as those published in the literature for conventional thoracotomy (See Table 1). Some groups have documented improved survival when VATS was utilized[6,14,25]. Reasons for the possible differences are unclear, but it has been postulated that preservation of immune function and less systemic release of inflammatory cytokines may contribute[44]. Final resolution of these issues awaits a larger prospective registry trial, proposed by the Cancer and Leukemia Group B in the United States.

SUMMARY

Minimally invasive approaches to lung cancer treatment have been demonstrated to be safe and effective for patients with early-stage lung cancer. Thoracoscopic lobectomy is designed to achieve the same oncologic result as conventional lobectomy: complete hilar dissection and individual vessel control. The recognized advantages of thoracoscopic anatomic resection include less short-term postoperative pain, shorter hospital stay, and preserved pulmonary function. Although there are no prospective randomized studies comparing the thoracoscopic approach to conventional thoracotomy, there is no data from published series to suggest any difference in oncologic efficacy. Current studies may demonstrate whether patients who undergo thoracoscopic lobectomy demonstrate superior compliance with adjuvant therapy.

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