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MULTIMEDIA MANUAL OF CARDIO THORACIC SURGERY
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Anterior approach for Pancoast tumor resection

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Tumors arising anteriorly in the apex of the chest were long considered unresectable because of early invasion of vascular structures limiting radical resection through the conventional Paulson approach. These tumors became operable in 1993 when Dartevelle popularized the cervico-thoracic transclavicular technique for resecting these neoplasms. Since then several different surgical approaches to anterior Pancoast tumors have been proposed, drastically improving the rate of radical resections of these tumors. However, there is no consensus on which anterior surgical approach provides the best access to all of the apical non-small cell lung cancers of the thoracic inlet. Moreover, it is still unclear if integrated neoadjuvant and adjuvant treatments can improve the rates of complete resection, local recurrence and long-term survival.

Keywords: Anterior approach; Hemiclamshell approach; Lung cancer; Pancoast tumor; Transmanubrial approach

Introduction

For many years, apical chest tumors have represented a challenge for thoracic surgeons.

Tumors arising posteriorly in the lung apex (currently referred to as superior sulcus tumor or Pancoast tumors), became 'surgically manageable' after the experience of Shaw and Paulson in 1961 [1, 2]. By contrast, tumors of the apical lung involving anterior outlet structures (mainly subclavian vessels), were not amenable to surgical resection. In recent years, anteriorly situated apical lung cancer (the so-called 'anterior Pancoast tumors'), have been progressively defined as an independent category with specific clinical characteristics [3, 4]. These include symptoms of shoulder and thoracic pain due to first rib and anterior scalene muscle infiltration, phrenic nerve palsy, venous dilation and stasis due to subclavian vessels' compression or infiltration and specific radiological features at presentations. These tumors became resectable after the publications by Dartevelle et al. in 1981 [5] and subsequently in 1993 [6], that popularized the cervico-thoracic 'transclavicular' technique used by French vascular surgeons [7].

Since then several different surgical approaches to anterior Pancoast tumors [8–10] have been pro-

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posed, drastically improving the resectability even in cases with involvement of the subclavian vessels. However, the ideal anterior approach capable of exposing the anterior anatomical structures of the thoracic inlet is not yet defined, and the choice on which one to use depends on the experience and the personal feeling of each surgeon.

History

In 1932, Pancoast first described the clinical and radiological findings associated with tumors arising in the apex of the lung with invasion of the outlet structures [1]. The prognosis of these tumors, representing $<5\%$ of all NSCLC, remained poor until 1961 [2] when Shaw and Paulson reported their satisfactory results with bimodality therapy of preoperative radiotherapy followed by surgical resection through a posterior thoracotomy approach. This experience was confirmed by several others [3–10] reporting a 5-year survival of 25–30% achieved by this combined approach, which became the standard treatment for the past 25 years.

All these studies recognized radical surgical resection as the major prognostic factor influencing long-term survival. In this regard, the Paulson approach was successful in dealing with posteriorly located Pancoast tumors while it was unsatisfactory in the presence of invasion of anterior located structures, especially the subclavian vessels.

In 1979, Masaoka et al. [3] first proposed an anterior trans-sternal approach performed through a proximal median sternotomy extended into the anterior fourth intercostal space below, and the base of the neck above on the appropriate side. This approach guaranteed excellent exposure of the tumor anteriorly, however, the exposure of the brachial plexus, the ribs posteriorly, the transverse processes and the border of the vertebral bodies was limited making resection of these structures difficult. Later, to address these limitations, the Masaoka group [4] described a variation of this approach using the so-called 'Hook approach', performed with a long periscapular skin incision around the axilla from the level of the seventh cervical vertebra to the midclavicular line above the nipple. However, it was not popularized because of the enormous extension of the incision, which led to serious wound closure complications. In 1993, Dartevelle and colleagues [5–7] popularized the transcervical-thoracic approach. This technique, realized through a large L-shaped anterior cervical incision and the removal of the internal half of the clavicle, achieved an encouraging percentage of radical surgical resections with an acceptable percentage of morbidity and mortality, even in cases of subclavian vessels infiltration and sectioning its muscular insertions led to serious postoperative alterations (Photos 1 and 2).

Photo 1. Patient with functional and cosmetic consequences after surgery with transclavicular approach.

Photo 2. Shoulder deformity following the resection of the clavicle with the transcervical (Dartevelle) approach.

In 1997, Grunenwald and Spaggiari [8] proposed the transmanubrial approach. A manubrial L-shaped transection and first cartilage resection allow retraction of an osteomuscular flap including but sparing the clavicle and its muscular insertion. This approach affords excellent access to the subclavicular region with safe resection of neurovascular outlet structures during the resection of apical chest tumors, thus avoiding the functional and cosmetic consequences of clavicle resection (Photo 3).

Thoracic surgeons of the Memorial Sloan-Kettering Cancer Center, reported in 1994 by Bains et al. [9]

Photo 3. Clavicle transmanubrial approach preserving the symmetry of the thoracic inlet.

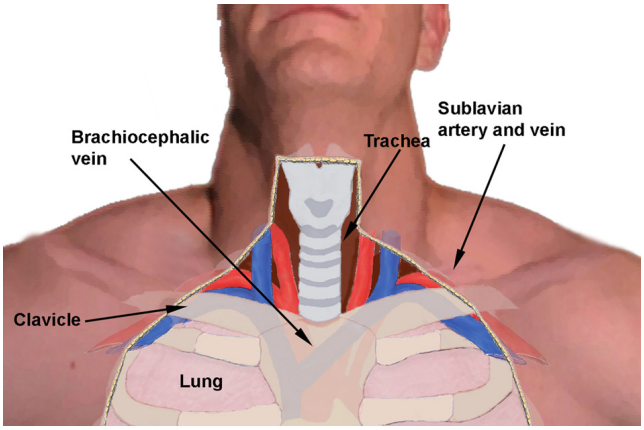
and in 1998 by Korst and Burt [10], used the hemiclamshell approach for the resection of the cervicothoracic tumors.

So far, several modifications of these techniques have been proposed without adding significant clinical innovation [11–16].

Anatomy of the thoracic inlet

The thoracic inlet is the most superior aperture to the thorax and the boundary of the roof of the mediastinum. The bony margins of the thoracic inlet are the first thoracic vertebra posteriorly, the first rib laterally and the first costal cartilages and the manubrium sterni anteriorly. Its anteroposterior diameter is generally of 4.5–6 cm and its transverse diameter is approximately 9–11 cm. The major vessels of the head and the upper extremities, as well as the trachea and the esophagus exit the thorax through the thoracic inlet (Schematic 1). This anatomical region can be schematically divided into three compartments by ideal planes corresponding to the anterior, middle and posterior insertion of the scalene muscles on the first two ribs.

The anterior compartment (prescalene) lies anterior to the insertion of the anterior scalene muscle onto the first rib and contains the sternocleidomastoid, the platysma and the omohyoid muscles and the lymphatic chains. This plane also gives passage to the subclavian veins, immediately behind the clavicles. Both these veins combine with the internal and external jugular veins creating the brachiocephalic veins that confluence into the superior vena cava (SVC). At this level, the thoracic duct also flows into the SVC while the phrenic nerves lie on the anterior surface of the



Schematic 1. Anatomy of the thoracic inlet.

anterior scalene muscles. The middle compartment (interscalene) extends from the posterior margin of the anterior scalene muscle to the posterior border of the middle scalene muscle. This area is crossed by the main arteries exiting the thorax: the innominate artery on the right side, which gives rise to the right carotid and the right subclavian artery; and the left carotid and subclavian artery on the left side. This space is also occupied by the trunks of the brachial plexus and medially, by the vagus nerves. Finally, the posterior compartment (extrascalene) lies posteriorly to the middle scalene muscles giving passage to the posterior scapular arteries and including the accessorius spinalis nerves, the sympathetic chain, the stellate ganglion, the neural foramina and the vertebral body.

Pathology

These tumors represent $<5\%$ of all non-small cell lung cancers. Adenocarcinoma is the most common histological type reported, followed by squamous cell carcinoma and large cell carcinoma [17]. Recent reports indicate that its biology is not different from the usual NSCLCs with high predilection for local recurrence, nodal involvement and distant metastases conditioning the prognosis [17–21]. Pancoast tumors can be schematically classified into three groups, each presenting different technical considerations in choosing the best surgical approach for radical tumor resection en bloc with the involved structures.

- Posterior: NSCLC infiltrating one of the following structures: the posterior arc of the first rib, the nerve root of the brachial plexus, the sympathetic chain, the stellate ganglion, the neural foramina and/or the vertebral body (C7-D1).
- Anterior: NSCLC involving one of the following structures, the anterior arc of the first rib, the scalene muscle, the subclavian vein and/or the subcla-

vian artery, the 'Pirogoff' (jugulo-subclavian) confluence.

- Mixed

Macchiarini [22] recently reviewed the indications for using the Shaw and Paulson approach or an anterior surgical approach in these cases. He proposed an anterior approach for the resection of any superior sulcus tumor involving the Sibson's fascia (endothoracic fascia) at the upper thoracic aperture. Otherwise Pancoast tumors with predominantly posterior spread, without evidence of invasion of the Sibson's fascia may be radically resected by the classic posterior approach.

Patient selection

Patient selection is a crucial step in determining the success of the surgical treatment. Each case should be evaluated preoperatively to assess operability on the basis of both oncological and functional criteria.

Oncological criteria of patient selection at the European Institute of Oncology

The preoperative evaluation for all patients presenting with anterior Pancoast tumor includes history, physical examination, routine blood tests, ECG, spirometry, and perfusion lung scan. Staging protocol for all cases includes chest radiography, fiberoptic bronchoscopy, thoracic, upper-abdominal, and cerebral CT scan and PET scan. Standard angiography and MRI are not routinely employed and they are performed on a case-by-case basis. The presence of extrathoracic metastases as well as histologically confirmed contralateral mediastinal lymph-node involvement (pN3) and pN2 disease represent an absolute contraindication to surgical resection. In case of suspicion of N2 disease revealed by CT scan (lymph node enlarged >1.5 cm) and/or positive PET scan, mediastinoscopy is performed and cases of confirmed N2 disease are excluded from surgery.

Patients with pathological ipsilateral supraclavicular lymph-node disease are considered for resection (after induction chemotherapy) if a mediastinoscopy excludes the presence of associated N2 disease. There is evidence reported in literature that patients with anterior Pancoast tumor with ipsilateral pN3 disease show a prognosis more akin to that of pN1 features and overall better than pN2 disease [23].

Induction chemotherapy of three cycles is administered to all candidates for surgical resection, followed by re-evaluation with total body CT scan and PET scan. In case of stable or regressive disease, the patients undergo the operation. Otherwise, patients with progression of disease are excluded from surgery.

The rationale for induction chemotherapy alone or in combination with radiotherapy has been widely described [24, 25–32].

Functional patient selection

Functional evaluation of patients with anterior Pancoast tumors is an essential step in assessing the overall operative risk and in estimating the residual cardiac and respiratory reserve after surgery. The preoperative work-up includes routine blood tests, ECG, echocardiography, spirometry with DLCO and perfusion lung scan. Other functional tests can be performed as needed to assess the overall operative risk. Resection is considered functionally possible in the absence of major morbidities with a predicted postoperative FEV1 $\geq 40\%$. Otherwise, in the presence of values of predicted FEV1 between 30% and 40% the final decision on the functional operability is decided on a case-by-case basis, considering associated comorbidities.

Finally, smoking cessation, respiratory exercises, and an optimal postoperative pain management are essential steps in reducing the risk of postoperative complications

Surgical technique

At the European Institute of Oncology we usually approach anterior Pancoast tumors using the transmanubrial and/or the hemiclamshell accesses.

We generally use the transmanubrial approach (TMA) in cases with involvement of the subclavian vessels while we prefer the hemiclamshell one, if the tumor involves the brachiocephalic veins and/or the Pirogoff confluence (jugulo-subclavian-brachiocephalic veins confluence). Rarely, both accesses are required in a single case.

The transmanubrial (TMA) approach

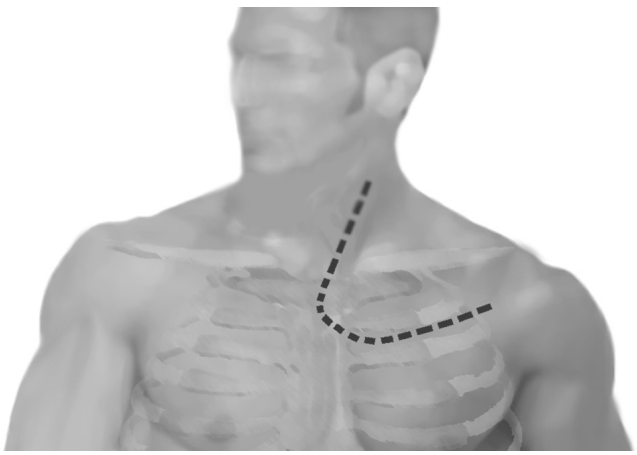
The patient is placed in the supine position on the operating table with arms abducted 90° and a roll is placed under the shoulder on the side of TMA (Photo 4).

An L-shaped skin incision is performed with the upper line on the anterior part of the sternomastoid as far as the angle of manubrium and two fingers below the

clavicle (Schematic 2 and Photo 5). The clavicle and its muscular insertions are not divided. The major pectoral muscle is spared and the sternomastoid muscle is freed along its anterior part from cervical tissue up to internal jugular vein exposing the sternal manubrium (Video 1).

The internal thoracic mammary peduncle is divided and the superoexternal part of the manubrium (2 cm $\times$ 2 cm) is sectioned through an L-shaped incision resecting the sternoclavicular articulation (Schematic 3, Photo 6, Videos 2 and 3). In order to subsequently lift the osteomuscular flap, the first costal cartilage has to be is resected (Photo 7). Afterward, the costoclavicular ligament is dissected to open the pincer formed by the first rib below and the clavicle above (Photo 8). The flap is then progressively elevated by means of a lace around the manubrial 'edge' (Schematic 4, Photos 9 and 10, Video 4).

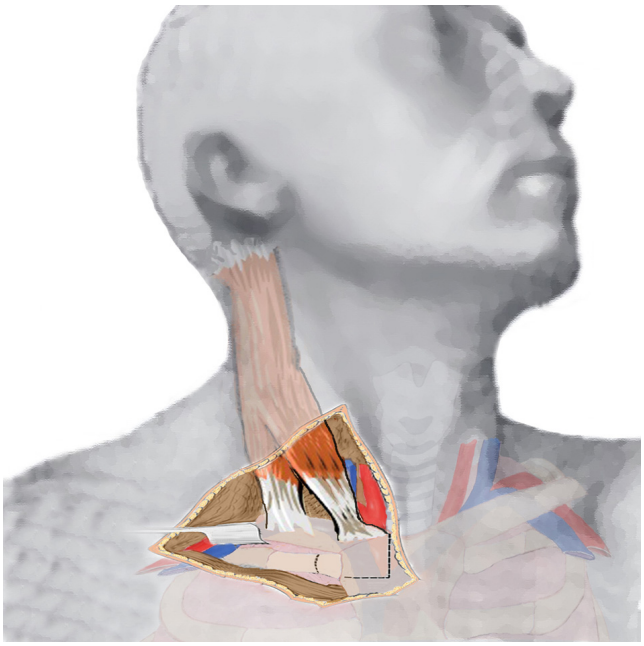
Photo 4. Patient position for transmanubrial access with associated anterolateral thoracotomy for pulmonary lobectomy and radical lymphadenectomy.



Schematic 2. Cutaneous incision.

Photo 5. Cutaneous incision of the TMA approach.

Video 1. The transmanubrial approach: surgical technique. A left L-shaped skin incision is performed along the anterior margin of the sternocleidomastoid muscle below the manubrium sterni and two fingers below the inferior margin of the left clavicle. The operation proceeds with the dissection of the internal jugular vein.



Schematic 3. Manubrial resection.

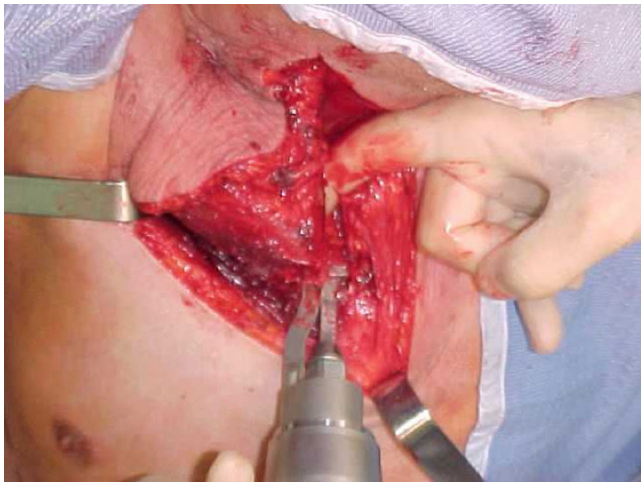
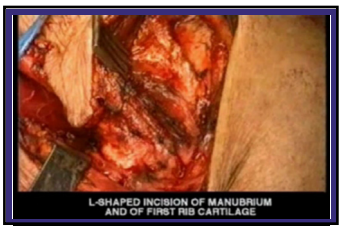


Photo 6. Manubrial resection with sternotomy.

Video 2. Patient from Video 1. The clavicular portion of the major pectoral muscle is sectioned and separated by its clavicular portion, exposing the costal plane. The first intercostal space is opened and the internal mammary peduncle isolated, bound and sectioned.



Video 3. Patient from Video 1. The superior-external portion of the manubrium sterni is sectioned using the sternotome.

Afterwards, starting from the internal jugular vein and Pirogoff confluence, the subclavian vein is carefully dissected from the subclavian muscle. Venous branches must be cautiously divided to mobilize the main venous axis and to expose the phrenic nerve and the anterior scalene muscle (Video 5). At the same time, the laterocervical vascular vessels (carotid arteries) can be controlled and the cervical lymphadenectomy can be performed. The section of the anterior scalene muscle exposes the subclavian artery and its branches (Photo 11). The subclavian artery may then be carefully dissected as well as the brachial plexus and the posterior part of the first rib isolated, if necessary (Video 5).

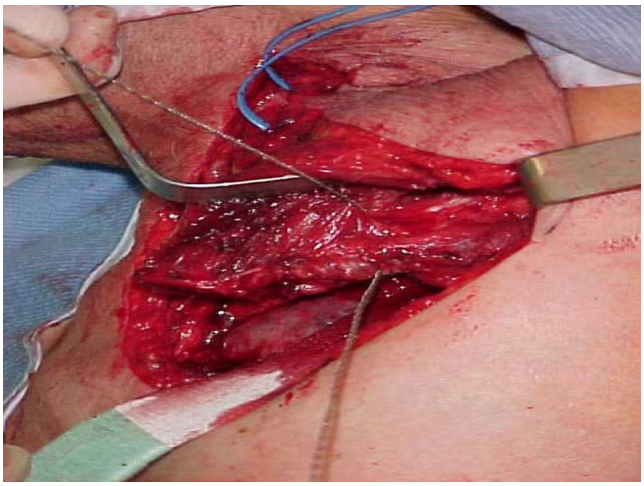


Photo 7. Resection of the cartilage of the first rib with Gigli's saw.

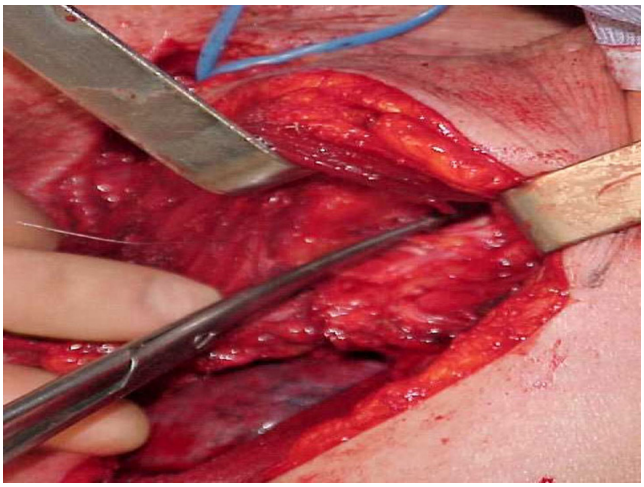
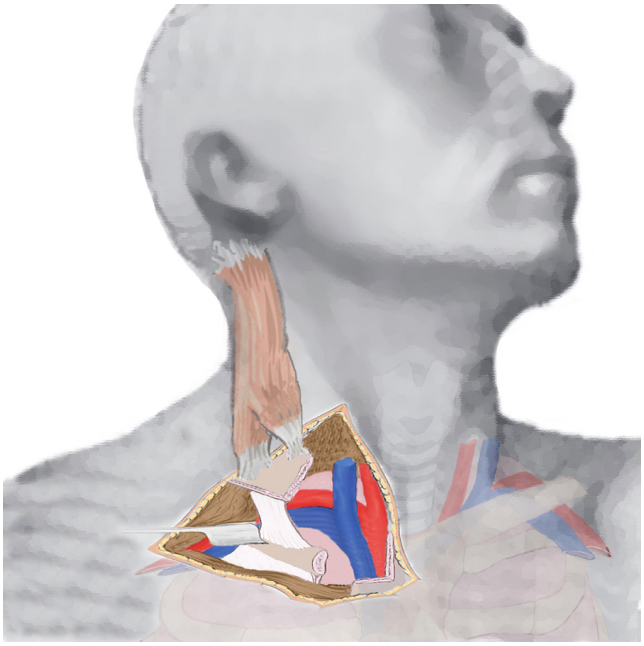


Photo 8. Dissection of the costo-clavicular ligament.



Schematic 4. Opening of the costo-clavicular space.

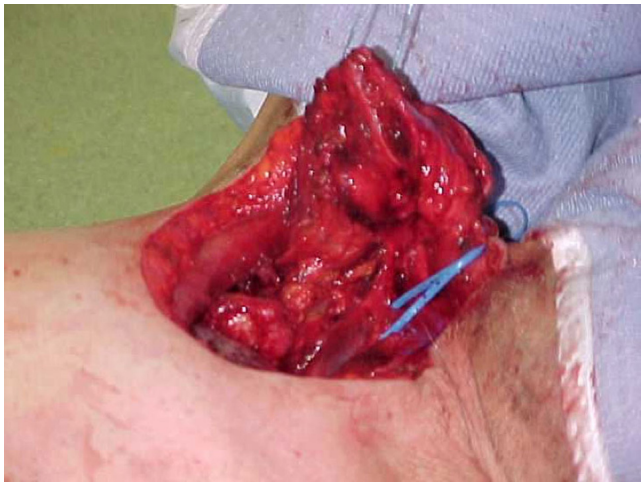


Photo 9. Intraoperative picture of the retraction of the clavicle allowing for the dissection of the subclavian veins.

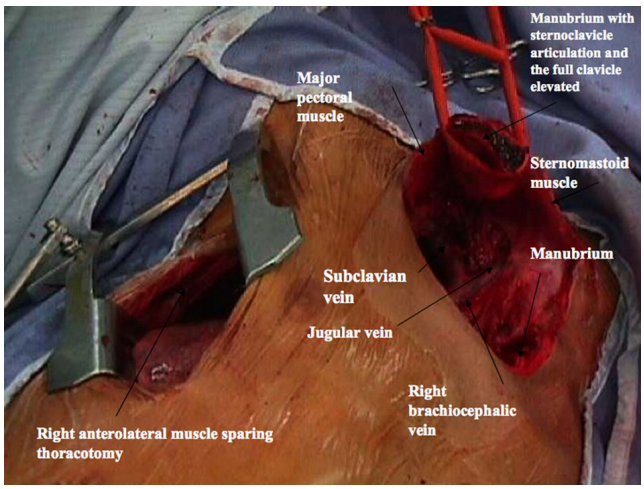
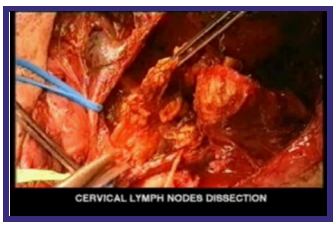


Photo 10. Intraoperative picture of transmanubrial approach and anterolateral thoracotomy for pulmonary resection and mediastinal lymphadenectomy.

Video 4. Patient from Video 1. The first costal cartilage is sectioned using the Gigli saw. To complete the mobilization of the clavicle, the costo-clavicular ligament is sectioned. This structure is thick and hard anchoring the clavicle to the first rib. This section must be performed with caution to avoid injury to the subclavian vein situated immediately behind the ligament.

As far as the subclavian vessels are concerned, in the majority of cases the artery can be freed resecting the adventitial plane (Video 6); sometimes, the dissection



Video 5. Patient from Video 1. The confluence between the internal jugular vein, the subclavian vein and the brachiocephalic vein must be prepared to achieve complete vascular control. The subclavian lymph-node dissection and the section of the anterior scalene muscle permits exposure of the subclavian artery. The artery can be freed by the tumor on the subadventitial plane. The brachial plexus is then prepared and if required some branches may be sacrificed.

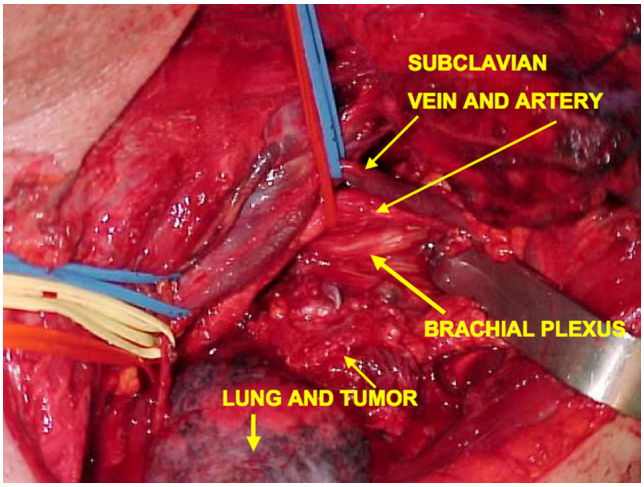
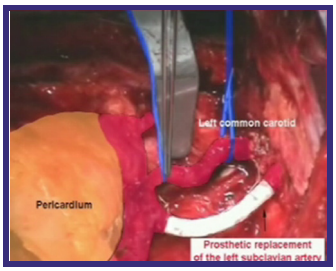


Photo 11. Intraoperative picture with a view of the superior thoracic inlet after vascular dissection.



Video 6. Vascular procedures. Apical chest tumor involving the subclavian vessels. The vessel can be freed using the subadventitial plane. If the cancer infiltrates the vessel's wall the clamping and the resection of the vessel en bloc with the tumor may be required. The vascular reconstruction may be obtained performing an end-to-end anastomosis or using a prosthesis.

requires a complete clamping to resect the collateral circle just at the origin of the subclavian artery (Video 6). Instead, when the arterial wall is infiltrated, the resection of the artery may be safely achieved and the vessel can be reconstructed by an end-to-end

Video 7. In this case, there is an associated posterior thoracotomy to allow en bloc resection of the thoracic wall, transverse vertebral processes, pulmonary lobectomy with lymphadenectomy. The incision at the 5th intercostal space allows for exploration of the cavity before the resection of the thoracic wall, which is excised en bloc with the tumor.

anastomosis or by a polytetrafluoroethylene graft (Video 6). The subclavian vein can be resected when infiltrated without subsequent revascularization. When the apical portion of the tumor is completely freed from anterior cervico-thoracic structures the upper lobectomy and a mediastinal lymph-nodal sampling can be achieved through the same surgical approach. However, we prefer to perform the lobectomy with radical mediastinal lymph-node dissection through an accessory antero-lateral muscle sparing thoracotomy performed without changing the patient position on the operating table (Photos 4, 10 and 12). Otherwise, Paulson thoracotomy is preferred in cases of large posterior chest wall resection, and in cases with vertebral body infiltration (Photo 13, Videos 7–10). At the end of the dissection, manubrium osteosynthesis is performed by means of two separate non-reabsorbable threads.

The hemiclamshell approach

The position of the patient may be variable according to the type of resection planned. When the tumor

Photo 12. Intraoperative picture at the end of the surgery.

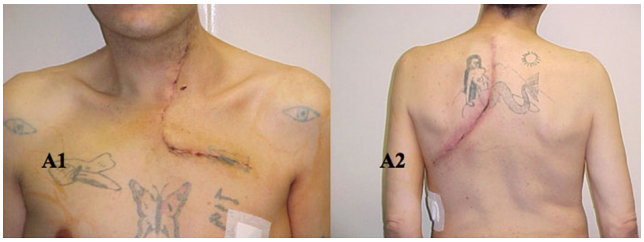
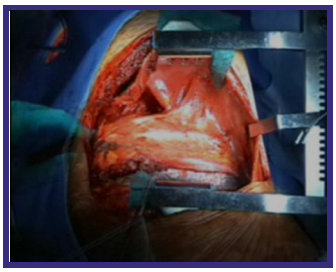


Photo 13. Patient with TMA and associated posterior thoracotomy for vertebral involvement.

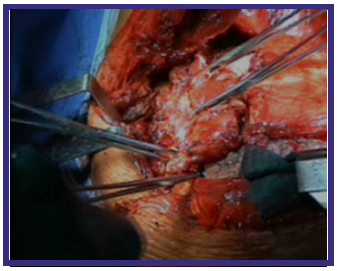
invades anteriorly situated structures without major involvement of the bronchial tree, the patient is placed in the supine position with both arms abducted. When associated bronchoplasty is necessary, the patient is placed in the lateral position.

The first step is an antero-lateral muscle sparing thoracotomy entering at the IV space (Video 11). Through this initial approach, it is possible to evaluate the extension of the tumor onto the thoracic inlet and the grade of infiltration of the involved structures. The skin incision is then completed from the medial margin on the sternocleidomastoid muscle to the middle of the sternum as far as the thoracotomy. The thoracic internal mammary peduncle is sectioned and a partial sternotomy is made to join the opened intercostal space obtaining a sternocostal flap (Video 11). The flap is then progressively elevated.

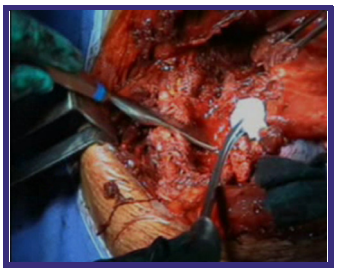
The sternoclavicular junction is left untouched. Through this surgical approach it is possible to have the area of the origin from the aortic arch of the carotid and subclavian arteries on the left side (Video 12) and of the superior vena cava and the Pirogoff confluence on the right side all under control (Video 13). Otherwise the distal part of these vessels is not completely accessible rendering the posterior chest wall resection difficult. We reserve, therefore, this surgical approach to apical chest tumors infiltrating the venous system proximally as well as the arterial branches. In the majority of cases, the arteries can be freed resecting the adventitial plane. This approach



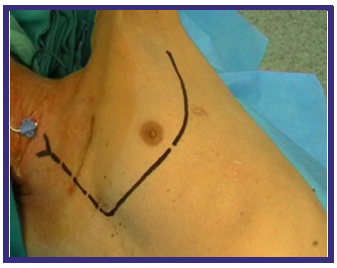
Video 8. Patient from Video 7. The thoracotomy begins with the section of the anterior margin of the infiltrated ribs, at least 3–4 cm from the tumor.



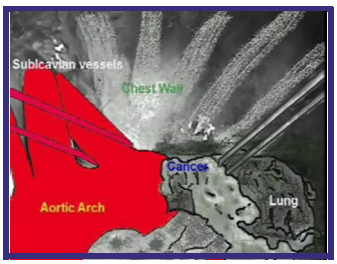
Video 9. Patient from Video 7. The ribs are disarticulated posteriorly, and some transverse processes are sectioned.



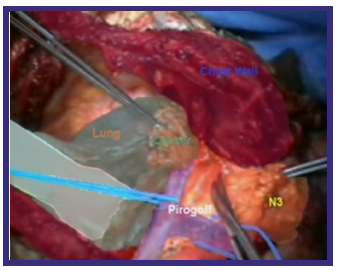
Video 10. Patient from Video 7. At the end of the disarticulation, the roots of C8-T1 are sectioned.



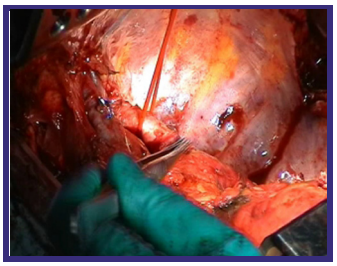
Video 11. Patient with left pulmonary tumor infiltrating the subclavian artery up to its origin. Histological diagnosis is obtained with left anterior mediastinotomy. A nearly complete response is obtained with 3 cycles of induction chemotherapy. A left hemiclamshell approach is used with the patient in left lateral decubitus position.



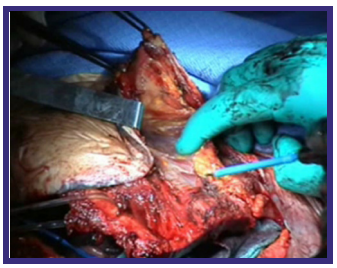
Video 12. Patient from Video 11. Subadventitial dissection of the aortic arch, at the level of the origin of the subclavian artery. Tissue samples from the vascular wall are sent for intraoperative histologic exam.



Video 13. Mediastinal lymphadenectomy and isolation of the venous trunk of the supraaortics.



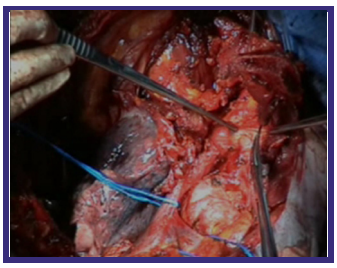
Video 14. Patient from Video 3. It is not possible to control the right subclavian artery distally via the hemiclamshell approach, therefore, a TMA is undertaken. Section of the manubrium, the cartilage of the first rib with Gigli saw, and of the costoclavicular ligament. The exposure is obtained.



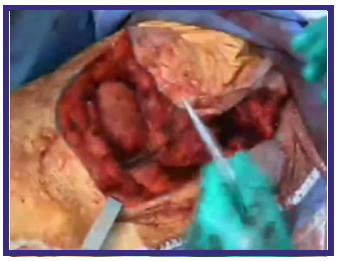
Video 15. Patient from Video 3. Vascular dissection is underway.

also permits both tangential or complete resection of the superior vena cava with end-to-end anastomosis or followed by prosthetic replacement. Through the same access it is also possible to perform thoracotomy extended over the second rib as well as lobectomy with radical mediastinal lymph-node dissection (Video 13). The hemiclamshell approach is closed by using reabsorbable sutures (Video 14).

Rarely an accessory anterior approach may be required to radically resect the infiltrated structures of the thoracic inlet, such as the distal portion of the subclavian artery. In these cases we add the hemiclamshell approach to the transmanubrial one (Videos 15–17).



Video 16. Anterior scalene muscle section that allows the liberation of the subclavian artery. Completion of the thoractomy with section of the posterior portion of the first rib.



Video 17. Closure of the thoracotomy. Note the en bloc section of the resected tumor with 2 ribs. View of the patient postoperatively.

Results

A review of the English-language international literature over the last 10 years, excluding case reports, revealed only four published series in which the cervico-thoracic approach was used for anteriorly situated NSCLC [6, 10, 33, 34].

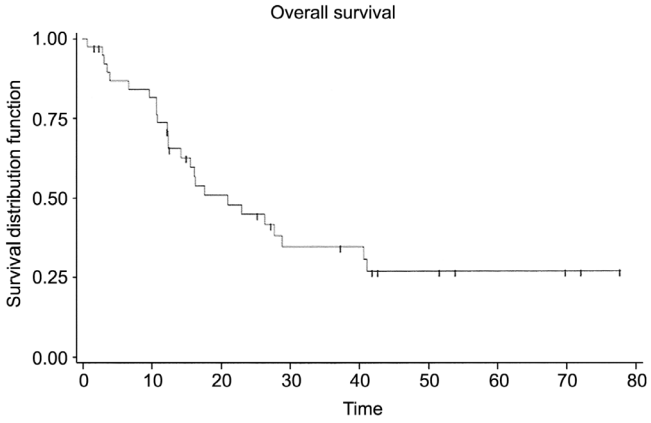
Dartevelle and colleagues in 1993, presented a series of 29 patients operated on for apical NSCLC during a period of 11 years by using the transclavicular approach. In this series 14 patients underwent wedge resections and 20 patients required a second posterolateral thoracotomy to complete the resection. Despite their frequent use of wedge resections that can compromise curability, the results in terms of 5-year probability of survival were 31%, similar to the survival results in superior sulcus tumor series [6]. Even though no significant prognostic factors affecting survival were identified in this study, the transclavicular approach demonstrated great advantage in terms of exposure and radical resection of the invaded cervical structures in comparison with the classic posterolateral Paulson incision.

In 1998, Korst and Burt [10] published an interesting series of 42 patients operated on for different neoplasms involving the cervico-thoracic junction, including 12 patients with NSCLC excised using the hemiclamshell approach. In their experience this sterno-thoracotomic approach allowed complete resection of the neoplasm with anatomical lung resection and lymph-node dissection. A total of seven vertebrectomies were also performed proving that hemiclamshell approach is not contraindicated in cases of vertebral involvement.

In 1999, we published a series of 14 patients operated on for different apical chest tumors, including nine apical NSCLC resected using TMA [33]. In our series TMA allowed a safe and complete resection of the neoplasms with extended vascular (subclavian artery) and vertebral resection. In this paper we presented the combination of the TMA with the anterolateral muscle sparing thoracotomy, that improves versatility of TMA allowing an en bloc resection of the apical chest tumor with the cervicothoracic structures involved. It also permits safe hilar control during lung resection, radical lymph-node dissection, and a less invasive procedure for the patient.

Recently, Alifano et al. [18] reported a series of 77 patients with Pancoast tumor resections with more than 50% of cases combining both an anterior and posterior surgical approach. This strategy allowed vascular resections of the subclavian vessels in 20 cases, with 82% complete resections.

Our recent unpublished experience consists of 41 patients with apical non-small cell lung cancer with a prevalent anterior spread. All the cases had been resected through the TMA+TL (58.5%) or the hemiclamshell surgical approaches (36.5%) or both (5%). We preferred the TMA when a suspicion of sublcavian vessel involvement was present, reserving the hemiclamshell approach when the brachiocephalic vein was involved or when the proximal portion of the epiaortic arteries was implicated. Vascular infiltration was never a cause of inoperability and complete pathological surgical resection was achieved in 97% of cases through anatomical pulmonary resection with an ipsilateral lymph-node dissection. The morbidity rate observed was 41% and no postoperative deaths occurred. The median survival was 21 months. The overall Kaplan–Meier survival analysis at 5-year survival was 27% (Graph 1). By univariate and multivariable analyses the T status had a significant impact on survival with worse prognosis in pT4 cases. Age, induction chemotherapy, surgical approach, lung side, type of extended resection performed, histology, pN status, and the postoperative treatment did not influence the long-term outcome. Several factors may explain this figure: meticulous patient selection, the high percentage of induction therapy (46.3%) carried out and the high percentage (97%) of radical resections achieved. All these findings confirm the impor-



Graph 1. Survival curve of 41 patients with anterior access for resection of NSCLCs.

tance of using the anterior surgical approaches as a safe and efficacious way to radically resect apical non-small cell lung cancer thus improving long-term survival.

Conclusion

Even though different techniques have been described for providing 'optimal' access to the cervico-thoracic junction, and even though none of these techniques is without its drawbacks, the use of the transmanubrial osteomuscular sparing approach and hemiclamshell approach, has been demonstrated to be safe in the dissection and resection of cervico-thoracic neoplasms. This technique provides good local control with relatively low aggressiveness for the patients, and is not associated with procedure-related complications such as shoulder instability and deformities, flail chest, etc. Subclavian vessel involvement no longer represents a contraindication to surgical resection, thanks to these anterior approaches. Concerning extended resection of the vertebrae 'en bloc' with the tumor, this technique represents a technically demanding operation with a high risk of postoperative complications, for which an oncological advantage has yet to be demonstrated. However, some long-term survivors do exist after hemivertebrectomy for apical NSCLC [35], the majority being in the group of patients who underwent aggressive multimodality treatment and with negative margins. Therefore, this 'extreme' surgery should not be considered an absolute contraindication to surgical resection, but should be selected on a case-by-case basis.

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