



Transcervical Approach for Thoracic Operations

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Abstract

Aim: The aim of this study is to summarize our experience regarding thoracic operations performed through the use of the extended transcervical approach.

Material and Methods: Transcervical extended approach utilizes a collar incision in the neck with elevation of the sternal manubrium with a mechanical retractor. A bilateral visualization of the laryngeal recurrent and vagus nerves is usually performed to avoid injury of these structures. The procedures performed solely through the transcervical incision, or combined with videothoracoscopy (VATS) or/and subxiphoid incision were analyzed.

Results: There were 1,984 transcervical operations from September 01, 2000 to September 30, 2016, including 405 transcervical-subxiphoid VATS maximal thymectomies for myasthenia gravis, thymomas or rethymectomies, 1,224 transcervical extended mediastinal lymphadenectomy (TEMLA) procedures for staging of non-small cell lung cancer (NSCLC), 332 resections of the mediastinal tumors and the mediastinal metastases (mostly from thyroid cancer), 17 pulmonary lobectomies combined with TEMLA for NSCLC and 6 attempts of closure of the right main bronchus postpneumonectomy fistula. There were 5/1984 (0.3%) patients who had to be converted because of technical difficulties, in no case there major bleeding, or other severe intraoperative complications or deaths. There were 14/1984 (0.7%) patients who required revision because of postoperative bleeding (through the original incision in all but one patient, who necessitated thoracotomy). There was morbidity of 6.2 % (128/1984) and mortality of 0.4% (7/1984).

Conclusions: Transcervical extended approach with elevation of the sternal manubrium enables performance of various thoracic surgical procedures with minimal invasiveness, low mortality and morbidity and very high effectiveness.

Keywords: Thoracic operations; VATS; Thoracic surgery

Introduction

Most of general thoracic surgical operations are performed through the traditional thoracotomy, sternotomy or videos-assisted thoracic surgery (VATS) approach. Significant severity of pain is a common disadvantage of all these procedures, even in case of VATS. In recent years our team developed the transcervical extended approach for various thoracic surgical procedures, originally introduced by Cooper et al. [1] for thymectomy.

The extended transcervical approach for thoracic operations is characterized by the use of elevation of the sternal manubrium; otherwise it would not be possible. With elevation, however the cervical wound is like utility thoracotomy for video-assisted thoracic surgery (VATS), which enables performance of a variety of operations. The transcervical thoracic operations are divided into two categories. One type includes procedures performed solely through the cervical incision without additional approaches. Such procedures might be done with preservation of the mediastinal pleura, or may include deliberate opening of the pleural cavity. The other type of procedures combines a transcervical approach with VATS and/or subxiphoid incision. Nevertheless, the transcervical extended approach with elevation of the sternum is the common feature of all these procedures. This article is based mainly on our institutional experience, with description and discussion of the techniques we introduced or developed. Procedures such as standard mediastinoscopy,

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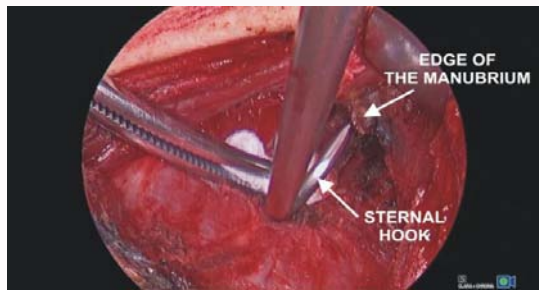


Figure 1: Introduction of the hook under the manubrium.

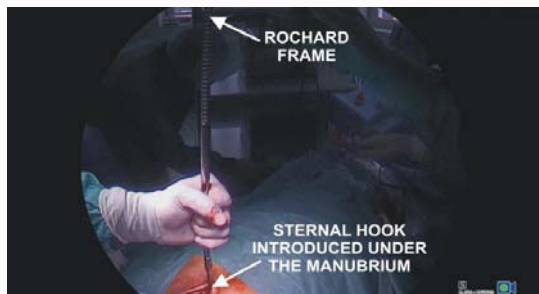


Figure 2: Elevation of the patient with use the sternal frame.

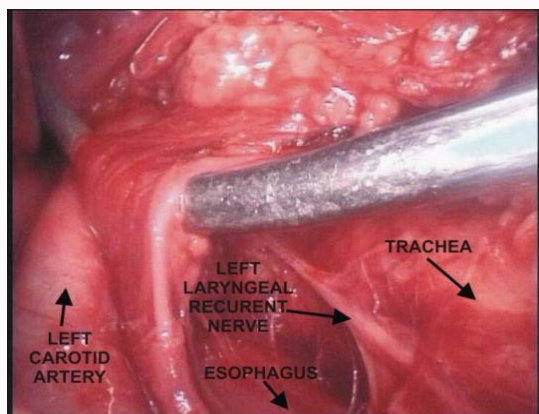


Figure 3: Visualization the left laryngeal recurrent nerve.

video-mediastinoscopy, anterior mediastinotomy, the tracheal and esophageal procedures will not be described here.

Surgical Technique of the Transcervical Extended Approach

Transcervical extended approach utilizes a typical a 5 cm to 8 cm collar incision in the neck. The critical technical point enabling a wide access to the chest is an elevation of the sternal manubrium with a special retractor (modified Rochard frame, Asculap-Chifa, Poland) (Figure 1 and 2). Even though the elevation of the sternum does not create a big enlargement of the wound, nevertheless it facilitates access to the mediastinum with the aid of the Linder-Dahan expandable blades mediastinoscope (Richard Wolf, Germany) or/ and long narrow wound retractors. The very important maneuver is a bilateral visualization of the laryngeal recurrent and vagus nerves are usually performed to avoid injury of these structures [2].

The subplatysmal flaps are dissected well outside the area of skin incision. Omission of such extensive dissection creates an obstacle for further dissection inside the mediastinum.

Visualization of both laryngeal recurrent and vagus nerves is achieved with division of the fascial layers of the carotid sheath covering these nerves (Figure 3). During visualization of the recurrent nerves it is recommended to preserve the last, deepest fascial membrane covering the nerve to avoid its injury. Circumferential dissection of any nerve is not advised.

Both vagus nerves run laterally to the carotid arteries. To expose these nerves, which are important landmarks of further dissection, one must open the carotid sheath and dissect the vagus nerve running between the carotid artery and the internal jugular vein.

Elevation of the sternum with a hook inserted under the manubrium is an extremely important maneuver because it widens the access to the mediastinum. We use a hook with sharp teeth (with 1 or 3 teeth) connected to the frame mounted to the operating table (Rochard frame, Aesculap-Chifa, Poland). An operator stands behind the patient's head and the assistant stands on the operator's right side. The biggest part of the transcervical operation is an open surgical procedure performed with standard surgical instruments. Only for dissection of the structures located deep in the mediastinum dissection is performed with aid of the Linder-Dahan mediastinoscope [3]. For better illumination of the operating field and teaching purposes a videothoracoscope might be used for dissection of aorta-pulmonary window area. In some patients the mediastinal pleura is preserved, it might be necessary however to open the pleura deliberately, or it is done incidentally. In case of injury of the mediastinal pleura, expansion of both lungs with high positive end expiratory pressure (PEEP) and insertion of the fibrin sponge to seal the pleural injury is usually suffice to manage the problem. Generally, chest tube insertion is not necessary.

Types of Surgical Operations Performed through the Extended Transcervical Approach

The extended transcervical can be used for thymectomy, for myasthenia gravis and thymoma, rethymectomies, resection of the benign or early-stage malignant mediastinal tumors and resection of the metastatic mediastinal lymph nodes. The most advanced transcervical procedures include closure of the bronchial stump postpneumonectomy fistula and pulmonary resections, including wedge resection and lobectomy.

Transcervical thoracic operations performed solely through the neck

These procedures include transcervical extended mediastinal lymphadenectomy (TEMLA), transcervical thymectomy and rethymectomy, resection of the primary and metastatic mediastinal tumors and closure of the bronchopleural fistula after pneumonectomy.

Surgical technique of TEMLA

The technique of this procedure introduced by the first author of this article (MZ) was described elsewhere [3] the detailed discussion of possible pitfalls and the methods of management of intraoperative complications were published elsewhere [4]. In brief, the technique of TEMLA included dissection of all mediastinal nodal stations except for the pulmonary ligaments nodes (station 9). Most of the procedure was performed in the open fashion, with the subcarinal and the periesophageal nodes (stations 7 and 8) removed in the mediastinoscopy-assisted technique and the paraaortic and the pulmonary-window nodes (stations 6 and 5) removed in the

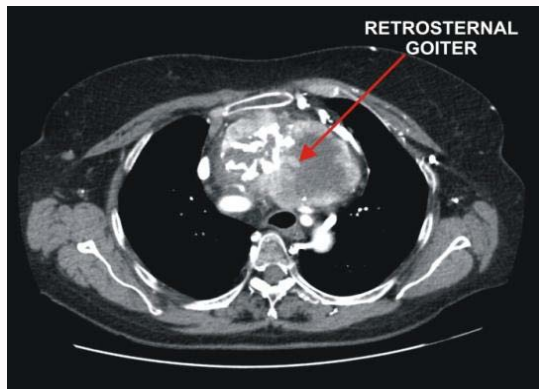


Figure 4: Large retrosternal goiter removed through the transcervical approach – transverse CT scan.

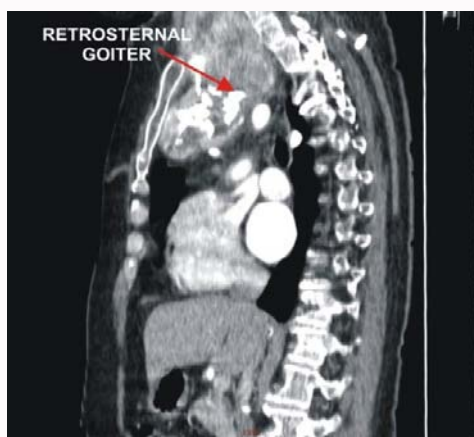


Figure 5: Large retrosternal goiter removed through the transcervical approach – sagittal CT scan.



Figure 6: Elevation of the sternum with two hooks connected to the Rochard frame during thymectomy.

videothoracoscopy-assisted technique, with the videothoracoscope inserted through the transcervical incision. Generally, the mediastinal pleura were not violated and no drain was left in the mediastinum. Bilateral supraclavicular lymphadenectomy and even deep cervical lymph node dissection is possible during TEMLA through the same incision.

Mediastinal tumors

Technique of resection of the mediastinal tumors and the mediastinal metastases is virtually similar to the technique of TEMLA. In case of larger tumors transcervical incision is combined

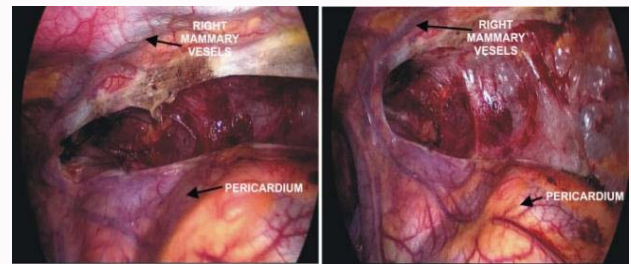


Figure 7: The view of the mediastinum before and after elevation of the sternum during thymectomy with significant widening of the space between the sternum and the pericardium after elevation of the sternum.

with VATS. There are four types of localization of the mediastinal tumors that can be removed with the use of transcervical approach. There are tumors of the superior mediastinum, located above the level of the tracheal bifurcation. These tumors can be further differentiated in the anterior, middle and posterior categories. The other type is tumors located in the inferior mediastinum, below the tracheal bifurcation. The transcervical approach can be useful in removal of all these tumors. Radical surgery can be performed in the encapsulated tumors, or in selected patients with limited infiltration out of the capsule. In case of more extensive tumors a transcervical incision is combined with VATS and subxipoid incision, or a classic open approach through sternotomy or thoracotomy is used for complete resection. The size of the tumor is also important. Although, there is no specific size limit for the use of transcervical approach, however, it would be extremely difficult to remove completely the tumors of a diameter larger than 8 cm to 10 cm, without disruption of the tumors' capsule.

The tumors of the superior anterior mediastinum include mainly ectopic goiter and thymic tumors like thymomas and cysts. The next category is retrosternal goiters with significant part of the mass located in the mediastinum (Figure 4 and 5). The other types of tumors are metastatic nodules of various origin (thyroid cancer, ectopic parathyroids and the others) and germ cell tumors (rarely applicable for transcervical resection due to large size at presentation).

The tumors of the superior middle mediastinum include metastatic nodes, ectopic parathyroids and mediastinal cysts (Figure 6).

Tumors located in the aorta-pulmonary area also belong to this category. The tumors of the superior posterior mediastinum are usually neurinomas.

There are selected tumors of the inferior mediastinum that can be resected through the transcervical approach. These tumors include mediastinal cysts and metastatic nodes positioned close to the esophagus and the bronchi. The other tumors of the inferior mediastinum cannot be removed with the transcervical technique.

Thymectomy and rethymectomy

Surgical technique of transcervical thymectomy is virtually the same as described by Cooper et al. [1]. Contrary to the other authors we did not use this approach for nonthymomatous myasthenia gravis (MG), but for small cranially located thymic tumors or cysts. However, for the majority of early-stage thymomas, however we use the transcervical-subxiphoid-VATS or the subxiphoid-right VATS approaches, described elsewhere [5,6].

During transcervical repeated thymectomy (rethymectomy) we

Table 1: Complications of TEMPLA procedures.

| Complication | N (%) |
|--|-----------|
| Injury of the esophagus and the right main bronchus with formation of the esophago-bronchial fistula managed successfully with right thoracotomy, suturing of the esophagus and repair of the bronchus with intercostal flap | 1 (0.1%) |
| Injury of the right main bronchus | 1 (0.1%) |
| Injury of the right segment 1 bronchus | 1 (0.1%) |
| Injury of the right pulmonary artery | 1 (0.1%) |
| Injury of the azygos vein | 2 (0.2%) |
| Postoperative bleeding requiring revision | 2 (0.2%) |
| Late pulmonary haemorrhage | 2 (0.2%) |
| Haemorrhagic brain infarct | 1 (0.1%) |
| Cardiac infarct | 3 (0.2%) |
| Sudden cardiac arrest | 1 (0.1%) |
| Pleural effusion (conservative treatment) | 12 (1.0%) |
| Laryngeal recurrent nerve palsy- overall | 30 (2.5%) |
| Temporary left laryngeal recurrent nerve palsy | 21 (1.7%) |
| Temporary right laryngeal recurrent nerve palsy | 2 (0.2%) |
| Temporary bilateral laryngeal recurrent nerve palsy | 2 (0.2%) |
| Permanent laryngeal recurrent nerve palsy | 5 (0.4%) |
| Pneumothorax (necessitating chest drainage) | 5(0.4%) |
| Respiratory insufficiency (ventilator) | 6 (0.5%) |
| Postoperative psychosis | 2 (0.2%) |
| Perforation of the peptic ulcer | 1 (0.1%) |
| Cerebral ischemia | 1 (0.1%) |
| Subarachnoid haemorrhage | 1 (0.1%) |
| Cardiovascular insufficiency | 3 (0.3%) |
| Overall morbidity | 75 (6.1%) |
| Death | 6 (0.5%) |

used a technique similar to that described by Komanapalli et al. [7] including deliberate opening of both pleural cavities to achieve better control of complete removal of the adipose tissue of the superior and anterior mediastinum. We used this approach for patients who underwent previous VATS thymectomy. In case of large amount of fatty tissue after previous VATS thymectomy we used transcervical-subxiphoid-bilateral VATS approach.

Technique of closure of the bronchial fistula after pneumonectomy

The approach to the main bronchus is achieved in same way as during TEMPLA. The main bronchus is dissected circumferentially, and then the endostapler is applied and fired.

Transcervical pulmonary lobectomy

Transcervical lobectomy can be performed with the use of the uniportal technique, or one or two additional VATS port as be described previously [8,9].

The uniportal transcervical VATS lobectomy for NSCLC is preceded by TEMPLA to enable optimal intraoperative staging of the mediastinal nodes and perform extensive bilateral lymphadenectomy, which theoretically might affect survival. VATS lobectomy is the next step after obtaining results of intraoperative examination of the nodes performed with the imprint cytology technique [10]. Ventilation of the operated lung is disconnected and the mediastinal pleura are opened. Pleural adhesions are divided. The branches of the pulmonary

artery and vein and the lobar bronchus are sequentially dissected and managed with endostaplers. The fissure is divided with endostapler and the resected lobe is removed in an endobag.

Transcervical thoracic operations combined with VATS and/or the subxiphoid incision

These procedures include transcervical-subxiphoid-VATS maximal thymectomy for myasthenia gravis (MG) or/and early stage thymoma, pulmonary resection of the right and left upper lobes, and esophagectomy performed through transcervical-laparotomy (laparoscopy) approach.

Technique of transcervical-subxiphoid-VATS maximal thymectomy

The cervical incision is combined with the subxiphoid incision and bilateral single-port VATSA. Two sternal retractor connected to the Rochards frame are used, one for the elevation of the manubrium and the second one is placed under the sternum, which is elevated to facilitate access to the anterior mediastinum from below (Figure 7). An operation may be performed by two teams – one called the “cervical team” working from above and the second one called, “the subxiphoid team” working from below the sternum with control of the videothoracoscope (VATS). Alternatively, the whole operation is performed by one surgical team performing “the cervical” and “the subxiphoid” parts of the operation sequentially. The whole thymus with the surround fatty tissue of the areas of the neck, perithymic, aorta-caval groove, aorta-pulmonary window and the right and left

Table 2: Postoperative complications in 400 patients after transcervical-subxiphoid-VATS maximal thymectomy for MG and thymomas.

| Complication | Number of complications (%) |
|--|-----------------------------|
| Respiratory Insufficiency (ventilator) | 12 (3.0%) |
| Postoperative bleeding (reoperation) | 5 (1.3%) |
| Mediastinal haematoma (conservative treatment) | 0 |
| Pericardial effusion | 0 |
| Pneumonia | 1 (0.3%) |
| Subarachnoid haemorrhage | 1 (0.3%) |
| Pneumothorax | 1 (0.3%) |
| Wound dehiscence | 2 (0.5%) |
| Wound infection | 0 |
| Temporary phrenic nerve palsy | 0 |
| Temporary laryngeal recurrent nerve palsy | 1 (0.3%) |
| Permanent nerve palsy | 0 |
| Overall | 23 (5.8%) |

epiphrenic fat pads is removed en-bloc.

Results

Starting from September 01, 2000 to September 30, 2016 there were 1,931 transcervical operations including 392 transcervical-subxiphoid VATS maximal thymectomies for myasthenia gravis (MG), 8 thymectomies for thymoma, 1,224 TEMPLA procedures for staging of non-small cell lung cancer (NSCLC), 286 resections of the mediastinal tumors and the mediastinal metastases (mostly from thyroid cancer), 17 pulmonary lobectomies combined with TEMPLA for NSCLC (in 7 patients TEMPLA was combined with 1 or 2 intercostal ports, in the other 10 patients a uniportal transcervical technique was used) and 6 attempts of closure of the right main bronchus post pneumonectomy fistula.

Postoperative complications for TEMPLA, transcervical-subxiphoid VATS maximal thymectomy, transcervical lobectomy and resection of the mediastinal tumors are presented in Tables 1-4.

For the whole group there were 14/1,931 (0.6%) patients required revision because of postoperative bleeding (through the original incision in all but one patient, who necessitated thoracotomy). There were 6 postoperative deaths with 30-day postoperative mortality 0.3% (6/1931): 5 patients died after TEMPLA (unrelated causes) and 1 patient died after transcervical-VATS left upper lobectomy because of pulmonary embolism. Complications occurred in 144/1,931 patients (morbidity 7.5%).

In the group of the mediastinal tumors there were 3/286 (1.0%) patients who had to be converted because of technical difficulties,

Table 3: Types and complications of transcervical uniportal VATS lobectomies combined with TEMPLA.

| Type of lobectomy | Number of patients | Characteristic of the procedure | Postoperative complications |
|-----------------------------|--------------------|---|--|
| Right upper | 7 | In 1 patient additional wedge resection of the tumor of the left upper lobe | Temporary left laryngeal nerve palsy – 1 Additional pleural drainage – 1 |
| Left upper | 6 | In 1 patient pleural cavity completely obliterated | Temporary left laryngeal nerve palsy – 1 Left phrenic nerve palsy – 2 Pulmonary embolism - death |
| Right lower | 3 | In 1 patient pleural cavity completely obliterated | |
| Left lower | 1 | Conversion to a uniportal VATS | |
| Overall Morbidity Mortality | 17 | | 6/17 (35.3%) 1/17 (5.9%) |

VATS: Video-Assisted Thoracic Surgery; TEMPLA: Transcervical Extended Mediastinal Lymphadenectomy

Table 4: The results of 286 transcervical resection of mediastinal tumors.

| Type of mediastinal lesion | Number of patients |
|--|--------------------|
| Mediastinal metastases of thyroid cancer | 128 |
| Mediastinal tumor | 46 |
| Parathyroid mediastinal tumors | 6 |
| Ectopic goiter | 19 |
| Anterior mediastinal cyst | 15 |
| Posterior mediastinal cyst | 4 |
| Other mediastinal metastases | 68 |
| Overall | 286 |

Table 5: Complication of 286 transcervical resection of the mediastinal tumors.

| Complication | N (%) |
|---|----------------|
| Injury of the innominate artery | 1 (0.3%) |
| Packing for severe intraoperative bleeding | 2 (0.7%) |
| Revision for postoperative bleeding | 2 (0.7%) |
| Respiratory failure (ventilator) | 5 (1.7%) |
| Tracheostomy for laryngeal nerve palsy | 4 (1.2%) |
| Laryngeal recurrent nerve palsy- overall | 6 (2.1%) |
| Incomplete resection | 6 (2.1%) |
| Biopsy only | 4 (1.2%) |
| Transcervical incision combined with VATS | 1 (0.3%) |
| Transcervical incision combined with a subxiphoid incision and VATS | 1 (0.3%) |
| Conversion to sternotomy/thoracotomy | |
| Pneumothorax (necessitating chest drainage) | 3 (10.4%) |
| Cardiovascular failure | 0 |
| Overall morbidity | 5 (1.7%) |
| Deaths | 40/332 (13.9%) |
| | 0 |

in another 2 patients packing of the mediastinum was necessary for major bleeding; the packing was successfully removed after 2 and 3 days. There were no other severe intraoperative complications or deaths.

In Tables 1-5, the results and complications of TEMPLA, transcervical-subxiphoid-VATS thymectomy, and pulmonary lobectomies performed solely through the cervical approach and resection of the mediastinal tumors are presented.

Discussion

The main advantage of the transcervical approach is much lesser postoperative pain in comparison to thoracotomy, sternotomy

and even VATS. This observation was made by us on the clinical ground; however, we did not any specific studies comparing severity of pain for patients undergoing operations with use of the approaches mentioned above. Most of the transcervical procedures need no postoperative mediastinal drainage. Recovery of patients after transcervical operations is very fast. The rate of postoperative respiratory insufficiency with the need of a ventilator is very low. To get a wide and safe access to the chest two principles must be obeyed. The first one is that the major mediastinal vessels including the innominate artery, the common carotid arteries and the left innominate vein must be carefully dissected free before retraction. Dissection makes these structures more movable and therefore protects them from traction injury. In case of severe atherosclerotic lesions of the arteries and the aorta the retraction must be very delicate or, in a very occasional case another approach to the chest must be chosen. The second principle is the elevation of the sternal manubrium with the sternal retractor, which provides the wider access to the mediastinum, together with upwards retraction of the mediastinal structures. Performance of operations according to these rules enables easy access to the mediastinum down to the bifurcation of the trachea. Operations through the transcervical approach are feasible even in excessively obese patients; however in such cases performance of procedure is more difficult. With use of special retractor (Aesculap-Chifa, Poland) it is possible to retract the tracheal bifurcation and the right main bronchus and to dissect the esophagus down, almost to the hiatus. Opening of the mediastinal pleura and disconnecting of the ventilation of one lung enables access to the pleural cavity and performance of the right or left upper pulmonary lobectomy, under control of the thoracoscope inserted through the VATS port, with the other VATS port used for introduction of the endostapler, while the whole dissection is performed through the cervical incision, which has a role of the utility thoracotomy. The advantage of this approach is the use of the classic open surgical technique with regular surgical instruments, without necessity of the use of fine thoracoscopic instruments.

The 30-day mortality rate for patients undergoing TEMLA was 0.5% which was slightly higher in comparison with recent publications. The mortality rates of the largest series of mediastinoscopies reported by Hammoud et al. [11] and Lamaire et al. [12] were 0.2% and 0.05%, respectively. The morbidity of TEMLA was higher in comparison to the largest series of mediastinoscopies reported recently; however the life-threatening vascular complications reported in these studies were completely avoided in our patients [13,14]. Most of surgical complications of TEMLA were mild and subsided without any treatment; the most serious complications were purely medical.

TEMLA proved to be a diagnostic procedure with an extremely high diagnostic yield. Our recent study showed that TEMLA had 98.6% sensitivity and 99.7% negative predictive value (NPV), significantly higher than endobronchial ultrasound/endoesophageal ultrasound (EBUS/EUS). Similar difference between TEMLA and EBUS/EUS was noted in regard to the mediastinal restaging after neoadjuvant therapy. Currently, TEMLA is used for staging and restaging of all patients with NSCLC who are possible candidates for surgery.

The incision in the neck enables access to the tumors of the anterior, middle and posterior mediastinum, including small thymomas, the other thymic tumors, ectopic goiter, parathyroid

adenomas, metastatic mediastinal nodes and neurinomas of the apex of the chest. In case of thymomas, especially with associated myasthenia gravis (MG) the transcervical incision is combined with the subxiphoid and bilateral port VATS approach (one port to each pleural cavity) to get maximal completeness of removal of the mediastinal adipose tissue, that might contain the ectopic foci of the thymic tissue.

There was no mortality in patients undergoing thymectomy for MG or thymomas. The morbidity rate was 5.8%, with no severe intraoperative complications. The postoperative myasthenic crisis rate was 3.0% and the revision rate for bleeding was 1.3%. These results are similar to the results reported by the other authors [13,14].

Our late institutional results of presented technique of thymectomy has been very favourable – 5-years complete remission rates 53.1% in comparison to 20.0% complete remissions rate after the basic trassternal thymectomy ($p < 0.0001$), which can be only explained by the removal of ectopic foci of the thymic tissue from the neck and the mediastinum in these patients [5]. Due to the incidence of the ectopic foci of the thymic tissue in all areas of the mediastinum, including both epiphrenic fat pads we are reluctant to perform thymectomy solely through the neck because in this procedure a large part of the adipose tissue of the lower mediastinum is not dissected, which might affect the final results of complete remission rates of MG. In our opinion the extensive dissection of the fatty tissue of the mediastinum and the lower neck is not as necessary in thymomas without MG, because in such cases complete removal of the whole thymus containing the thymoma is the priority.

Conclusions

Transcervical extended approach with elevation of the sternal manubrium enables performance of various thoracic surgical procedures with minimal invasiveness, low mortality and morbidity and very high effectiveness.

Author Contributions

- Marcin Zieliński (conception and design, collection and assembly of data, final analysis and interpretation, manuscript writing, final approval of manuscript).
- Mariusz Rybak (collection and assembly of data, manuscript writing, final approval of manuscript).
- Katarzyna Solarczyk-Bombik (collection and assembly of data, manuscript writing, final approval of manuscript).
- Michal Wilkojc (collection and assembly of data, manuscript writing, final approval of manuscript).
- Wojciech Czajkowski (collection and assembly of data, manuscript writing, final approval of manuscript).
- Sylwester Kosinski (collection and assembly of data, manuscript writing, final approval of manuscript).
- Edward Fryzlewicz (collection and assembly of data, manuscript writing, final approval of manuscript).
- Tomasz Nabialek (collection and assembly of data, manuscript writing, final approval of manuscript).
- Juliusz Pankowski (collection and assembly of data, manuscript writing, final approval of manuscript).

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