Surgical Exploration of the Mediastinum by Mediastinoscopy, Parasternal Mediastinotomy and Remediastinoscopy: Indications, Technique and Complications

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R. RAMI PORTA

Section of Thoracic Surgery
Hospital Mútua De Terrassa
Terrassa, Barcelona (Spain)

Abstract

Imaging diagnostics often fail to provide enough certainly to make therapeutic decisions, since radiological images do not always correlate well with the pathological condition of the lesions. Surgical exploration of the mediastinum by mediastinoscopy allows to obtain very accurate information from inspection, palpation and biopsies of lymph nodes or tumors directly affecting the mediastinum. Mediastinoscopy assesses the upper mediastinum, including nodal stations 1, 2R, 2L, 3, 4L, 7, 10R and 10L. It can also assess direct invasion of the mediastinum from adiacent tumors. Parasternal mediastinoscopy is a complementary technique to reach nodal stations 5 and 6, which cannot be reached with standard cervical mediastinoscopy. Remediastinoscopy has been performed to restage tumors after delayed treatment and to stage second primary and recurrent tumors. It has proved useful, too, to restage N2 lung cancer after induction chemotherapy. In all these indications, remediastinoscopy was technically possible. All these techniques are associated with very few complications (around 3%) and a low mortality rate of less than 1%.
Key words: Lung cancer, mediastinoscopy, mediastinotomy, remediastinoscopy.

Riassunto

Le tecniche di imaging non appaiono in grado di offrire informazioni certe per determinare le scelte terapeutiche nei pazienti con carcinoma del polmone perché spesso non sono aderenti alla realtà clinico-patologica del paziente. L'esplorazione chirurgica del mediastino attraverso la mediastinoscopia appare in grado di fornire informazioni accurate grazie alla ispezione, palpazione e possibilità di eseguire biopsie dei linfonodi o di masse neoplastiche direttamente sviluppatesi nel mediastino. La mediastinoscopia esamina il mediastino superiore e, nello specifico, le stazioni linfonodali 1, 2R, 2L, 3, 4L, 7, 10R e 10L. Inoltre può valutare l'invasione diretta da parte della neoplasia degli organi mediastinici. La mediastinoscopia parasternale rappresenta una metodica di indagine complementare poiché permette di raggiungere le stazioni linfonodali 5 e 6 non esplorabili attraverso la mediastinoscopia cervicale standard. Le procedure di remediastinoscopia consentono la ristadiazione di neoplasie dopo trattamento, di lesioni recidive come pure di secondi tumori primitivi. Inoltre un ruolo fondamentale riveste nella ristadiazione di tumori N2 dopo trattamento chemioterapico induttivo. In ognuna di queste indicazioni, la remediastinoscopia è stata tecnicamente realizzabile.

Introduction

Histology and classification-stage grouping are the most important prognostic factors in lung cancer. Clinical classification and staging is the assessment of the anatomic extent of the tumor before definitive therapy is administered. It is based on the findings of medical history, physical examination, imaging procedures, invasive procedures such as bronchoscopy, esophagoscopy, mediastinoscopy, mediastinotomy, thoracentesis and thoracoscopy, as well as any other procedure to demonstrate extrathoracic extension of the disease. Exploratory thoracotomy is included in the pathologic classification and staging process[1].

The minimal requirements for the clinical and pathologic classification-staging are the T (tumor), (N node) and M (metastasis) descriptors, and the histopathological grading (Tab. I)[1, 2]. Additionally, lymphatic invasion (Tab. II),

Tab. I G – HISTOPATHOLOGICAL GRADING

GX	Grade of differentiation cannot be assessed
G1	Well differentiated
G2	Moderately differentiated
G3	Poorly differendiated
G4	Undifferentiated

Tab. II L – LYMPHATIC INVASION

LX	Lymphatic invasion cannot be assessed
L0	No lymphatic invasion
L1	Lymphatic invasion

Complessivamente, tali metodiche appaiono gravate da una bassa percentuale di complicanze (circa 3%) e da una mortalità inferiore all'1%.
Parole chiave: Carcinoma del polmone, mediastinoscopia, mediastinotomia, remediastinoscopia.

venous invasion (Tab. III), residual tumor (Tab. IV) and the certainty factor (Tab. V) are optional descriptors that either help in the assessment of the tumor extent or in evaluating the intensity of the explorations[2].
Histopathological grading and lymphatic and venous invasions are entirely the domain of the pathologist. Assessement of residual tumor is both responsibility of the surgeon, who will define the location and extent of the macroscopic residual disease, and of the pathologist, who will examine the surgical margins of the resected specimens. Both surgeon and pathologist share responsibilities in the definition of the certainty factor.
Depending on the type of explorations used by the specialist in charge of the clinical classification and staging, the certainty factor will range from C1 to C3, C3 being the most accurate clinical classification. Both surgeon and pathologist will define C4 and, finally, C5 will be defined by the pathologist.
Surgical techniques for mediastinal exploration, such as mediastinoscopy, parasternal mediastinotomy or thoracoscopy help in the assessment of tumor extent, both locally (assessment of T factor) and regionally (assessment of N factor), and are included in the explorations for clinical classification and staging. At the same time, the evidence obtained by these explorations falls into the certainty factor C3 category, that is the most accurate evidence for clinical classification and staging. Given the importance of clinical classification and staging in planning and deciding on the most adequate treatment, it would be desirable that these surgical explorations were profusely utilized.

Tab. III V – VENOUS INVASION

VX	Venous invasion cannot be assessed
V0	No venous invasion
V1	Microscopic venous invasion
V2	Macroscopic venous invasion

Tab. IV R – RESIDUAL TUMOR

RX	Presence of residual tumor cannot be assessed
R0	No residual tumor
R1	Microscopic residual tumor
R2	Macroscopic residual tumor

Tab. V C – CERTAINTY FACTOR

C1	Evidence from standard diagnostic means (e.g., inspection, palpation, and standard radiography, intraluminal endoscopy for tumors of certain organs).
C2	Evidence obtained by special diagnostic means (e.g., radiographic imaging in special projections, tomography, computed tomography, ultrasonography, lymphography, angiography, scintigraphy, magnetic resonance imaging, endoscopy, biopsy and cytology).
C3	Evidence from surgical exploration, including biopsy and cytology.
C4	Evidence of the extent of the disease following definitive surgery and pathological examination of the resected specimen.
C5	Evidence from autopsy.

Mediastinoscopy

Indications

In lung cancer staging, mediastinoscopy is usefull in assessing the upper mediastinum, where there is the highest concentration of lymph nodes. Nodal stations #1, #2R, #2L, #3 pretracheal, #4R, #4L, #7, #10R and #10L[3] can be inspected, palpated and biopsied through mediastinoscopy. Mediastinoscopy can obtain histopathological diagnosis of a lung tumor that remained undiagnosed by other means (as in cases of small-cell lung cancer, for example), stages the nodal status of the tumor and assesses the T factor if the tumor is invading mediastinal structures that can be reached with the mediastinoscope. Therefore, mediastinoscopy can be both a diagnostic and a staging technique. Depending on the staging protocols of each team or working group, mediastinoscopy is indicated selectively, depending on the findings of the imaging techniques, usually computed tomography, or systematically, regardless of the radiological findings.

Technique

Position and preparation

Under general anesthesia and tracheal intubation, the patient is positioned in the supine decubitus. A sand bag between the patient's shoulders provides some hyperextension of the neck. The head is allowed to rest on a circular cushion to prevent lateral displacement of the neck during the operation.
The neck and the anterior chest wall to the lower costal

margin distally and to the posterior axillary line laterally on both sides are thoroughly cleaned with alcohol and Betadine. The operating field is limited with field towels and the patient is drapped. Four field towels limit the operating field from the thyroid, cephalad, to about two centimeters below the upper margin of the sternum, caudally. Towels on both sides go along the sternocleidomastoid muscles.

Incision and access to the mediastinum

A 5-cm transverse neck incision is performed above the superior border of the sternum. The subcutaneous tissue is incised with electrocautery till the sternal insertions of the sternocleidomastoid muscles are seen. An avascular area in the mid-line, between the paratracheal muscles, can be seen at this moment. This mid-line is incised with electrocautery and the paratracheal muscles are bluntly dissected and separated lateraly with Farabeuf retractors. Finally, the pretracheal fascia is seen. It is held with forceps and incised with scissors. A finger is slidded through this incision down into the mediastinum between the trachea and the sternum and behind the right innominate artery and vein.

Palpation of superior mediastinum

With the index finger, the trachea is palpated and the mediastinal fat separated from it in order to create a space wide enough to insert the mediastinoscope. Finger palpation is useful to determine whether the trachea adheres to the mediastinal tissue, whether there are lymph nodes and their consistency, and whether the lymph nodes or other tumors adhere to the trachea or mediastinal tissue.
Finger palpation must identify the right innominate artery, which runs about two centimeters deep from the neck incision. The right innominate artery can be followed with the index finger to its origin in the aortic arch. From this point, the posterior wall of the ascending aorta, in front of the trachea, can be palpated.

Inspection with mediastinoscope

The mediastinoscope is inserted into the superior mediastinum in front of the trachea and behind the right innominate artery and vein. If mediastinoscopy is indicated for staging of bronchogenic carcinoma, the inspection must be systematic in order to explore all lymph node stations that can be reached with this technique: highest mediastinal (#1), right and left superior paratracheal (#2R and #2L), pretracheal (#3), right and left inferior paratracheal (#4R and #4L), subcarinal (#7), and right and left hilar (#10R and #10L) nodes[3].

Biopsy

After identifying the tissue that has to be biopsied (tumor, lymph node), the surrounding fat has to be dissected away with the help of a suction-coagulation dissector. The area to be biopsied is then punctured with a needle connected to suction. This is an important step to perform before biopsying the lesion, since some vessels, especially veins, may look like lymph nodes, which are black or dark blue due to antracosis. If a vessel is punctured, the needle is withdrawn. The small hemorrhage usually stops spontaneously. Alternatively, the bleeding point can be compressed with a gauze for one or two minutes.
When mediastinoscopy is indicated for lung cancer staging, all accessible nodal stations must be explored. Some times, the paratracheal nodes are not evident and must be dissected out from the paratracheal fat. The suction-electrocoagulation dissector is very useful in these cases. Usually, there are more nodes on the right paratracheal stations than on the left.
On the right paratracheal area, the trachea is separated from the right mediastinal pleura by fatty tissue and lymph nodes. Tearing of mediastinal pleura may cause pneumothorax. Anterior to the trachea lays the superior vena cava, the biopsy of which must be avoided.
At the level of the carina, the subcarinal lymph nodes are covered by the distal extension of the pretracheal fascia. It must be incised to reach the subcarinal lymph nodes. At least, one subcarinal node can be identified, but two or three are usually seen along the inferior margins of the main stem bronchi. In this group of lymph nodes there is more bleeding after biopsy, in comparison with other nodal stations. This is due to the presence of bronchial arteries. However, bleeding is easily controlled with electrocoagulation or gauze compression. Occasionally, clipping of a bronchial artery is necessary.
On both sides of the carina, the right and left main stem bronchi can be dissected and identified along two or three centimeters from the trachea. On the right side, except in cases in which the tumor is too close to the tracheobronchial angle, the mediastinoscope can be passed under the azygos vein and the right upper lobe artery and, sometimes, the origin of the right upper lobe bronchus can be seen. On the left side, the mediastinoscope can reach the left pulmonary artery.
On the left paratracheal area, the tissue that has to be biopsied must be clearly seen and the fatty tissue dissected away from it in order to avoid injury of the left recurrent laryngeal nerve, that runs along the left paratracheal margin. Electrocautery is kept to the minimum to avoid its injury, too. Dissection should not be followed too posteriorly, since the esophagus lays behind the trachea and can also be injured.
In front of the trachea, the pretracheal lymph nodes can be identified and easily biopsied after they are dissected from the surrounding fatty tissue.

Hemostasis

Before withdrawing the mediastinoscope and terminate the operation, all biopsy sites much be checked for bleeding. Coagulation or gauze pressure are used as needed.

Closure

The paratracheal muscles are not approximated to the mid-line. The platisma and the subcutaneous tissue are sutured in one layer using 2-0 absorbable material. An intradermic suture with 3-0 absorbable material is used for the skin.

Complications

Surgical complications of mediastinoscopy include: wound infection, mediastinitis, pneumothorax (usually on the right side), injury to left recurrent laryngeal nerve, esophageal perforation and venous or arterial hemorrhage.

Parasternal mediastinotomy

Indications

Parasternal mediastinotomy is a complementary technique for left lung cancer staging, since standard mediastinoscopy cannot reach the subaortic (#5) or the para-aortic (#6) nodes[3]. It also allows to delucidate whether a lung cancer is actually invading mediastinal structures or not; in this case, parasternal mediastinotomy is particularly helpful in the assessment of tumors located in the aortic-pulmonary window.
Parasternal mediastinotomy can be performed simultaneously with mediastinoscopy.
Finger palpation with both hands and through both incisions allows a very thorough evaluation of the aortic arch, especially in tumors of the aortic-pulmonary window.
In expert and trained hands, parastemal mediastinotomy can be substituted by the so called extended cervical mediastinoscopy[4, 5] Through the mediastinoscopy incision, the mediastinoscope is inserted between the brachyocephalic and the left carotid arteries, posterior or anterior[6] to the left innominate vein, into the subaortic space.
This approach is useful to reach the subaortic nodes, but palpation of the subaortic area is virtually impossible.

Technique

Position and preparation

The patient is positioned and the operating field is prepared as for mediastinoscopy. The inferior border of the operating field is limited by a field towel at the level of the third rib.

Incision and access to the mediastinum

This procedure can be performed both on the right and left sides, depending on the indication. If parasternal mediastinotomy is indicated for left lung cancer staging, it is performed on the left side to explore the subaortic region and to biopsy the subaortic and anterior mediastinal lymph nodes.
A 6-7 centimeters transverse incision is performed on the second left costal cartilage.
Dissection is carried out separating the fibers of the left pectoralis major muscle. The second costal cartilage is resected subperichondrally.
Below the perichondrium there appear the left internal mammary artery and veins. These vessels are ligated independently. Alternatively, about one centimeter of the medial end of the second cartilage is saved, so that the internal mammary vessels remain protected under the cartilage; in this case, ligation of the vessels is avoided. If there are lymph nodes at this level, they should be biopsied or resected and sent for pathological diagnosis. In patients with bronchogenic carcinoma, these nodes can be affected, although this finding is not very common. Once the interior mammary vessels are ligated or kept under the cartilage, the mediastinal pleura is separated laterally with an index finger. This manoeuvre allows access to the deep subaortic region in an extrapleural fashion.

Palpation

Once the mediastinal pleura is separated, the ascending aorta, the aortic arch and the subaortic space can be palpated. Lymph nodes or tumors adhered to or invading the aortic-pulmonary window can be palpated.

Inspection with mediastinoscope

A flat retractor can keep the mediastinal pleura separated laterally and the subaortic space can be inspected directly. Alternatively, the mediastinoscope can be inserted through the same insicion. In obese patients, inspection of this space is limited by mediastinal fat. A small rib spreader is helpful in keeping the insicion open when peanuts on forceps, suction tubes or biopsy forceps are used.

Biopsy

Biopsying nodes or tumors in this area must follow the same rules as in mediastinoscopy. The tissue to be biopsied must be punctured with a needle connected to suction to avoid biopsy of vessels.
Lymph nodes must be dissected from the surrounding fatty tissue to avoid injury to the vagus or left laryngeal recurrent nerves. If dissection is carried out too anteriorly, the left phrenic nerve can be injured, too.
On the right side, special caution must be taken not to injury the superior vena cava and accompanying right phrenic nerve.

Hemostasis

All biopsy sites, mediastinal fat, stumps of internal mammary vessels, pectoralis major muscle and perichondrium must be checked for bleeding.

Closure

The incision is closed in four layers: perichondrium, pectoralis major muscle, subcutaneous tissue and skin. For the first three layers, 2-0 absorbable material is used. The skin is closed with 3-0 absorbable material in an intradermic fashion.

Complications

Wound infection, mediastinitis, injury to the internal mammary vessels and pneumothorax may occur on both sides. On the right side, injury to superior vena cava and phrenic nerve are specific complications of right parasternal mediastinotomy. On the left side, structures that can be injured include: left phrenic, vagus and recurrent laryngeal nerves. The aorta and the left pulmonary artery can be injured during exploration of the subaortic space.
Complications of both mediastinoscopy and parasternal mediastinotomy are very rare and occur in around 3% of the cases. Mortality rate is below 1%[7, 8].

Remediastinoscopy

Indications

Remediastinoscopy has been indicated to stage second primary and recurrent tumors[9, 10], to complete an inadequate first mediastinoscopy[11], to restage tumors after delayed treatment[12] and to restage lung cancer after neoadjuvant chemotherapy for N2 disease[13]. In all these situations, remediastinoscopy is technically possible and in the cases of restaging after induction chemotherapy, our own experience with 23 cases shows that the same nodal stations that were biopsied in the first mediastinoscopy can be biopsied again in the remediastinoscopy. Fifteen of the 23 cases had persistent N2 (14 cases) or new N3 (1 case) disease after induction chemotherapy and were excluded from surgical treatment.

Technique

The rules for mediastinoscopy also apply for remediastinoscopy. We resect the previous incision. Dissection has to be meticulous due to the adhesions caused by the first procedure, but a wide enough passage along the trachea can be made combining digital dissection and electrocautery.
When remediastinoscopy is performed for restaging after induction chemotherapy, the objective must be to biopsy, at least, the same nodal stations that were positive in the first procedure. However, if possible, other stations should be biopsied, too, to rule out progression of disease and new N3 disease, as in one of our patients.
Parasternal remediastinotomy is also possible and should be done in those cases in which the nodal stations #5 or #6 were positive. The technique does not differ from standard parasternal mediastinotomy.

Complications

The same complications can occur as in mediastinoscopy and parasternal mediastinotomy. Patience, meticulous dissection and precise technique are the key points to avoid complications.

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