28 Thoracic and Thoracolumbar Anterior Approach: Surgical Anatomy

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The effectiveness of anterior approaches to corpus vertebra and disc pathologies are well known (13). Anterior approaches to thoracic and thoracolumbar vertebrae provide good overview ofthe pathological area and allow anterior segmental releasing (2,4,12,18,20). Thoracotomy is the most appropriate technique for T2-L2 vertebrae anterior approach (5). In surgical treatment of disc herniations, infections, osteomyelitis, vertebral body tumors and traumatic burst fractures of thoracic and thoracolumbar region may be required the anterior approach (2,4,6,14,18,20).

Variety of anterior approaches has been described for the thoracic and thoracolumbar vertebrae (13). These approaches can be classified as transpleural or retropleural based on whether open the pleura or not and also can be classified according to the anatomical level of the lesion (2). Cervico-thoracic approaches can be used to reach T1-T2 vertebrae. These approaches are rarely required and used to reach C7, T1 and T2 vertebrae. This region is quite complicated due to the important mediastinal and neck structures (10). It is usually possible to reach T1, T2 level by standard anterior cervical approach (21). Left side should be preferred to reduce the risk of recurrent laryngeal nerve injury (4,15,17,21). This approach is very difficult due to the presence of many vital structures (ossöz, articular, vascular and neural) and limited overview to vertebrae. This approach is not suitable for the level of T4 due to the deep and narrow surgical region (4,15). Median sternotomy was described by Cauchoix and Binet in 1957. In first clinical series mortality rate was reported approximately 40% and therefore not used today. Manubrial window (manubrio-klavikulotomi): This approach has been described by Sundaresan et al. in 1984. Half of the manibrium and 1/3 medial clavicle has removed. Exposure is providedgood view from C3 up to T4. The pleura does not open so there is no need the chest tube (21). This method provides optimal view with less risk (4). Open door "trap door" exposition: This approach has been described by Nazzaro et al. in 1994 and provides to reach C3 vertebrae (21). In addition to standard anterior neck dissection, partial medial sternotomy and anterolateral thoracotomy is applied (6). In recent years modified trans-manubrial approaches have been described which allow to proper perspective from T5 to C7 vertebrae (4,17). Also right thoracotomy at the level of T1-T2 is an alternative approach (2).

Cervico-thoracic approaches can be used to reach T1-T2 vertebrae. These approaches are rarely required and used to reach C7, T1 and T2 vertebrae.

Median sternotomy was described by Cauchoix and Binet in 1957. In first clinical series mortality rate was reported approximately 40% and therefore not used today.

Right thoracotomy (transpleural orretropleural) approach is the best method to reach T2 and T6 vertebrae (2-4,10,13,17,20). Left thoracotomy (transpleural orretropleural) approach is the best technique to reach T6 and T12. However, surgeons should be careful for the localization of the Adamkiewicz artery. If a significant number of segment involvement was determine in distal T6 region preoperative angiography should be necessary to detect Adamkiewicz artery (2). Left thoracoabdominal (transpleural o rretropleural) retroperitoneal approach is used to reach from T6 to L3 vertebrae (2,4,20).

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History

The first reports of the anterior transthoracic interventions have been dealing with tuberculosis of the spine (4,10,14,17). In 1934, Ito et al. described anterior approach for debridement of the vertebrae for Pott's disease (9,10). In 1945, Capener et al. Have described the use of anterior tibial graft by transperitoneal approach (9). Hodgson in 1956 and Stock in 1960 have popularized the anterior thoracotomy for Pott's disease. Same authors reported their series of 100 patients whom were treathed by anterior debridement and fusion in 1960 (4,9,10,18). However, development of anti-tuberculosis antibiotic treatment reduced the necessarity of surgical intervention (4,17). Perot and Munro defined transthoracic transpleural surgical treatment in 1969 for disc herniation which occured spinal cord compression (3,9). During the same period, Dwyer et al. Reported anterior treatment of scoliosis (10).

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Indications

Indications for anterior thoracic and thoracolumbar junction pathologies are; 1- disorders such as tuberculosis which destructed vertebral bodies and discs, 2- pyogenic infections, 3- primary and metastatic vertebrae tumors, 4- degenerative disc diseases, 5- thoracic and/or upper lumbar vertebrae's traumatic burst fractures, 6- spinal deformities, such as scoliosis andkyphosis (2,6,14,17).

Alsoanterior compression of the spinal canal, presence of pathologyin vertebral body, the vertebral instability due tocorpus injury are indications for anterior approach.

These indications are intended for drainage of abscess in spinal infections, removing of necrotic tissues, tumors and fusion-stabilization after decompression of spinal canal in spinal cord compressions. In this way reducing of pain, improvement of diseases such as infections and tumors, correction of deformities and prevention of progressive neurological deficitis could be ensured (2). Alsoanterior compression of the spinal canal, presence of pathologyin vertebral body, the vertebral instability due tocorpus injury are indications for anterior approach (16). Scheuermann's kyphosis (disease) or adult idiopathic scoliosis deformities are can be listed anterior approach's indications (2,18).

Preoperativepreparation

Preoperative preparation is very important for anterior thoracic interventions (4,8,20). Lung function tests, blood gas analysis and preoperative evaluation of cardiac performance status are important for prevention of post-operative complications (2,4,17). In upper thoracic region, the use of a double-lumen endotracheal tube will help the surgeon when needed to deflation the lung (1-3,5,8,11,17,20). A single dose of antibiotic before surgery (cefazolin 1g intravenously) should be applied. High-speed drill tour and the operating microscope could require during decompression (20).

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Preoperative radiological preparedness and planning is extremely important. Surgical planning should be done with detailed analysis of radiological tests should be done a few days before the operation. For pre-operative good planning thorax and thoracic spine plain radiography (anterior-posterior and lateral), computed tomography (CT) and magnetic resonance imaging (MRI) should be taken. Marking of T12 or L1 level in sagittal MRI facilitates the localization, during the operation especially in soft tissue pathologies such as thoracic disc herniations (8,11). In patients with lumbosacral transitional abnormalities marking of L5 in MRI is recommended (11). Use of radiolucent table will be useful to determine the pathological level and the position of the implants under fluoroscopy

during the operation (3,4,11,14,20). Intraoperative neuromonitorisation and somatosensory evoked potentials (SSEP) help the surgeon and protect the patient from spinal cord damage (2,4,8,17,20).

The size and location of the arteries (aorta or azygos/hemiazygos systems, etc.) should be evaluated well before the operation in the presence of pathologies such as thoracic tumors prevertebral soft tissue infections (11). In some patients, preoperative angiography may need to determine the Adamkiewicz artery (2,4). In malignant lesions with excessive vascularization, embolization can be done before surgery to reduce the risk of bleeding (4,6).

Unlike posterior interventions, chest and/or general surgery team are required in anterior interventions (2,4,10,16,17).

Position

The patient is positioned in lateral decubitus and to prevent patient's slide during surgery, patient should be fastened to shoulder and hip joints of the table on anterior-posterior directions with the bands.

The patient is positioned in lateral decubitus and to prevent patient's slide during surgery, patient should be fastened to shoulder and hip joints of the table on anterior-posterior directions with the bands (Figure 1-2). Unless there isa special situation,while right side should be upper in the upper thoracic interventions (T2-T6), in middle and lower thoracic and thoracolumbar interventions left side should be the upper (2-4,6,8,10,13-18,20) (Figure 3). In this way, vena cava with a greater risk of injury than aorta will befurther away from the surgical site (3,4,8,16,18) and liver will remain outside of vision. Also convex side (apex) should be on top in scoliotic deformity (2,4,10,17,18). In kyphosis aorta often curves to the left side so right approach should be preferred in kyphotic pathologies (10). The general believe is pathology should belocated on the upper side (3,5, 6,15,18). Patients with history of thoracic surgery,approach should be done in the other hemithorax to reduce the bleeding postoperative air leaks and the risk ofimplants contamination (4,6). Determination the position of the great vessels in MRI and/or CT is quite important to better assess and decide the direction of approach. Descending aorta rarely can be settled posteriorly on the left side and it can prevent to reach the region. In this cases, surgeon may need to approach from the right side (8,18).

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With the patient in the lateral decubitus position, lower arm should be extended straight forward and an axillary roll is placed to prevent brachial plexus injury. The upper arm at the elbow flexed 90 degrees and should fixed to the operating table with an arm rack (Figure 1). The ulnar groove should be relaxed and pillows placed to both armsto protect them against pressure and tension (3,5,8,11,18). The upper leg should be flexed and the lower leg should be in extension. In this way, the psoas muscle will be relaxed. At the level of the knee, protector pillows should be put between the two legs to protect peroneal nerve (3,11,14,18). Flexion of the table or placing a pillow to lesion level closure the region to surgeon and this maneuver makes surgery easier (5,14,18) (Figure 4). Head should be in neutral position in coronal plane (Figure 2). Otherwise, neck pain and stiffness will occur inthe postoperative period (11,18) After obtainingthe proper position, the patientshould be fixedon the table from hip, knee andshoulder bya wide flasters. The purpose offixed the patient during the operation is bending backwards the patient in horizontal plane if needed (3,5,11,14,18).

With the patient in the lateral decubitus position, lower arm should be extended straight forward and an axillary roll is placed to prevent brachial plexus injury.

After patient is stabilized to the table, skin incision should be determined according to projection of the desired vertebra on the skin. If the pathology can not be determined directly with fluoroscopy (e.g. disc herniation), level must be determined by the counting method from the L5 vertebra. Pathological level accepted as central and skin incision is marked parallel to the ribs. Surgical area should be sterile and covered from axilla to iliac crest (11,18).

Figure 1

Fixing of the patient in full lateral position to the table is very important in thoracotomy application. The patient should not be slipped for topographic anatomy of the spinal cord after draped (Kaptanoğlu archive).

Transpleural Th oracotomy Approach In upper thoracic approach "J-shaped" (hockey stick-shaped) skin incisionis made.

Figure 2

Posterior view of the patient to thoracotomy. Some patients may also need to fixing from shoulder to anterior and posterior direction with bands (Kaptanoğlu archive).

Surgical Approaches

1) Transpleural Thoracotomy Approach

In upper thoracic approach "J-shaped" (hockey stick-shaped) skin incisionis made (9,15) (Figure 5). Starting point of theskinincision ismid-point ofthe line, which connects the posterior edge ofthe scapula and spinousprocesses and continues through the medial and loweredgeofthe scapulaand terminated 2 cm under nipple in the mid-axillary line (5,9,15). In the middle and lower thoracic interventions, incision should be parallel tothe targeted rib (15). Usually, one or two intercostal space above the pathological corpus and/or disc is preferred (3,4,6,8,9,14,17,18). Incision starts from 4 cm lateral of the spinous process and ends in mid-axillary line (9,15).

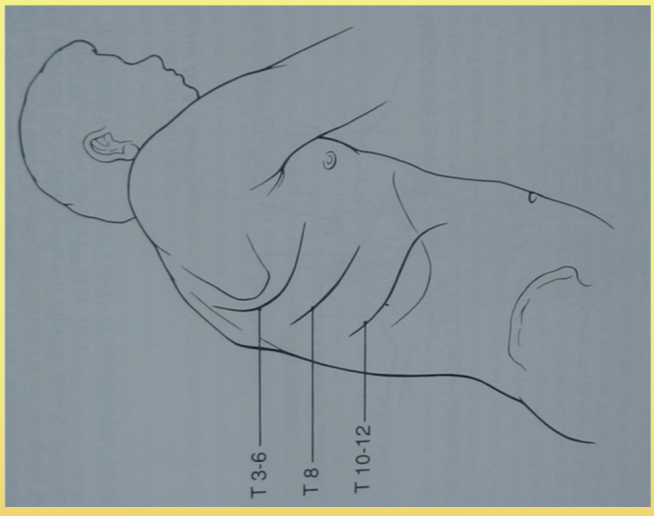


Figure 3

In thoracic region approaches, appropriate skin incisions for desired levels are seen.

Figure 4

Before flexed the operating table, the region should be supported by placement of pillow below the desired level. In this way, the surgeon will be closer to the region. Another purpose of this is, to prevent table space which will occur with table flexion (Kaptanoğlu archive).

In the presence of suspicion for detection of planning rib, fluoroscopy can be taken after marking the rib.

After skin incision, subcutaneous tissue cut with electrocautery (18). Trapezius muscle fibers are separated. latissimus dorsi and rhomboid muscles dissected from the bottom edge of the scapula and the freed from the lower edge ofthe scapula (9,15). This dissection process allows to scapula retracted and count the ribs (9). While serratus anterior muscle is cut to reach the upper thoracic vertebrae, in the mid-thoracic region dissection is enough (18). (Figure 6). The first palpable rib in proximal is usually second rib (5,9,18). In the presence of suspicion for detection of planning rib, fluoroscopy can be taken after marking the rib (18). After determining the target, two different techniques can be used to movethe chest wall (5). 1- If an approach is planned without removing the rib, intercostals muscles are cut along the top edge of the rib with electrocautery (5,11). In this way, neurovascular band along the bottom edge of the rib ispreserved (5). 2- If the rib resection is planning, periosteum along the outer face is cut with electrocautery. Subperiosteal dissection is performed. Rib is cut from both end and could be used as a bone graft if necessary (2-5,8-10,14,17) (Figure 7-8-9).

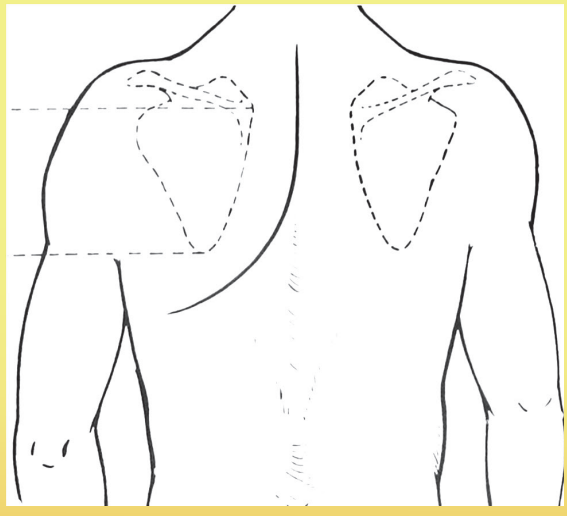


Figure 5

For upper thoracic approaches the hockey stick-shaped skin incision is observed.

Figure 6

In high-thoracic approaches, if hockey stick-shaped skin incision is continued to the sternum even can reached up to first thoracic vertebrae. Here, with high thoracic surgical incision, anterior-posterior plain radiograph of a patient is seen whom applied T3corpectomy and T2, T4 anterolateral instrumentation (Kaptanoğlu archive).

During the cutting of the parietal pleura, lung's breathing movements should be observed to avoid parenchymal damage.

In both techniques, next stageis to reach the endothoracic fascia and parietal pleura by the transition of intercostals muscle layers. Intercostal muscles are inthreelayers. These are external intercostal, internal intercostals and inner most intercostal muscles (from outside to inside). Inner most intercostals muscle is called transverse thoracic muscle in anterior, subcostal muscle in posterior and lateral inner most intercostal muscle in lateral localization. Neurovascular band passes through the lower edge of the rib. Vein is at the superior of the artery and drained to Azygos vein. Artery is directly originated from the descending aorta. Neurovascular band runs between the internal intercostal muscles and innermost intercostal muscles (18).

After dissecting the intercostal muscles, endothoracic fascia is cut and parietal pleura is seen (9,18) (Figure 10). During the cutting ofthe parietal pleura, lung's breathing movements should be observed to avoid parenchymal damage. After opening the parietal pleu-

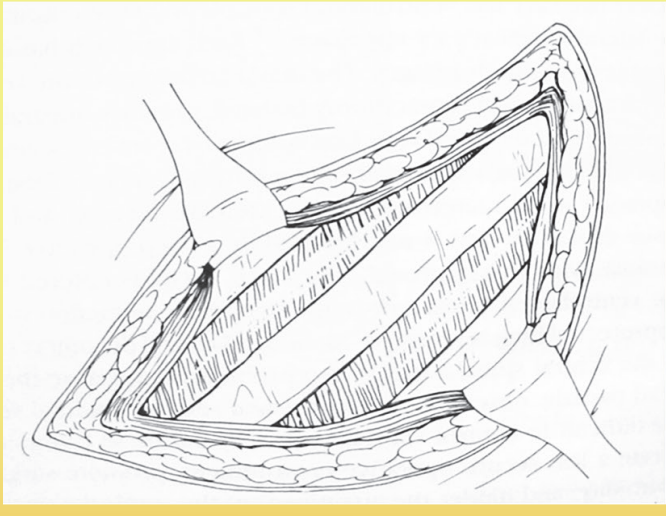


Figure 7

Outer surface and the upper edge of the rib are clearing by electro-cautery before rib resection is observed.

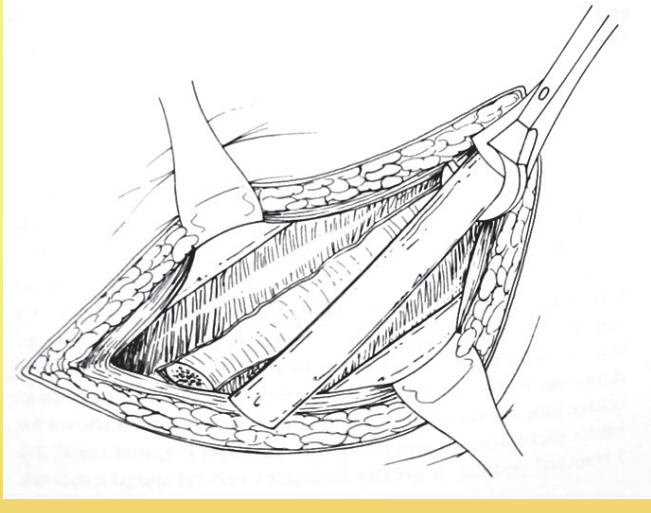


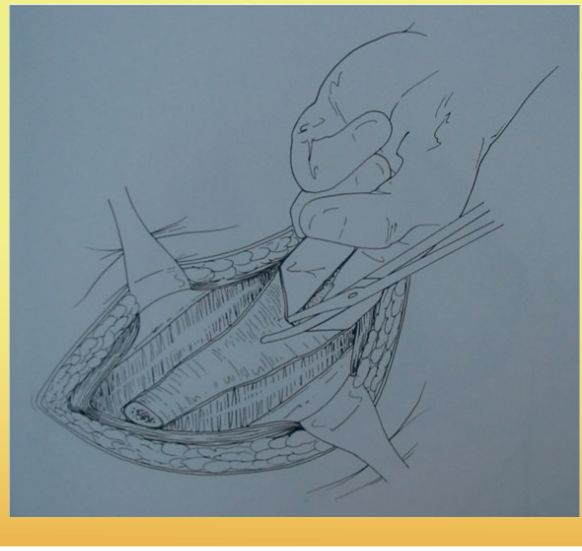
Figure 8

Removing the rib by cut at both ends is observed.

Use of double-lumen endotracheal tube facilitate retraction lung in the upper-middle thoracic approach.

ra left hand index finger inserted and pleura cut controlly along the rib (5). (Figure 9). In pleural space lung is deflated, lung and visceral pleura separated along the chest wall (5,18). Then the ches tretractor is placed slowly and carefully to enhance the intercostal space (5,8,9). If necessary scapula removed by scapular retractor (5).

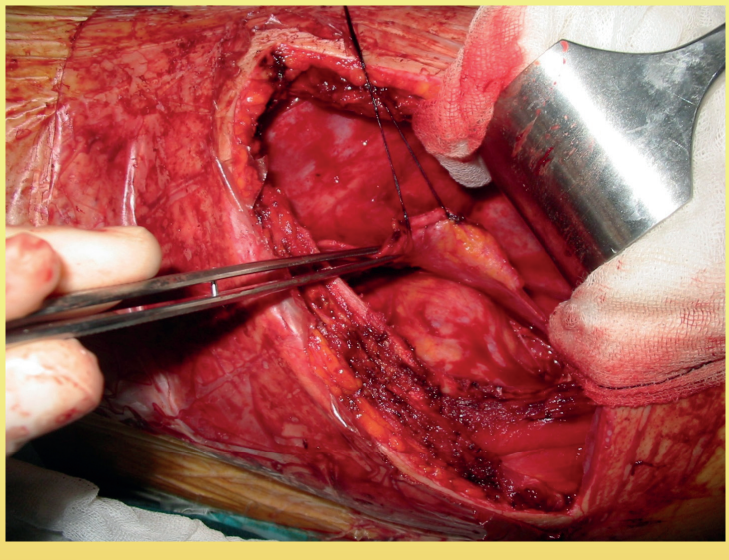
Approach to the lower thoracic vertebrae lung parenchyma can be retracted with a wet compress (5,8,9). Mean while, the aorta felt with the finger tip (5). Use of double-lumen endotracheal tube facilitate retraction lung in the upper-middle thoracic approach. After that, the segmental vessels on the vertebrae and can be palpated and determined easily (2,18). Parietal pleura on the vertebrae cut and peeled along the longitudinal axis (5,6,9,11,18).



Şekil 9

To prevent damage to lung parenchyma while opening of the parietal pleura, index finger and 3th finger of the left hand is inserted between the lung and the pleura.

Retropleural Th oracotomy Approach In upper thoracic interventions right side is oft en preferredand "J-shaped" skin incision is made along the medial and inferioredges of thescapula.



Şekil 10

After thoracotomy the parietal pleura is seen. In this patient pleura is very thick due to an infection (Kaptanoğlu archive).

2) Retropleural Thoracotomy Approach

In upper thoracic interventions right side is often preferredand "J-shaped" skin incision is made along the medial and inferioredges of thescapula. Scapula peeled from medial and inferiormusclesandretractedupward. Thus, desired rib can be determined by palpation. In the middle and lower thoracic interventions left side should be preferred and the skin incision should be parallel to the rib. This incision starts from 4 cm lateral of spinous processes and ends in the posterior axillary line (3,9,15).

After determine thelevelwith fluoroscopy, 8-10 cm of rib is dissected from intercostal muscles and removed (Figure 11). Neurovascular structures along the bottom edge of the rib should be protectedas much as possible. Proximal 4cm part of the rib is joint with the transverse process vertebrae which is called rib head and this part is was initially left intact. Endothoracic fascia, which is similar to the transverse fascia that surrounds the abdominal wall, is seen after removing of the rib. It merges with rib andvertebralbody's

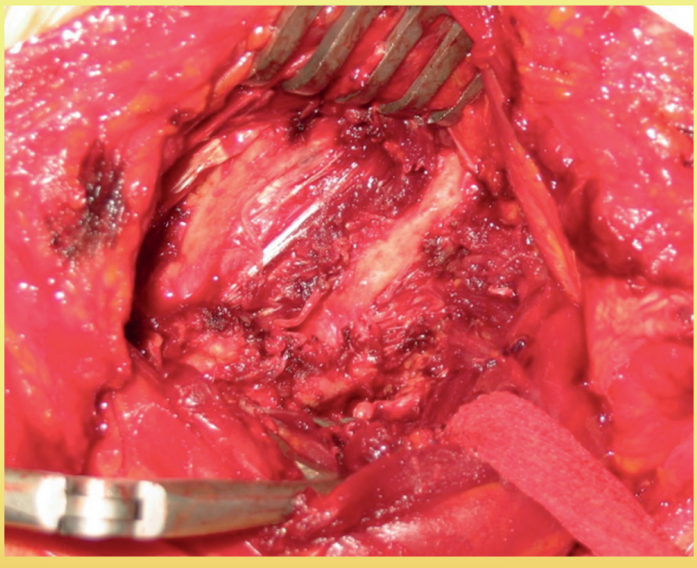


Figure 11

In retropleural approach rib is demonstrated after dissected from surrounding tissues (Kaptan- oğlu archive).

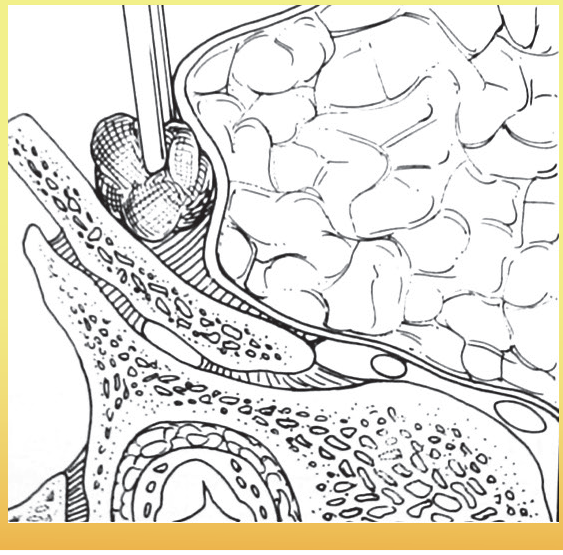


Figure 12

In retropleural approach, after rib resection parietal pleura is dissected with nuts buffer until reach to vertebrae corpus.

The parietal pleura separated from endothoracic fascia with blunt dissection. At this stage, lung could be deflated with a double-lumen endotracheal tube.

periosteum (3,13,15) (Figure 12-13). Parietal pleura adheres loosely to fascia inside of the chest wall. After placingan automatic retractor endothoracic fasciais cut through the rib and reach to parietal pleura. The parietal pleura separated from endothoracic fascia with blunt dissection (3,10,13,15,19). At this stage, lung could be deflated with a double-lumen endotracheal tube. This is not necessary, but provides easier lung retraction in the upper thoracic procedures. Parietal pleura and lung were retracted anteriorly and dissection continued untill joint point of rib head and transverse processes. Then dissection move to anteriorly and parietal pleura completely dissected from vertebrae corpus (3,13,19).

Soft tissue adhesions, costotransverse and stellat ligaments are cut at the proximal part of the rib head. Then rib head is released and resected. Thoracic sympathetic chain, intercostal vessels, thoracic duct and azygos veins are lay in the endothoracic fascia on chest wall and vertebral body. Meanwhile, maximum effort should be given to protect sympathetic chain (3,13,15). Segmental vessels are ligated and cut as much as possible proximally (19).

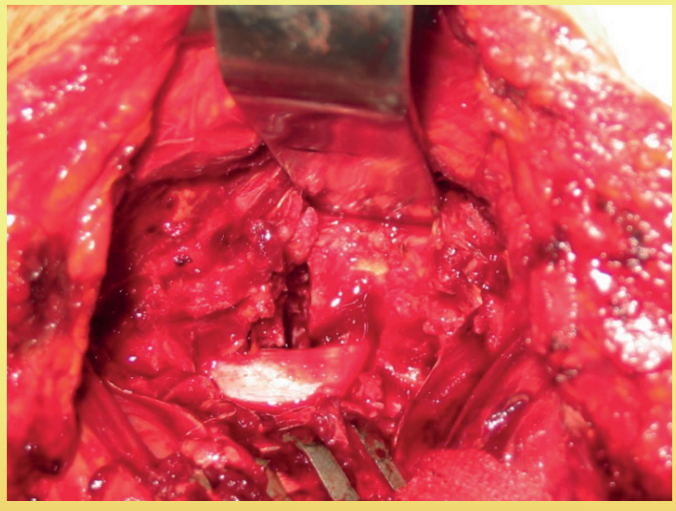


Figure 13

In retropleural approach it may be possible to reach lateral sides of the dura mater and vertebrae corpus (Kaptanoğlu archive).

3) Transpleural Thoracotomy and Retroperitoneal Thoracoabdominal Approach

An obliqueskin incision which continue along the 10th or 11th ribs made between mid-axillary line and lateral edge of rectus abdominis muscle. The fluoroscopy should be used to determine the incision level (7,9,12,16,18).

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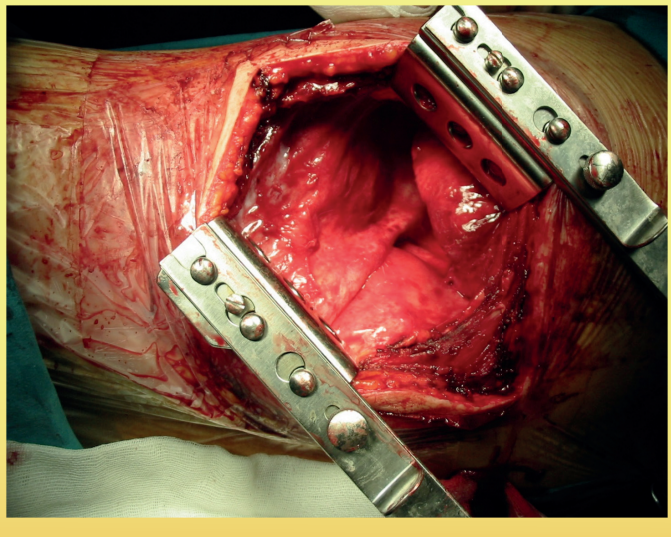

Figure 14

In transpleural-retroperitoneal thoracotomy after opening the thorax, diaphragm is demonstrated (Kaptanoğlu archive).

After skin incision, subcutaneous tissue cut with electrocautery (18). Latissimus dorsi and serratus anterior muscle's fibers are separated. After separation the external oblique muscle, internal oblique and transverseabdominal muscle's fibers separated respectively (12,16,18). Then, transverse fascia is cut and entered the retroperitoneal region. The lower surface of the diaphragm will be seen from opening (16). Rib is dissected from periost (16,18). If rib removing is planned, removing should be done 4 cm distally from costovertebral joint (16).

Endothoracic fascia and parietal pleurais opened below the rib (9,16,18). This openness usually occurs involuntary and is extended parallel to the ribs curvature. Thoracic retractors are placed between the ribs and the lungis retracted with wet compresses to cranially and medially to reach thoracic vertebrae (12,18). In the meantime, deflating of the left lung is not mandatory (7). Diaphragm is cut along the bottom edge of theribs, however in T12-L1 level lateral and medial arcuate ligaments are cut with electrocautery untill to reach vertebral body (12,16) (Figure 14). In this stage, maximum effort should be given to protect the phrenic nerve and blood vessels. Tagging sutures can also be placed on the diaphragm and chest wall cuff to mark reference points to facilitate closure (12,18). During this process to facilitate suturing, muscle tissue should be left up to 1-2 cm on the rib cage (2-4,8,9,11,12,14,16-18,20). Diaphragmis cut and retracted to anteromedially then transverse fascia is cut to dorsally and retroperitoneal adipose tissue is seen. Retroperitoneal adipose tissue and organs separated from abdominal wall with blunt dissection. This processis continued until it reaches the edge of the front side of the vertebrae (2,10,12,16,18). At this stage, peritoneum should be protected. If damaged is detected, peritoneum should repaired primary. The ureter is observed on the back surface ofthe peritoneum. Ureteral peristaltic action is seen and it should not dissected from the peritoneum. Peritoneum with all contents retracted frontally and finally reach to vertebral bodies (18). Parietal pleura is cut and dissected along the vertebrae in vertical plane (12). Aorta and vena cava are seen in front of the vertebrae (16). Segmental vessels are ligated and cut and the aorta is mobilized medially (12) (Figure 15,16).

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Iliopsoas and quadrates lumborum muscles completely cover the lateral side of the lumbar vertebral bodies in retroperitoneal region (12,16). Therefore, L1 and the distal lumbar vertebral bodies and disc spaces can not be seen like in the thoracic region. After vertebral bodies and disc spaces determined, if pathology is not clear fluoroscopy will be necessary to detect pathology level. Nerve roots run in or under the psoas muscle fibers after exiting from neural foramina. For this reason, the muscle should be dissected from anterior to posterior (16).

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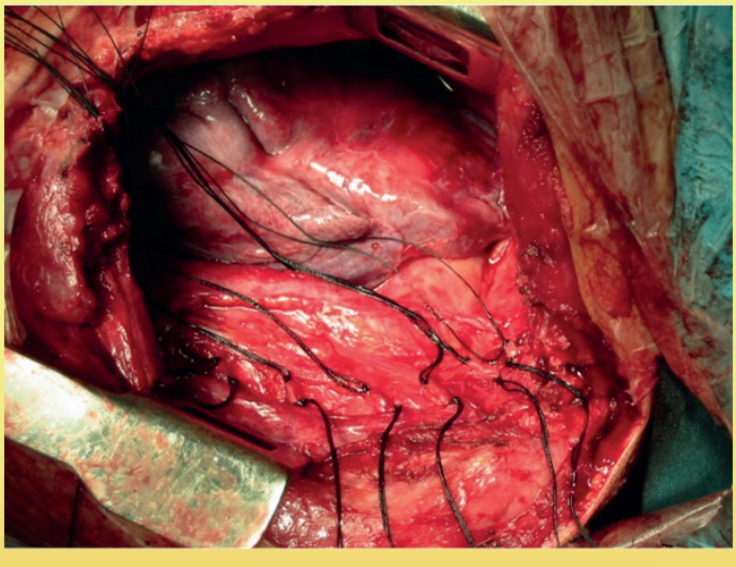

Figure 15

In this patient high thoracotomy is applied for long segment deformity surgery, the proximal and distal segmental vessels are ligated for cut (Kaptanoğlu archive).

4) Retropleural Thoracotomy and Thoracoabdominal Retroperitoneal Approach

Although retroperitoneal approach is used for the lumbar vertebrae interventions, transpleural approach is used for anteriorthoracic interventions (3,13). Transpleural thoracic approach is an extensive intervention that requires lung retraction directly. Although retropleural thoracotomy has been described as an alternative way (13,17,19) it is not achoiceas the standard approach (3,13).

Retropleural thoracotomy is the shortest intervention that allow to reach thoracic vertebrae without to enterto pleural space.

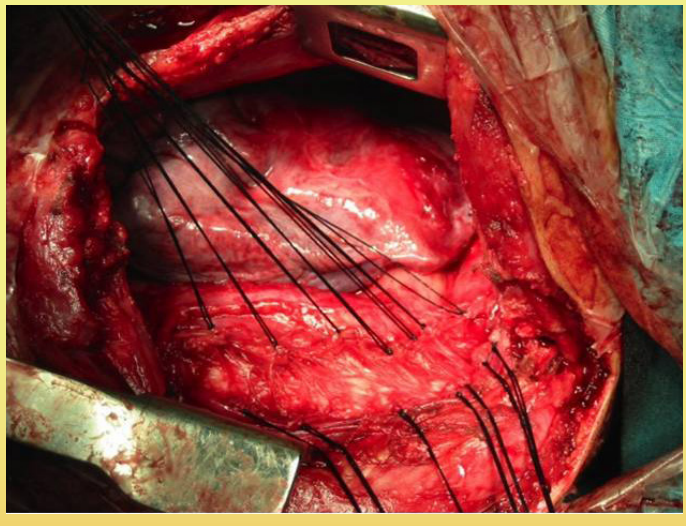

Figure 16

After cut of segmental vessels, easily mobilization of aorta was observed in this patient (Kaptanoğlu archive).

Retropleural thoracotomy is the shortest intervention that allow to reach thoracic vertebrae without to enterto pleural space. This opening provides direct vision to the vertebrae and front of the spinal canal and postoperative pain and pulmonary complications are less common. This form is an appropriate approach to reach thoracic and thoracolumbar (T3-L1) anterior pathologies (3,13). This method reduces the diaphragm dysfunction, postoperative pain and pulmonary complications. Also provides better wound healing (3,10,17). There is no need to usea chest tube. However, if parietal pleura is damaged during surgery and can not be repaired primary, useof a chest tube is mandatory (3,15).

Dissection of peritoneum from transvers fascia of abdominal wallis similar to dissection of parietal pleura from endothoracic fascia, which is described in retropleural thoracotomy and retroperitoneal thoracoabdominal approaches.

In this approach,the skin incision and rib resection are applied above the two levels ofthe targeted vertebral body. For example, if pathology is at T12 vertebral body skin incision is planned at 10th rib level. This incision starts in the posterior axillary line and continues anteriorly to 4 cm away from midline. Up to10 cm rib is dissected and removed. Endothoracic fascia is seen. Under the endothoracic fascia, parietal pleura and the diaphragm's movement is felt. Pleural surface of the diaphragm is determined (13). Endothoracic fascia opened. In addition to dissection of the parietal pleura in the thoracic vertebraeas described above, diaphragm dissected sharply from afterinner surfaces ofthe 11th-12th ribs. Thus, retroperitoneal adipose tissue and retroperitoneal space are opened. After medial dissection of the diaphragm, medial arcuate ligament of the diaphragm dissected from the psoas and quadratus muscles. Ipsilateral diaphragm crus dissected and retracted to medially. Four cm proximal part of the T12 vertebrae is rib head and removed similar to described in retropleural thoracic approach (3,13).

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dissected from anterior to posterior on T12 vertebral body level. Thus, the T12 vertebral body, adjacent disc space and T12 pedicle will be revealed. After this stage, discectomy or corpectomy is applied (13).

Exposition of the Pathological Region

After thoracotomy, we reach parietal pleura onthe anterolateral side of the thoracic vertebrae. Firstly parietal pleurais incised and segmental arteries and azygos veins are seen. These vessels are ligated and cut, so aortais mobilized (5,8,9,11,16,18). In pathologies that corpectomy is required, segmental arteries are should be ligated at upper and lower vertebra levels on which instrumentation will be applied (3,6,11,14,16,18). Thoracic and lumbar vertebrae including L4 vertebra are supplied by segmental arteries. Segmental arteries originated directly from aorta and pass through middle of the vertebral body then are divided into two branches dorsal and lateral. Then spinal branch is originated from dorsal branch and enters to neural foramen. Spinal branch makes an anastomosis with other spinal branches. It is important to know the anatomic anastomotic network. If spinal artery is ligated nearest the neural foramen this anastomotic network could damage neurological deficits can occur Therefore, segmental arteries should ligate before entering to the neural foramina (2,16,18,19).

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In literature behavior to segmental arteries is controversial. In simple discectomy and anterior releasing, segmental arteries can be protected (9,15,18) (Figure 17). Especially in left side approaches, avoid to ligate segmental arteries (4). However, in 1996, Winter et al. reported 1.200 patients with segmental artery ligation during anterior spinal intervention. Only five of the 1.200 patients had developed neurological deficits. Authors specified that neurological deficitis could have developed due to mechanical reasons in 4 of 5 and the fifth stated that the suspects. So authors concluded that unless multi-level artery ligation will not occur neurological deterioration (9,18).

In simple discectomy and anterior releasing, segmental arteries can be protected.

Adamkiewicz artery is the main feeder for the anterior and posterior thoracolumbar spinal artery area. In some cases, in order to reduce the risk of paraplegia preoperative selective angiography is recommended to determine the artery (7). Preoperative MRI is a safe tool in determining the Adamkiewicz artery (10,17). Adamkiewicz artery is the largest feeder of the lower half of the spinal cord, which settles around 80% on the left side and the thoracolumbar junction. It often seen on the T8-T12 level and less frequently seen in T5-L2 (2-4,7,10,17,18). In order to minimize the risk of spinal cord ischemia in left side approach, segmental arteries firstly clipped temporary and ligating after checked by SSEP (2,4,17,18).

Discectomy and Corpectomy Segmental vesselsare ligated and cut after lateral part of the vertebral bodies are revealed.

If discectomy is planned, rib resection is not required. However, the disk space is covered by the rib head so resection of the rib head will be required (e.g.for T8-T9 disc space 9th rib). In this way, the back edge of the disk space will be seen. Proximal part of the ribis articulated with the transverse processes. If necessary, rib head dissected subperiosteally with electrocautery and could remove (3,5,15). Distal resection of 2 cm of the rib head would be sufficient (3,18).

Discectomy and Corpectomy

Segmental vesselsare ligated and cut after lateral part of the vertebral bodies are revealed. The aorta is mobilized medially. At this stage, the level can be determined, with fluoroscopy (8,16,20). Following the intercostal nerve, we reach the pedicle. Upper part of the pedicle is drilled; dura and spinal canal are exposed. Disc capsule incised and discectomy is applied. Then the posterior longitudinal ligament (PLL) is resected and free fragments can be removed. High-speed drill tour (diamond tip) can be used for calcified discs (15).

If corpectomy is plannedfor resection pathology, resection of adjacent discs (for fusion) are required (14,20). Ventral dura should be seenfor security corpectomy. In thoracic region, pedicles, neural foramina and disc spacesare exposedafter adjacent rib heads are resected. Pedicle is removed with Kerrison rongeur and dura mater is seen (1,8,20). Thus, corpectomy can be applied without injury riskof the spinal cord and nerve roots (8,19). Cancellous portion of the vertebral body is removed with Kerrison rongeur and high-speed drill tour (8,14,20). During corpectomy anterior and opposite cortex of the vertebral body are maintained. This cortical shell will help to protect soft tissues and vital vascular structures. In traumatic bone fractures PLL is peeled off and the front side of the dura is seen (1,14). Fragments of bone, tumor or the disc are removed by angled-long curettes and the spinal canal decompression is completed. Retropulse broken bone pieces are removed in vertebral fractures (3,8,14,20). Corpectomy materials are preserved to be used for fusion in pathologies other than tumor and infections (20). Dural tears and epidural hemorrhage should be treated with thrombin-impregnated spongostan. To ensure decompression the spinal canal is crossed against pedicleis checked (14). After the disc has been removed graft or cage placed to corpectomy bed (8,20).

Especially in the lower left thoracotomy, segmental arteries can be protected to avoid the possibility of ligated the Adamkiewicz artery.

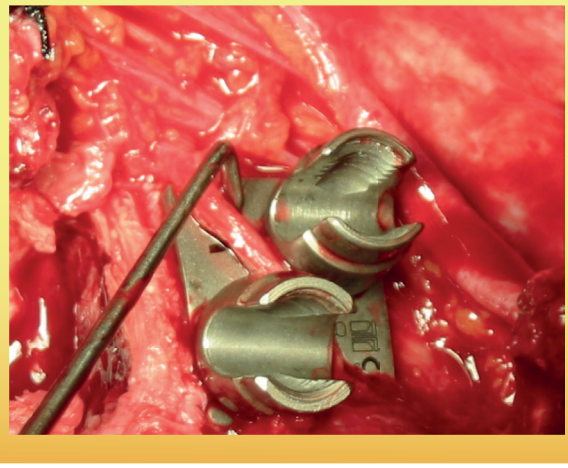

Figure 17

Especially in the lower left thoracotomy, segmental arteries can be protected to avoid the possibility of ligated the Adamkiewicz artery. In figure segmental arteries in a patient with anterior screw-rod instrumentation have been mobilized primarily from vertebra corpus. Then, instruments are placed with protecting arteries-veins package, at the end vessels running has been observed (Kaptanoğlu archive).

Surgical Closure

Surgical Closure In retroperitoneal thoracoabdominal approaches, aft er meticulous bleeding control, a suction drain is placed into retroperitoneal region.

In retroperitoneal thoracoabdominal approaches, after meticulous bleeding control, a suction drain is placed into retroperitoneal region (16). Then, transverse fascia innermost, internal oblique, and external oblique muscle layers sutured one by one. After decompression and stabilization operations diaphragm's arcuate ligaments should be sutured to psoas and quadrates lumborum muscles in thoracoabdominal approach (3,13).

In retropleural thoracotomy approach before closing, Valsalva maneuver should be done to examine pleura and dura mater. In the presence of tear in pleura and/or dura mater, it should be repaired primarily (3,13,15). If primary repair of the tear is not possible chest tube should be placed. Then, fascia, muscle layers subcutaneous tissues and finally skin sutured. In order to reduce deformity of the chest wall due to rib resection, adjacent ribs sutured each other. To prevent postoperative pain, more care should be taken to avoid compression of intercostal nerves between the sutures (3,13). This approach should not be used above T3 level (3).

In transpleural thoracotomy approach parietal pleura should be closed completely (17,18) (Figure 18). This will reduce the bleeding to thoracic cavity will serve as a protective layer on the implants (18). Diaphragm is sutured continuous with 0 or 1 number nonabsorbable (polypropylene) sutures (16,17). Intercostal muscles closed continue with PDS or Vicryl (16). At the beginning these sutures should be kept loose but after the detection of lung

ventilation sutures tight strongly. This will prevent injury to the lung during sutured and allows to see lung ventilation (2). Serratus anterior, latissimusdorsi and trapezius muscles are repaired directly, subcutaneous and the skin is closed (3,18).

Chest tube should be placed in all patients in transpleural approach (8,9,11,14-17) (Figure 19). Tube is placed from the upper intercostal space. End of the drain should show lung apex and bottom hole should be diaphragm (16,18). In some cases, the authors propose two different tube insertion (6,18). If the amount of fluid is less than 100-200cc for 24 hours, chest tube closed and followed 6 hours (6,8,11,17). At the end of this period if chest X-ray is normal tube can be pulled (11,17,18). Chest tube is usually kept 24-72 hours depending on the method of surgery (11).

After the operation, the patient can be extubated in the operating room. Rarely intubated ventilation may be needed after surgery. This is usually due to obstructive pulmonary disease, or prolonged operative time. The patient is monitored in intensive care until the chest tube is removed. Postoperative pain can be controlled with NSAIDs or analgesics including morphine and patient controlled analgesia (PCA). Patients are mobilized in first postoperative day. Respiratory physiotherapy should be started immediately after the patient waking up and cooperative (11).

Chest tube should be placed in all patients in transpleural approach. Tube is placed from the upper intercostal space.

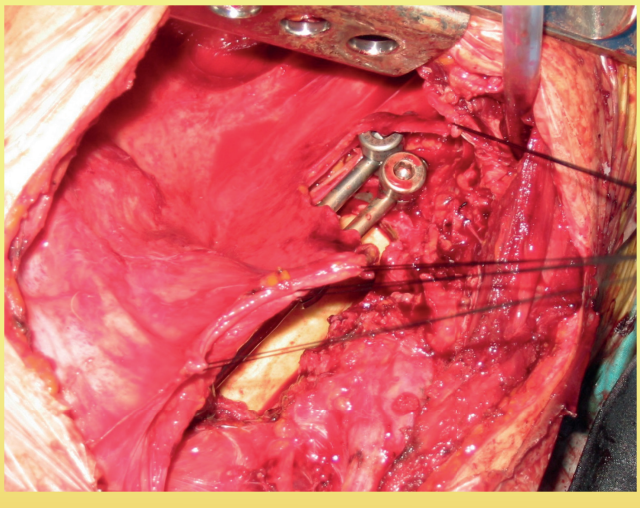

Figure 18

During closing the suturation of parietal pleura usefull. This process reduces bleeding and forms a protective layer on instruments (Kaptanoğlu archive).

Complications of retropleural, transpleural thoracotomy and retroperitoneal thoracoabdominal approach generally classified under three main headings.

Complications

Complications of retropleural, transpleural thoracotomy and retroperitoneal thoracoabdominal approach generally classified under three main headings. They are: 1- approach-related complications, 2- decompression-related (discectomy, corpectomy) complications, 3- stabilizing (fusion and/or instrumentation) complications (9). In every stage of anterior thoracotomy (exposure, decompression, reconstruction, fixation, closure or during the post-operative) complications are possible (18,20). Naunheim et al. reported an operative mortality rate as 3,2%. Different rates of complications such as 10-50% have been reported. These are pulmonary (pneumothorax, atalectasia, pneumonia), cardiac (arrhythmias, myocardial infarction), vascular (stroke, deep vein thrombosis), technical

Figure 19

In transpleural approaches or retropleural approaches if pleura is opened chest tube should be placed. İn figure placement of chest tube is seen at the end of the surgery. Before closing the thorax, it allows placement of chest tube manually to the desired location (Kaptanoğlu archive).

As a precaution, the appropriate pain control, perioperative use of spirometry and early mobilization of the patient is very important if not contraindicated.

(pneumothorax, wound and urinary tract infections, superficial wound infection, wound dehiscence and bleeding), and gastrointestinal (ileus) complications (10,17,19,20).

Pulmonary complications are the most common complications related to exposure (9,10,17). As a precaution, the appropriate pain control, perioperative use of spirometry and early mobilization of the patient is very important if not contraindicated (4,11). Retroperitoneal hematoma and postoperative ileus are potential complications for the retroperitoneal approach. Direct or indirect injuries of internal organs (lung, kidney and ureter), the blood vessels (aorta, segmental vessels, vena cava, azygos/hemiazygos vein) or other structures (diaphragm, thoracic duct, heart, intercostal vessels and nerves, sympathetic chain) are quite rare (11,20). Vascular injuries should be repaired primarily. Renal or ureteral injuries give evidence with pain and hematuria and diagnosed with CT, ultrasound, or intravenous pyelography. Treatment is repaired primarily. Undiagnosed injuries can result in peritonitis or sepsis (18).

One of the most afraid complications is the development of paraparesis or paraplegia due tospinal cord ischemia as a result of ligation of Adamkiewicz artery or bilateral segmental arteries.

Diaphragmatic rupture is a rare complication and gives evidence with pain and respiratory distress. The diagnosis is made by direct radiography or CT. Treatment is repair primarily (18). Meticulous closure of the diaphragm layers will also block wound separation (9,10,17,20). Chylothorax often seen in the right-sided approach inthoracic levels (10,17). Large lymphocele may occur as a result of retroperitoneal lymphatic (cisterna chyle/thoracic duct) injuries. If injury detected during surgery, it should be ligated with non-absorbable sutures (7,8).

One of the most afraid complications is the development of paraparesis or paraplegia due tospinal cord ischemia as a result of ligation of Adamkiewicz artery or bilateral segmental arteries. Two-sided segmental arterial injury rate is range 1% to 5% inthoracic spinal deformity correction surgeries (10). Although there are many published articles about the importance of Adamkiewicz artery injury, ligation is generally well tolerated (10,17).

Neural elements can injured during decompression, reduction or reconstruction. Neurological injuries determined early and evaluated by MRI. If dural tears occur durig the operation watertight closure should be done. Otherwise, hydrothorax can develop (18,20).

Neural elements can injured during decompression, reduction or reconstruction.

In these surgical approaches, optic neuropathy, retinal artery occlusion, a number of such unpredictable rare complications have been reported. Rupture of latissimusdorsi is a rare a postoperative wound complication. Post-thoracotomy incision pain (intercostal neuralgia) may occur (10). In addition, pseudoherni due to muscle denervation may cause pain.18

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