Abstract

Accurate mediastinal lymph node dissection during thoracotomy is mandatory for staging and for adjuvant therapy in lung cancer. Pretherapeutic staging for neoadjuvant therapy or for video assisted thoracoscopic resection of lung cancer is achieved usually by CT-scan and mediastinoscopy. However, these methods do not reach the accuracy of open nodal dissection. Therefore we developed a technique of radical video-assisted mediastinoscopic lymphadenectomy (VAMLA). This study was designed to show that VAMLA is feasible and that radicality of lymphadenectomy is comparable to the open procedure.

In a prospective study all VAMLA procedures were registered and followed up in a database. Specimens of VAMLA were analysed by a single pathologist. Lymph nodes were counted and compared to open lymphadenectomy. The weight of the dissected tissue was documented. In patients receiving tumour resection subsequently to VAMLA, radicality of the previous mediastinoscopic dissection was controlled during thoracotomy.

37 patients underwent video-assisted mediastinoscopy from June 1999 to April 2000. Mean duration of anaesthesia was 84.6 (SD 35.8) minutes.

In 7 patients radical lymphadenectomy was not intended because of bulky nodal disease or benign disease. The remaining 30 patients underwent complete systematic nodal dissection as VAMLA.

18 patients received tumour resection subsequently (12 right- and 6 left-sided thoracotomies). These thoracotomies allowed open re-dissection of 12 paratracheal regions, 10 of which were found free of lymphatic tissue. In two patients, 1 and 2 left over paratracheal nodes were counted respectively. 10/18 re-dissected subcarinal regions were found to be radically dissected by VAMLA. In 6 patients one single node and in the remaining 2 cases 5 and 8 nodes were found, respectively. However these counts also included nodes from the ipsilateral main bronchus (station 10). None of these nodes was positive for tumour.

Average weight of the tissue that was harvested by VAMLA was 10.1 g (2.2-23.7, SD 6.3). An average number of 20.5 (6-60, SD 12.5) nodes per patient were counted in the specimens. This is comparable to our historical data from open lymphadenectomy.

One palsy of the recurrent nerve in a patient with extensive preparation of the nerve and resection of 11 left-sided enlarged nodes was the only severe complication in this series.

VAMLA seems to accomplish mediastinal nodal dissection comparable to open lymphadenectomy and supports video assisted surgery for lung cancer. In neoadjuvant setting a correct mediastinal N-staging is achieved.

Keywords: mediastinoscopy, video-assisted surgery, lung neoplasm, carcinoma, non-small-cell lung, neoplasm staging
Zusammenfassung

Eine korrekte mediastinale Lymphknotendissektion während der Thorakotomie ist Voraussetzung für das Staging und die adjuvante Therapie des Bronchialkarzinoms. Das prätherapeutische Staging in neoadjuvan-ten Therapiekonzepten oder bei geplanter videoassistierter thorakoskopischer Resektion von Bronchialkarzinomen erfolgt üblicherweise durch CT Thorax und Mediastinoskopie. Jedoch erreichen diese beiden Methoden nicht die Präzision einer offenen systematischen Lymphadenektomie. Daher haben wir die Technik der systematischen videoassistierten mediastinalen Lymphadenektomie (VAMLA) entwickelt. Diese Studie soll die klinische Durchführbarkeit eine der offenen Lymphadenektomie vergleichbare Radikalität der VAMLA zeigen.

In einer prospektiven Beobachtungsstudie wurden alle VAMLA-Operationen in einer Datenbank registriert und verfolgt. Die Gewebeproben wurden alle von einem Pathologen untersucht. Das Gewicht der Präparate sowie die Anzahl der Lymphknoten wurden bestimmt und mit den Ergebnissen der offenen Lymphadenektomie verglichen. Bei Patienten, die nach VAMLA zur Tumorresektion thorakotomiert wurden, haben wir bei dieser Gelegenheit die Radikalität der vorangegangenen mediastinoskopischen Dissektion überprüft.

Von Juni 1999 bis April 2000 unterzogen sich 37 Patienten der videoassistierten Mediastinoskopie. Die durchschnittliche Anästhesiezeit war 84,6 Minuten (SD 35,8).

Bei 7 Patienten wurde die radikale Lymphadenektomie nicht angestrebt wegen benigner Grunderkrankungen oder extensivem mediastinalem Befall ("bulky disease"). Die übrigen 30 Patienten wurden komplett systematisch lymphadenektomiert im Sinne der VAMLA.

Bei 18 Patienten wurde in der Folge der Primär tumor reseziert (12 rechtseitige und 6 linkseitige Thorakotomien). Diese Thorakotomien erlaubten die offene Re-Exploration des zuvor lymphadenektomierten paratrachealen Areals bei 12 Patienten, wobei 10 paratracheale Regionen frei von residualem lymphatischem Gewebe waren. Bei 2 Patienten wurden 1 bzw. 2 verbliebene paratracheale Lymphknoten gezählt. Von 18 anlässlich der Thorakotomie revidierten subcarinalen Regionen waren 10 durch die VAMLA komplett disseziert. Bei 6 Patienten wurde nur noch ein Lymphknoten und bei 2 weiteren Patienten 5 bzw. 8 Lymphknoten gefunden. Allerdings beinhaltet diese Zählung auch Lymphknoten vom gleichseitigen Hauptbronchus (Station 10), die intraoperativ nicht immer präzise von den infracarinalen Lymphknoten differenziert wurden. Keiner der anlässlich der Thorakotomie nachträglich entfernten Lymphknoten war tumorbefallen.

Das durchschnittliche Gewicht der Dissektate war 10,1 g (2,2 bis 23,7, SD 6,3). Die durchschnittliche Anzahl der dissezierten Lymphknoten betrug 20,5 (6 bis 60, SD 12,5) pro Patient. Dies entspricht unseren Daten der offenen Lymphadenektomie.

Als Komplikation beobachteten wir eine linksseitige Recurrensparese nach extensiver Freilegung des Nerven und Resektion von 11 linksseitigen vergrößerten Lymphknoten.

Die VAMLA scheint nach den vorläufigen Ergebnissen der offenen Lymphadenektomie gleichwertig und erleichtert die videoassistierte thorakoskopische Chirurgie des Bronchialkarzinoms. In neoadjuvannten Konzepten wird ein korrektes prätherapeutisches N-Staging erreicht.

Introduction

Systematic radical mediastinal lymphadenectomy during primary tumour resection is the gold standard of lymph node staging. Precise staging of mediastinal lymph nodes is mandatory for the therapeutic concept of lung cancer. As for other primary tumours, sophisticated oncological concepts gain importance in lung cancer as well:

• Small tumours without lymph node metastases are resected using video assisted thoracoscopic surgery.
• Advanced tumours (T4, N2-3) receive neoadjuvant therapy before resection.
• In high-risk patients tumours without mediastinal lymph node metastases are resected and apart from that are treated conservatively.

These settings require preoperative nodal staging, which is frequently performed using computed tomography, magnetic resonance imaging and PET scanning. The low sensitivity and specificity of computed tomography for nodal staging are well known [1], [2], [3], [4]. Magnetic resonance imaging and PET scanning [5], [6], [7] are neither sufficiently reliable. The combination of several procedures improves the results [8], [9], [10] but is still markedly inferior to surgical staging and cannot be performed on a broad clinical basis.

While the specificity of mediastinoscopy is extremely high (practically 100%), its sensitivity largely depends on the examiner. The amount of lymph node tissue resected and the number of lymph node stations investigated vary considerably [11]. If only some mediastinal lymph nodes are involved, a not quite rare condition (in our own collective 25% of N2 stages [12]), the results depend on whether the lymph nodes involved are biopsied. Therefore mediastinoscopic lymph node biopsy may often lead to false-negative results due to sampling error.

For this reason, we tried to increase the sensitivity of mediastinoscopy to the level of open systematic lymphadenectomy by further technical and surgical development.

Since mediastinoscopy was introduced by Carlens in 1959 [13], it has hardly been modified from the technical point of view over three decades. Buess [14] developed a mediastinoscope with integrated optics (Richard Wolf GmbH, Postfach 1164, D-75434 Knittlingen, Germany) for transmediastinal dissection of the oesophagus. We also employed this instrument for diagnostic mediastinoscopy. Meanwhile, various companies offer conventional mediastinoscopes with integrated optics to be connected to a video system. These modifications, however, have not changed the surgical procedure developed by Carlens with mainly blunt and unimanual preparation with the aspirator tube. The only advantages are a magnified view of the operation field and a better surveillance of surgeons in training for mediastinoscopy.

Occasionally, the employment of a spreading laryngoscope for mediastinoscopy was reported on, preferably by otolaryngologists [15]. In 1992, on the basis of this device, Albert Linder und Marcel Dahan in cooperation with the Wolf Company (Richard Wolf GmbH, Postfach 1164, D-75434 Knittlingen, Germany) have started to develop a video-assisted mediastinoscope for bimanual preparation. The bimanual preparation markedly increases surgical options [15], [16]. After gathering some experience, we have been able to further develop the mediastinoscopic lymph node biopsy to systematic video-assisted mediastinoscopic lymphadenectomy (VAMLA) since 1999.

The present prospective observation study investigates the technical feasibility of this method. Furthermore, we compare the radicality of lymphadenectomy of the paratracheal and subcarinal compartment using VAMLA with lymphadenectomy during right-sided thoracotomy.

**Material and methods**

**Study design**

In a prospective observation study, all VAMLA procedures have been documented since the first one in June 1999. Our surgical technique of VAMLA was already described elsewhere [17]. Aim of this study was to investigate technical feasibility, limitations and problems of VAMLA. Furthermore, the total count of lymph nodes resected was compared to a historical collective of open lymphadenectomy. The quantification of the dissected lymph nodes by the pathologist has been a standard procedure at our hospital for years. From a previous evaluation of these data of patients undergoing open lymphadenectomy in 1994 and 1995 [12] we selected those patients with right-sided thoracotomy as historical control group. The subcarinal compartment and the combined paratracheal and right tracheobronchial lymph-node specimens of these patients were compared to those obtained from VAMLA.

The resected specimens of the VAMLA were weighed additionally. However, in this respect, there were no comparative data of the historical collective. Instead, preliminary data from an unpublished prospective evaluation are shown.

Immediately after VAMLA, the surgeon recorded intraoperative complications, his assessment concerning the radicality of dissection of the right paratracheal and infra-carinal compartment, and if appropriate the reason for a non-radical resection. Duration of surgery was taken from the anaesthesia record.

During any thoracotomy following VAMLA for resection of bronchial tumour the radicality of mediastinoscopic lymphadenectomy was controlled by re-exploration of the mediastinum. The number and exact location of lymph nodes found in the subcarinal or paratracheal compartment were documented. Furthermore it was documented if the surgeon found the preparation more difficult due to scarring from previous VAMLA. A change of the pN stage after thoracotomy in comparison to previous VAMLA (false negative N2) was documented as well.

**Instruments**

In contrast to a conventional mediastinoscope, the video-mediastinoscope (Figure 1) consists of two spatulas. After introducing and positioning the device in the pretracheal space, both spatulas at the tip can be opened thus creating an operative field for bimanual surgery below the upper (ventral), slightly longer spatula. This ventral spatula of the mediastinoscope houses an optics rinsing tube.
and a smoke aspirator as well as a special high-performance optics providing the view of the operating area (Figure 2). This optics is connected to a video system. Apart from the slim optics, there is sufficient space for dissecting devices and to be able to operate under direct visual control in case the optics has become dirty e.g. by blood.

![Figure 1: Video-mediastinoscope with spatulas opened](image1)

![Figure 2: Upper spatula, inner surface with optics, suction- and irrigation-channel](image2)

Various grasping forceps, dissecting clips and scissors were newly developed particularly for the bimanual preparation technique additionally to the known isolated dissecting aspirator and biopsy forceps. All instruments are slightly longer and slimmer than in conventional mediastinoscopy to adapt to the length of the video-mediastinoscope and the lack of space within the scope associated with bimanual preparation.

During bimanual preparation, the surgeon cannot hold the mediastinoscope in place himself. Therefore, initially a holding device for the mediastinoscope was positioned on the patient's chest. However, assistance was frequently required for exact positioning. After termination of this feasibility study a new holding device, that is to be attached directly to the operation table, has been introduced. With this new device, a single surgeon operation is possible (Figure 3).

![Figure 3: Video-Mediastinoscope (grey arrow-heads) fixed to the new holding device (black arrow-heads) and allowing bimanual dissection as a single surgeon](image3)

**Surgical technique of VAMLA**

Similar to standard mediastinoscopy the pretracheal plane is exposed via a jugular incision. Through the video-mediastinoscope, with its spatulas still closed, the anatomical landmarks (bifurcation, both main bronchi and the left recurrent nerve) are exposed and identified by preparation with the aspirator tube as in conventional mediastinoscopy. After that, dissection proceeds in bimanual fashion with the spatulas of the mediastinoscope opened widely.

Dissection of the subcarinal nodes starts with exposure of the medial surface of both main bronchi and the edge of the bifurcation. After the lymph nodes and the mediastinal fat tissue is separated cranially and laterally from the tracheal bifurcation and main bronchi, it can largely be separated in a blunt fashion from the oesophagus and is extracted en bloc through the mediastinoscope. By distal dissection of about 3 cm the complete subcarinal region can be cleared. Finally, the oesophagus and the mediastinal pleura are exposed between the two main bronchi (Figure 4).

On the left side, sometimes the upper pulmonary vein becomes visible caudally to the pulmonary artery. The right para-oesophageal nodes can be dissected caudally to the level of the right lower pulmonary vein. If necessary, the main bronchi can be exposed more easily on the right than on the left side ventrally towards the upper lobe origin. Here, the lymph nodes are often attached to the pulmonary artery or its superior trunk and require careful preparation. Hilar N1-nodes can be sampled in that area.
In respect of the left recurrent nerve (Figure 5) usually only node sampling is performed from the left paratracheal sulcus, the left tracheobronchial angle and subaortal region. The optical enlargement in video-mediastinoscopy (Figures 6, Figure 7) and the bimanual preparation (Figure 8) allow the safe removal of several complete left-sided lymph nodes in spite of the adjacent nerve. Complete dissection (Figure 9) is warranted in selected cases only. In cranial direction between aorta and trachea, there are hardly any lymph nodes found. Given a specific indication, this difficult region can be dissected more easily by VAMLA than by conventional mediastinoscopy.
The pre-tracheal, right paratracheal and right tracheobronchial compartments are mostly resected en bloc. Directly caudally to the brachiocephalic trunk on the right side of the trachea, the lymph nodes are grasped and pushed caudally to the left. Thus the small cranial vascular and lymphatic attachments can be clearly dissected. Subsequently, the lymph nodes are drawn en bloc to the left and are dissected in a mostly blunt fashion from the mediastinal pleura (Figures 10, Figure 11) and the vena cava on the right and ventral side (Videos 1 and 2). Frequently, a clip has to be applied to a small venous branch to the vena cava or azygos. Now, at the right dorsal side of the trachea, the oesophagus with the vagus nerve and after further caudal dissection, the junction of the azygos vein with the vena cava (Figure 12) and the right pulmonary artery are exposed (Video 3, Figure 13). As soon as the azygos vein is exposed, the lymph nodes are pulled into left-cranial direction and are removed at the distal margin of the tracheobronchial angle. At the end of surgery, the paratracheal, right-sided tracheobronchial and the infracarinal compartment are dissected completely (Video 4).
of a study of neoadjuvant radio-chemotherapy. In these mours underwent mediastinoscopy within the framework nodal stage. In addition, 14 patients with right-sided tu- lymp node metastases that would have indicated an N3 underwent mediastinoscopy for exclusion of paratracheal by CT-scanning. 14 patients with a left-sided tumour The remaining 32 patients had a lung tumour confirmed evidence for pulmonary malignancy.

establishing histological diagnosis in patients without harvesting enlarged mediastinal lymph nodes for Indication for mediastinoscopy in five out of 37 cases 50 ml. mediastinoscopic instrumentation with a blood loss below bleeding complications, one from the azygos vein and another from a bronchial artery, both managed by video-assistant mediastinoscopic instrumentation with a blood loss below 50 ml. Indication for mediastinoscopy in five out of 37 cases was harvesting enlarged mediastinal lymph nodes for establishing histological diagnosis in patients without evidence for pulmonary malignancy. The remaining 32 patients had a lung tumour confirmed by CT-scanning. 14 patients with a left-sided tumour underwent mediastinoscopy for exclusion of paratracheal lymph node metastases that would have indicated an N3 nodal stage. In addition, 14 patients with right-sided tumours underwent mediastinoscopy within the framework of a study of neoadjuvant radio-chemotherapy. In these cases, the study protocol required histological prove or exclusion of nodal involvement before starting treatment. In four more patients with a right-sided tumour and a high perioperative risk, a mediastinal lymph node involvement was to be excluded before proceeding with thoracotomy. Of those 32 patients with lung tumours histological examination confirmed 28 NSCLC, one SCLC and one mixed tumour. One tumour turned out to be a metastasis of a colon carcinoma. The histology of one left-sided tumour remained unknown, as resection could not be performed because of worsening of cardiac disease. In 30 patients radical lymphadenectomy by VAMLA was intended. In the remaining 7 patients a radical dissection was not attempted because of extensive nodal disease anticipated after CT-scanning or because of diffuse lymph node enlargement without lung tumour. The primary intention in these cases was to obtain a major amount of material for histological examination. In 27 out of those 30 patients in whom radical lymphadenec- tomic procedure was indicated a radical dissection was achieved as judged intraoperatively. In one of 3 incomplete dissec- tions, 20 lymph nodes (12 of them with tumour involve- ment) were resected during mediastinoscopy, however parts of calcified subcarinal lymph nodes were left in place. In 2 other patients with a left-sided tumour, a par- ticularly fatty mediastinum prevented a radical extirpation in the paratracheal space, although in one case 17 and in the other case 21 lymph nodes were resected. After "radical" VAMLA, we re-explored the paratracheal compartments of 12 patients during right-sided thoracot- omies performed for the resection of the lung tumour. In 10 paratracheal compartments we could not find any remaining lymphatic residual tissue. In one case two, in another case one lymph node was present. In those 12 right-sided and 6 more left-sided thoracoto- mies also the subcarinal region was re-explored. 10 of 18 re-explored subcarinal regions proved to be radically dissected by VAMLA. In six of the eight incomplete dissec- ted cases one node, in one case five nodes and in one more case eight nodes were found left behind by VAMLA. These data, however, include lymph nodes along the main bronchi of which the delineation from the subcarinal nodes is sometimes difficult and that are frequently as- signed hilar nodes (number 10). None of these nodes resected later during thoracotomy showed tumour involve- ment. Thus VAMLA did not result in any false negative N2-stage. The mean total number of lymph nodes resected using video-assisted mediastinoscopy was 20.5 (median 15, SD 12.5, minimum 6, maximum 60). From the left tracheobronchial location, a delicate region for dissection because of the proximity of the left recurrent nerve, a median amount of 4 (maximum 17) lymph nodes were removed (Table 1).

Figure 13: Right tracheobronchial region with azygos vein (1), right pulmonary artery (2) and right main bronchus (3) 4: node and lymphatic tissue in front of first segmental branch (A1/3) of the right pulmonary artery, 5: first segmental branch (A1/3) of the right pulmonary artery, 6: subcarinal region, 7: confluens of V. cava and V. azygos)

Results

From June 1999 until April 2000, 37 patients (30 men) with a mean age of 61 years (47-75, SD 7.7) underwent VAMLA. Mean duration of the anaesthesia was 84.6 minutes (25- 175, SD 35.8) including additional procedures. Mainly rigid bronchoscopy and/or transoesophageal ultrasound examination were performed in many of these patients during the same anaesthesia. Therefore, the average time needed for VAMLA alone was somewhat less. However, the exact time needed for the different interventions was not recorded. In general and under favourable circumstances, a radical paratracheal and subcarinal dissec- tion alone could frequently be achieved within 30-45 minutes. That is about the same time, which we need for an open nodal dissection. Complications observed in 37 VAMLA procedures comprised one left-sided recurrent nerve palsy after resection of 11 enlarged tracheobronchial lymph nodes on the left side with extended exposure of the nerve and two minor bleeding complications, one from the azygos vein and another from a bronchial artery, both managed by video-assistant mediastinoscopic instrumentation with a blood loss below 50 ml.

Indication for mediastinoscopy in five out of 37 cases was to be excluded before proceeding with thoracotomy. Of those 32 patients with lung tumours histological examination confirmed 28 NSCLC, one SCLC and one mixed tumour. One tumour turned out to be a metastasis of a colon carcinoma. The histology of one left-sided tumour remained unknown, as resection could not be performed because of worsening of cardiac disease. In 30 patients radical lymphadenectomy by VAMLA was intended. In the remaining 7 patients a radical dissection was not attempted because of extensive nodal disease anticipated after CT-scanning or because of diffuse lymph node enlargement without lung tumour. The primary intention in these cases was to obtain a major amount of material for histological examination. In 27 out of those 30 patients in whom radical lymphadenectomy was indicated a radical dissection was achieved as judged intraoperatively. In one of 3 incomplete dissec- tions, 20 lymph nodes (12 of them with tumour involve- ment) were resected during mediastinoscopy, however parts of calcified subcarinal lymph nodes were left in place. In 2 other patients with a left-sided tumour, a par- ticularly fatty mediastinum prevented a radical extirpation in the paratracheal space, although in one case 17 and in the other case 21 lymph nodes were resected. After "radical" VAMLA, we re-explored the paratracheal compartments of 12 patients during right-sided thoracotomies performed for the resection of the lung tumour. In 10 paratracheal compartments we could not find any remaining lymphatic residual tissue. In one case two, in another case one lymph node was present. In those 12 right-sided and 6 more left-sided thoracoto- mies also the subcarinal region was re-explored. 10 of 18 re-explored subcarinal regions proved to be radically dissected by VAMLA. In six of the eight incomplete dissec- ted cases one node, in one case five nodes and in one more case eight nodes were found left behind by VAMLA. These data, however, include lymph nodes along the main bronchi of which the delineation from the subcarinal nodes is sometimes difficult and that are frequently as- signed hilar nodes (number 10). None of these nodes resected later during thoracotomy showed tumour involve- ment. Thus VAMLA did not result in any false negative N2-stage. The mean total number of lymph nodes resected using video-assisted mediastinoscopy was 20.5 (median 15, SD 12.5, minimum 6, maximum 60). From the left tracheobronchial location, a delicate region for dissection because of the proximity of the left recurrent nerve, a median amount of 4 (maximum 17) lymph nodes were removed (Table 1).
In our historical comparative collective of open nodal dissections for lung cancer, a mean amount of 8.2 (median 7.5, SD 6.1, maximum 26) lymph nodes were resected from the paratracheal/tracheobronchial and subcarinal compartment together. In comparison, VAMLA harvested significantly (p<0.0001) more nodes (mean 18, median 14, SD 10.6, max. 51) from the same regions than open dissection.

The weight of the specimens is detailed in Table 2. In this respect, there were no comparative data from the historical collective. Therefore we designed a small prospective study that has not been published yet. This study compared weight and node count for VAMLA and open nodal dissection for the paratracheal and infracarinal regions prospectively but not randomised. Again VAMLA proved to be at least equal to open nodal dissection (Figure 14), however more patients with advanced stage were included in the VAMLA group. This may have biased the results.

Table 2: Weight of resected tissue (VAMLA)

| [g]   | Mean | SD | min. | max. | Median |
|-------|------|----|------|------|--------|
| paratracheal | 5.5  | 4.4 | 0.5  | 19.4 | 4.8    |
| subcarinal  | 4.1  | 2.6 | 1.0  | 10.6 | 3.3    |
| left       | 0.9  | 0.6 | 0.2  | 2.6  | 0.8    |
| total      | 10.1 | 6.3 | 2.2  | 23.7 | 9.0    |

SD: Standard Deviation, min.: Minimum, max.: Maximum

Discussion

We have developed VAMLA to achieve a sensitivity for mediastinal lymph node metastases similar to open lymphadenectomy. Our study proves the technical feasibility of a radical paratracheal and subcarinal mediastinoscopic lymphadenectomy.

The duration of VAMLA exceeds that of standard mediastinoscopy, during which the lymph node stations are biopsied only. The operation time of VAMLA is more or less in the range of an open radical lymphadenectomy. The number of lymph nodes resected by VAMLA is significantly higher than that of the specimens resected from comparable compartments in our historical comparative collective. Those open nodal dissections in the historical collective were performed by numerous surgeons with varying radicality, whereas all the VAMLAs in the prospective collective were performed by only one surgeon under study conditions. Still with these shortcomings of a historical comparison, the number of resected nodes and the findings during re-exploration in subsequent thoracotomies prove at least an equal paratracheal and subcarinal radicality of VAMLA compared to open lymphadenectomy.

We have not obtained any false-negative histological findings after VAMLA. For conventional mediastinoscopy, up to one half of false-negative findings with regard to the following thoracotomy are reported [18]. The data on sensitivity of conventional mediastinoscopy range from about 50% [18], [19] to 89% [20]. In clinical stage I without enlarged lymph nodes, sensitivity was only 27.3% [18]. Particularly in case of solitary lymph node involve-
ment, which we found in 25% of N2 stages [12], VAMLA might improve sensitivity of mediastinoscopy. The subaortic region is not accessible by conventional collar mediastinoscopy. In VAMLA, the left recurrent nerve is clearly visible and can be followed towards the aortopulmonary window. This allows for safe resection of several left tracheobronchial nodes. However, we would still favour an extended mediastinoscopy [21], [22], [23] or a left-sided VATS to evaluate the subaortic and paraaortic lymph nodes if necessary. Statements concerning the incidence of complications can only be made on the basis of more cases. In the literature, a bleeding rate of 0.16% to 1.4%, with lethal bleedings amounting to 0.03% to 0.2%, is reported on [24]. The bleeding complications in our collective were of minimal importance and could be managed by video-mediastinoscopy. Major haemorrhages from the central vessels such as superior vena cava, azygos vein and pulmonary artery are very uncommon during video-mediastinoscopy, because these vessels are clearly visible due to the optical enlargement and the bimanual preparation [16]. In the management of minor bleedings from the bronchial arteries or marginal branches of the vena cava, VAMLA is indeed superior to conventional mediastinoscopy. Even a major bleeding, e.g. from the azygos vein, can be managed more easily by the better vision of video-assisted mediastinoscopy and above all the bimanual technique. While one instrument temporarily controls the haemorrhage, a clip or a suture can be applied by the second hand.

Recurrent nerve palsy is reported on, depending on the patient collective and the method of examination, after conventional mediastinoscopy in 0.15% to 6% [24], [25], [26]. The incidence of postoperative left-sided palsy of the recurrent nerve after thorakotomy and open subaortic nodal dissection is supposed to be about 5% [27]. In order to further lower the incidence of nerve damage, monopolar coagulation should be replaced by other methods, e.g. bipolar coagulation. We will consider this in the further development of VAMLA. The still small number of cases does not allow a statement on the incidence of recurrent nerve palsy after VAMLA. One palsy in our collective possibly resulted from an extensive dissection of the left tracheobronchial and subaortic compartment. In our opinion, VAMLA is particularly indicated prior to the initiation of neoadjuvant therapy. One point of criticism in neoadjuvant studies always is the uncertain pretherapeutic staging. Furthermore, VAMLA allows for a definite exclusion of mediastinal lymph node metastases prior to thoracotomy in patients with a high surgical risk. In the standard indication of the left-sided bronchial carcinoma as well, VAMLA is superior to conventional mediastinoscopy as to the evidence of paratracheal lymph node metastases. In minimally invasive video-assisted resections of bronchial carcinomas, the exclusion of mediastinal lymph node metastases by imaging techniques is generally demanded, although their insufficient sensitivity and specificity are well known. The video-assisted thoracoscopic mediastinal lymphadenectomy is complicated and time-consuming. A "surgical splitting" in VAMLA and subsequent video-assisted lobectomy would at the same time support the indication for VATS-lobectomy and facilitate the minimal-invasive resection more easy. Video-assisted mediastinoscopy is particularly suitable for the training of thoracic surgeons. Vision is enlarged by video technique and each surgical step can be pursued on the monitor.

Conclusions

Video-assisted mediastinoscopic lymphadenectomy (VAMLA) offers a dissection of the paratracheal, tracheobronchial and subcarinal compartment comparable to lymphadenectomy via right-sided thoracotomy. In the left paratracheal and tracheobronchial region, a clear preparation of the lymph nodes next to the recurrent nerve is possible. If necessary, preparation is possible along the main bronchi up to the origin of the upper lobe bronchus. The complication rate is low. Bleeding can be easily managed because of a good vision and the bimanual technique. Thus, VAMLA is markedly superior to conventional mediastinoscopy and in our opinion constitutes an important contribution to the staging of bronchial carcinomas. It plays a major role in neoadjuvant and minimally invasive concepts and finally is particularly suitable for surgical training.

Attachments

Available from http://www.egms.de/en/journals/tss/2005-2/tss000007.shtml

1. GMS-Huertgen-Vide1.mp4 (86.46 MB)
   This rather long and "unplugged" video-sequence nicely shows the advantages of bimanual dissection in VAMLA, video-mediastinoscopic paratracheal dissection with wide exposure of the Vena cava and azygos vein.

2. GMS-Huertgen-Vide2.mp4 (32.77 MB)
   Continued paratracheal dissection of Video 1 gives a realistic impression what a normal VAMLA looks like.

3. GMS-Huertgen-Vide3.mp4 (2.63 MB)
   Normal, nevertheless impressive, exposure of the right pulmonary artery. The origin of the first apical branch to the upper lobe is visible.

4. GMS-Huertgen-Vide4.mp4 (11.11 MB)
   A final tour around the dissected area showing the oesophagus in the infracarinal region, the recurrent nerve on the left side, Vena cava, azygos vein and mediastinal pleura on the right.
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