Surgical Anatomy of the Lumbar Spine

4

Jian-gang Shi, Wen Yuan, and Jing-chuan Sun

1 Lateral Retroperitoneal Approach to the Lumbar Spine

1.1 Overview

Lateral retroperitoneal approach is mainly used to expose the vertebral bodies and anterolateral aspects of intervertebral discs at L1–L5 for lumbosacral surgery. Its indications include total or partial resection of a single lumbar vertebral body which is performed with bone grafting, anterior lumbar fusion, drainage of abscess in the psoas major muscle, dissection of an infectious lesion (especially tuberculosis) in a lumbar vertebral body, and resection of lumbar sympathetic ganglions. This approach can expose vertebral bodies and the lateral sides of intervertebral discs and avoid injury to the peritoneum and organs in the abdominal cavity at the same time.

1.2 Position

After general anesthesia, the patient is placed in the lateral position or recumbent position. The armpit and hip joint are cushioned by pillows (Fig. 4.1).

Soft pillows are used to cushion the left upper extremity and lumbar region (or elevate the jackknife of the operating table) so as to increase the distance between the subcostal margin and the iliac crest and thereby facilitate operation (Fig. 4.2).

1.3 Incision

Make an anterior-inferior incision from the point where the subcostal margin intersects with the posterior axillary line, i.e., at the distal end of the 12th rib, to the outer border of the rectus abdominis.

Attention should be paid to the protection of nerves in the abdominal wall during the incision of the skin and subcutaneous tissue. Injuries of the nerves often cause postoperative sensory disturbance or pain of the skin (Fig. 4.3).

Superficial layer of the abdominal wall (Fig. 4.4): the muscular portion of the external oblique muscle of the abdomen blends with the extending muscle fibers of the serratus anterior muscle, and some aponeuroses form the anterior layer of the sheath of the rectus abdominis.

Subcostal nerve: the anterior ramus of the spinal nerve T12, which travels together with subcostal vessels; it runs along the lateral arcuate ligament on the lower border of the 12th rib and the posterior portion of the kidneys, then travels in front of the upper portion of the quadratus lumborum muscle, next passes through the transverse fascia, and finally travels in the

J.-g. Shi (✉) • W. Yuan • J.-c. Sun
Department of Orthopedics, Changzheng Hospital, Shanghai, China
e-mail: shijiangang616@163.com; yuanwenspine@163.com; sjchxc@foxmail.com

J.-g. Shi et al. (eds.), *Anatomy Atlas and Interpretation of Spine Surgery*, https://doi.org/10.1007/978-981-10-5906-3_4

deep aspect of the internal oblique muscle of the abdomen; it is distributed in the skin in the anterior superior iliac spine region and hips, and it can run downward to the greater trochanter of the femur.

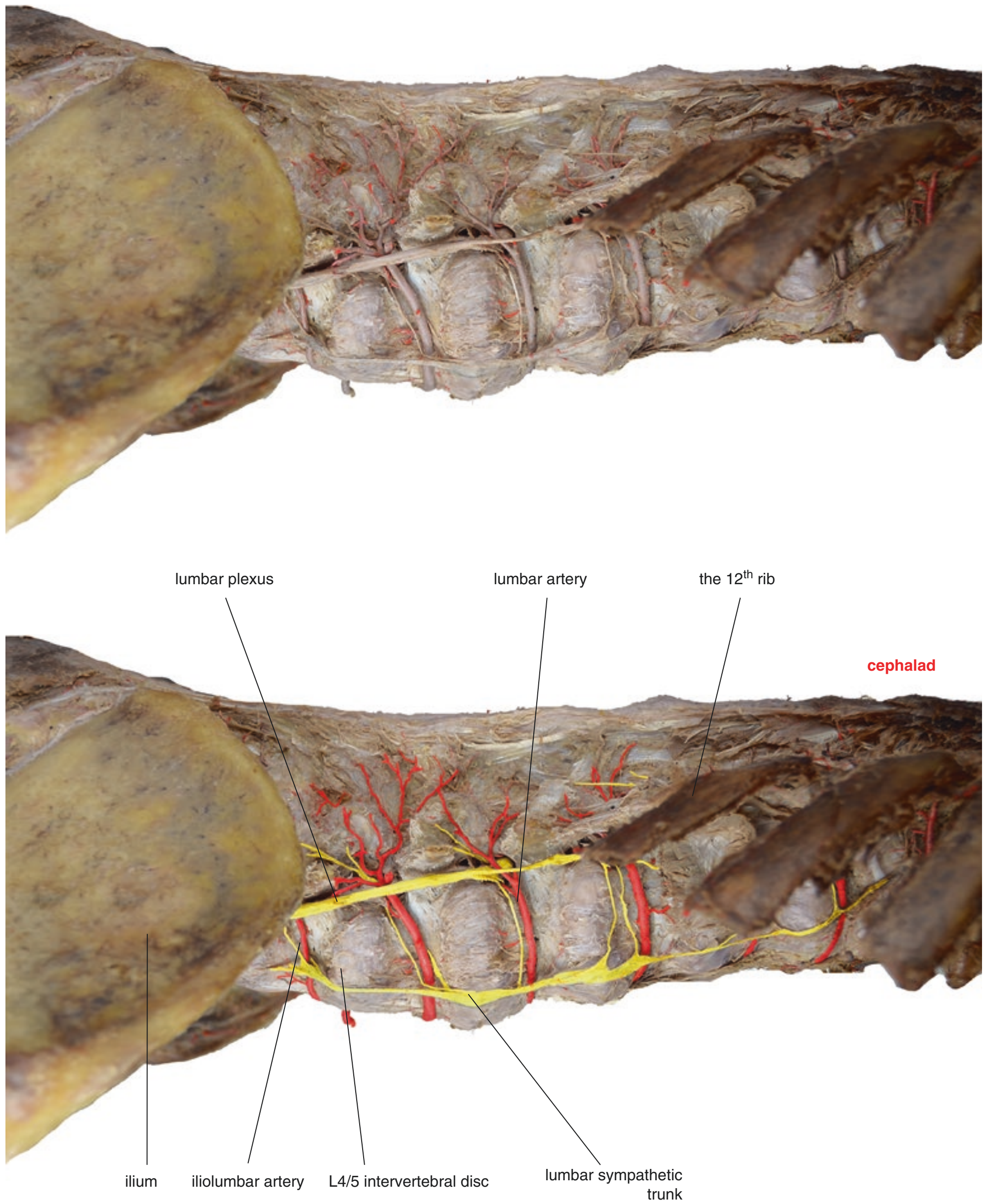
Iliohypogastric nerve: one of the branches of the anterior ramus of the first lumbar spinal nerve, which is located between the internal oblique muscle of the abdomen and the transverse abdominal muscle; it passes through the aponeurosis of the external oblique muscle of the abdomen at a point approximately 2.5 cm above the superficial inguinal ring; its anterior cutaneous branch innervates the abdominal skin above the pubic area.

Ilioinguinal nerve: one of the branches of the anterior ramus of the first lumbar spinal nerve, which is located approximately one finger below the iliohypogastric nerve and runs parallel with it; it runs across the inguinal canal with the spermatic cord, then emerges from the superficial inguinal ring, and distributes in the anterior scrotal skin. The genital branch of the genitofemoral nerve runs downward along the medial side of spermatic cord, then emerges from the superficial inguinal ring, and distributes in the cremaster muscle, inner thighs, and scrotums or the labia majora and mons pubis.

The vessels of the anterolateral abdominal wall include superior epigastric vessels of the internal thoracic vessel, branches of musculophrenic vessels, vessels of the inferior epigastric external ilium, deep circumflex iliac vessels, the arteria cruralis, superficial inferior epigastric and iliac circumflex vessels of the great saphenous vein, and the anterior branches of subcostal posterior intercostal vessels located in the 11th intercostal space.

Fig. 4.1 Position for lateral retroperitoneal approach

Fig. 4.2 The distance between the subcostal margin and the iliac crest



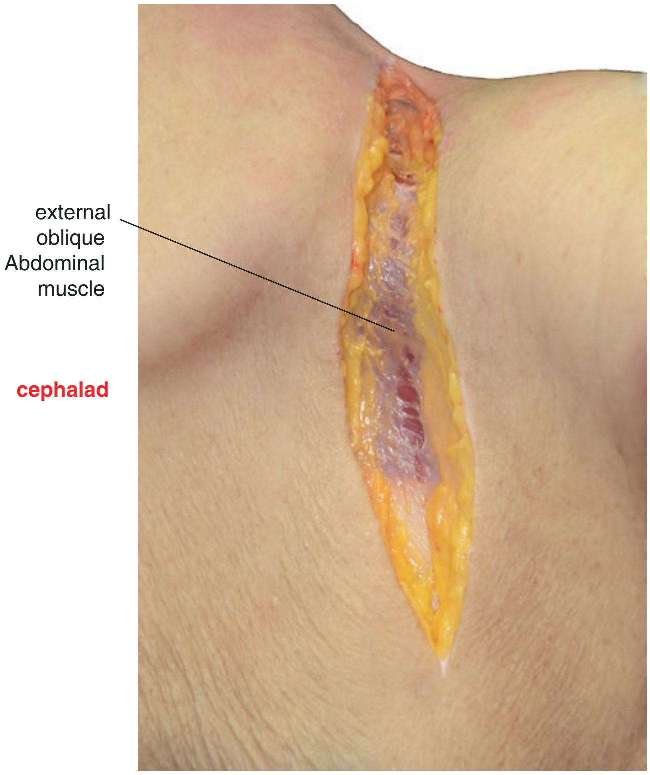


Fig. 4.3 Incision of lateral retroperitoneal approach

Incise the deep fascia and the muscle fiber of the external oblique muscle of the abdomen along the incision (Fig. 4.5) to expose the internal oblique muscle.

Dissect the internal oblique muscle of the abdomen vertically to the muscle fiber (parallel to the skin incision) (Fig. 4.6).

The transverse abdominal muscle and transverse fascia are dissected to expose retroperitoneal fat (Fig. 4.7). The transverse fascia is very thin; attention should be paid to avoid injury of the peritoneum.

The retroperitoneal fat and psoas major fascia are bluntly dissected, and the peritoneum and its contents are retracted toward the anteromedial side (Fig. 4.8).

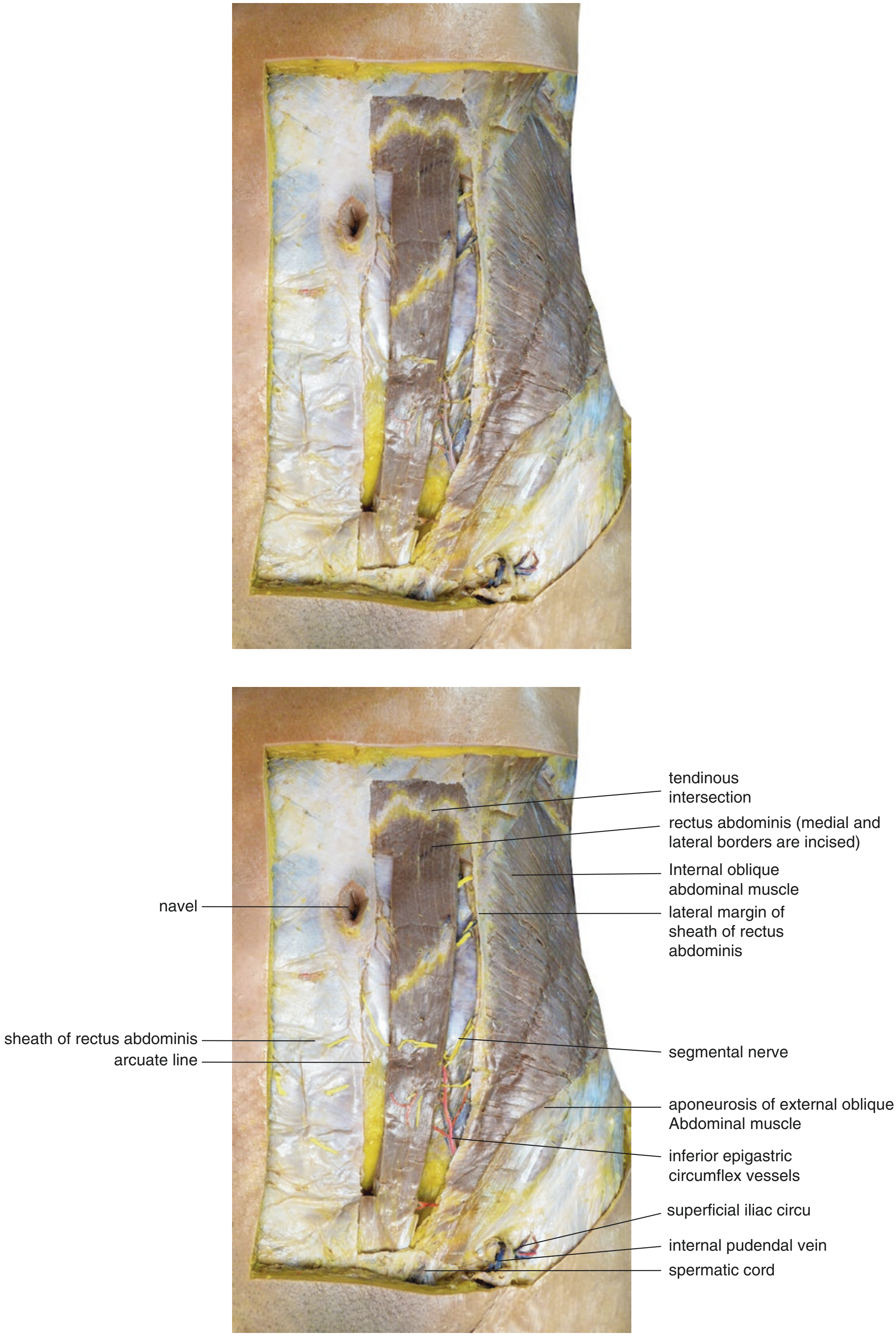


Fig. 4.4 Anatomy related to the abdominal wall

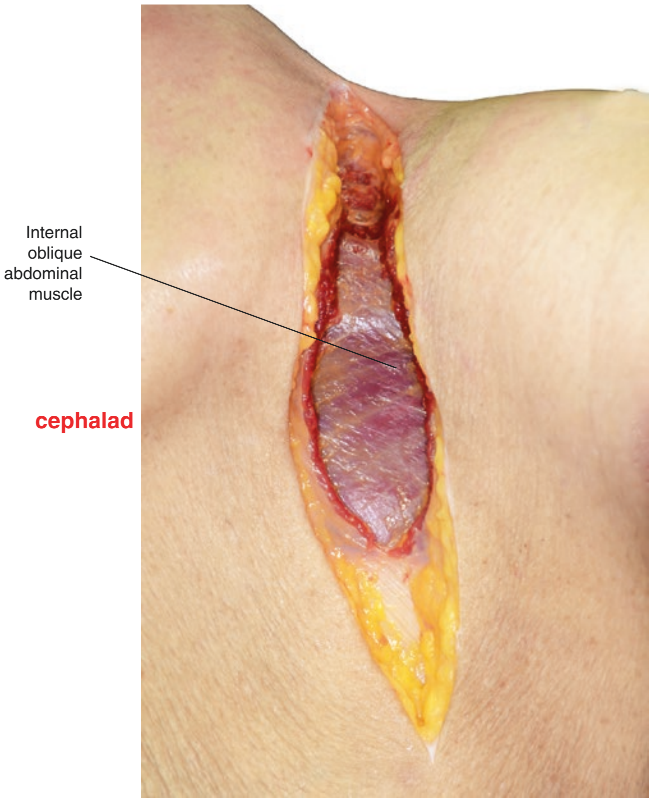


Fig. 4.5 Incision of the external oblique muscle of the abdomen

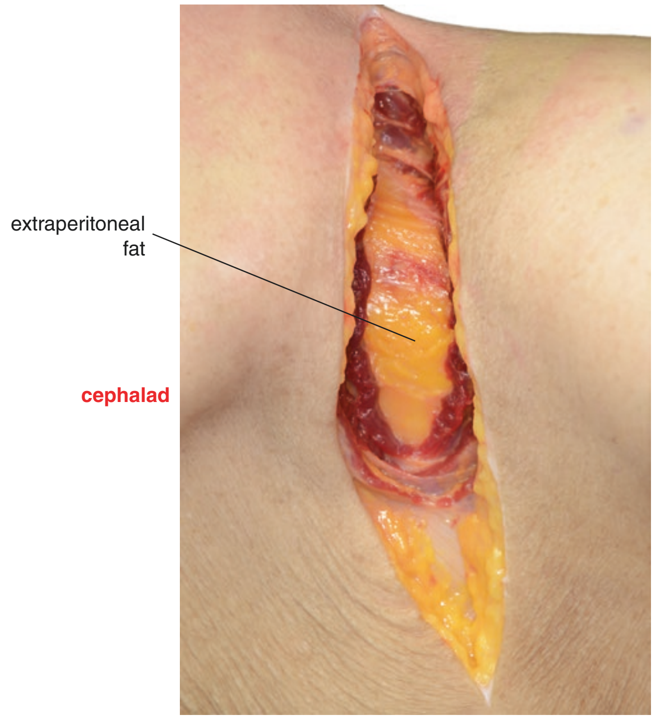


Fig. 4.7 Incision of the transverse abdominal muscle

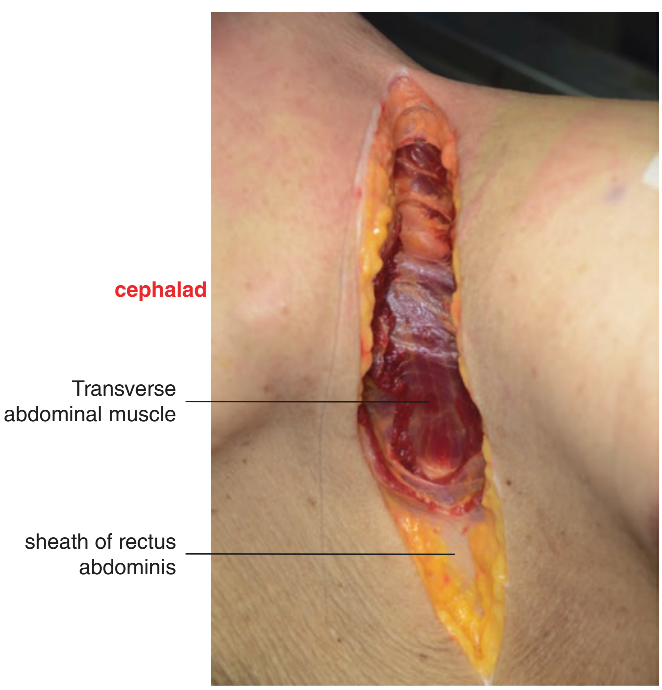


Fig. 4.6 Incision of the internal oblique muscle of the abdomen

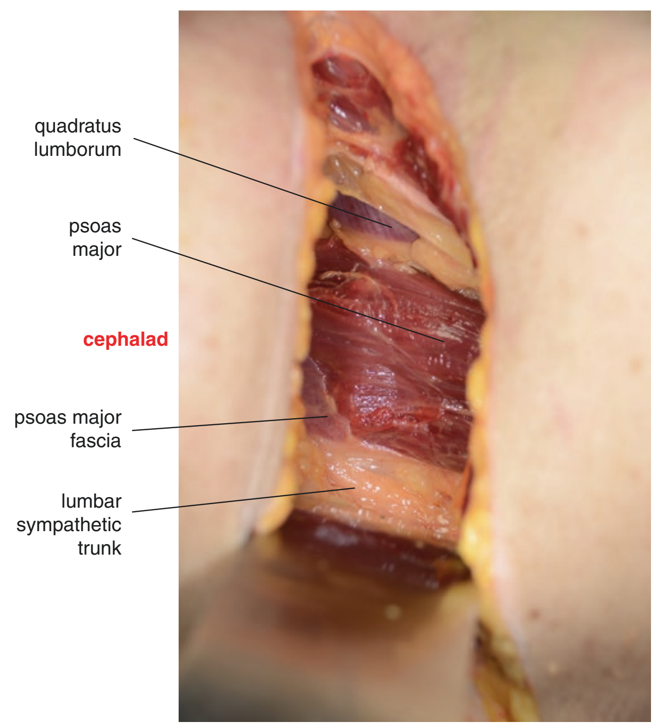


Fig. 4.8 Exposure of the psoas major muscle

External oblique muscle of the abdomen: the external oblique muscle of the abdomen starts from the lateral and inferior border of the 8th rib, and the bottom muscle bundle starts from the tip cartilage of the 12th rib, then runs in the lateral and anterior abdomen, with muscle fiber obliquing from anterolateral to inferior internal. Obliquus externus abdominis aponeurosis is distributed between the anterior superior iliac spine and the pubic tubercle, and its free margin forms the inguinal ligament. The muscle is innervated by terminal branches of the 8th to 12th intercostal nerves and the subcostal nerve and supplied by anterolateral abdominal wall vessels and the posterior lumbar artery. Its main function is to increase intra-abdominal pressure, resist gravity, and bend the trunk laterally (Fig. 4.9).

Internal oblique muscle of the abdomen: the internal oblique muscle of the abdomen has fiber mostly located in the deep layer of the external oblique muscle of the abdomen and is thinner than the external oblique muscle of the abdomen. It starts from the external two thirds of superior border of the inguinal ligament, and the internal oblique muscle of the abdomen starts from the superior iliac crest to the external and ends at the third or fourth rib inferior border and cartilago costalis. The obliquus internus abdominis is similar to the external oblique muscle of the abdomen in terms of innervation and blood supply. Its main function is to increase intra-abdominal pressure and resist gravity with lateral bending (Fig. 4.10).

Transverse abdominal muscle: the transverse abdominal muscle starts at the thoracolumbar fascia, iliac crest, and the external one third of the inguinal ligament and translates to the aponeurosis at the lateral border of the rectus abdominis. The transverse abdominal muscle is similar to the external oblique muscle in terms of innervation and blood supply. Its main function is to increase intra-abdominal pressure (Fig. 4.11).

Transverse fascia: it is close to the deep transverse abdominal muscle layer, and its anterior part connects inferior fascia of the diaphragm, while its inferior part continues to the fascia iliaca and pelvic fascia. Transverse fascia connects loosely to the transverse abdominal muscle but closely to the posterior sheath of the rectus abdominis layer (Fig. 4.12).

Parietal peritoneum: it is the innermost layer of the anterolateral abdominal wall, goes up toward the inferior peritoneum of the diaphragm, and continues down the peritoneum of the pelvic cavity (Fig. Fig. 4.13).

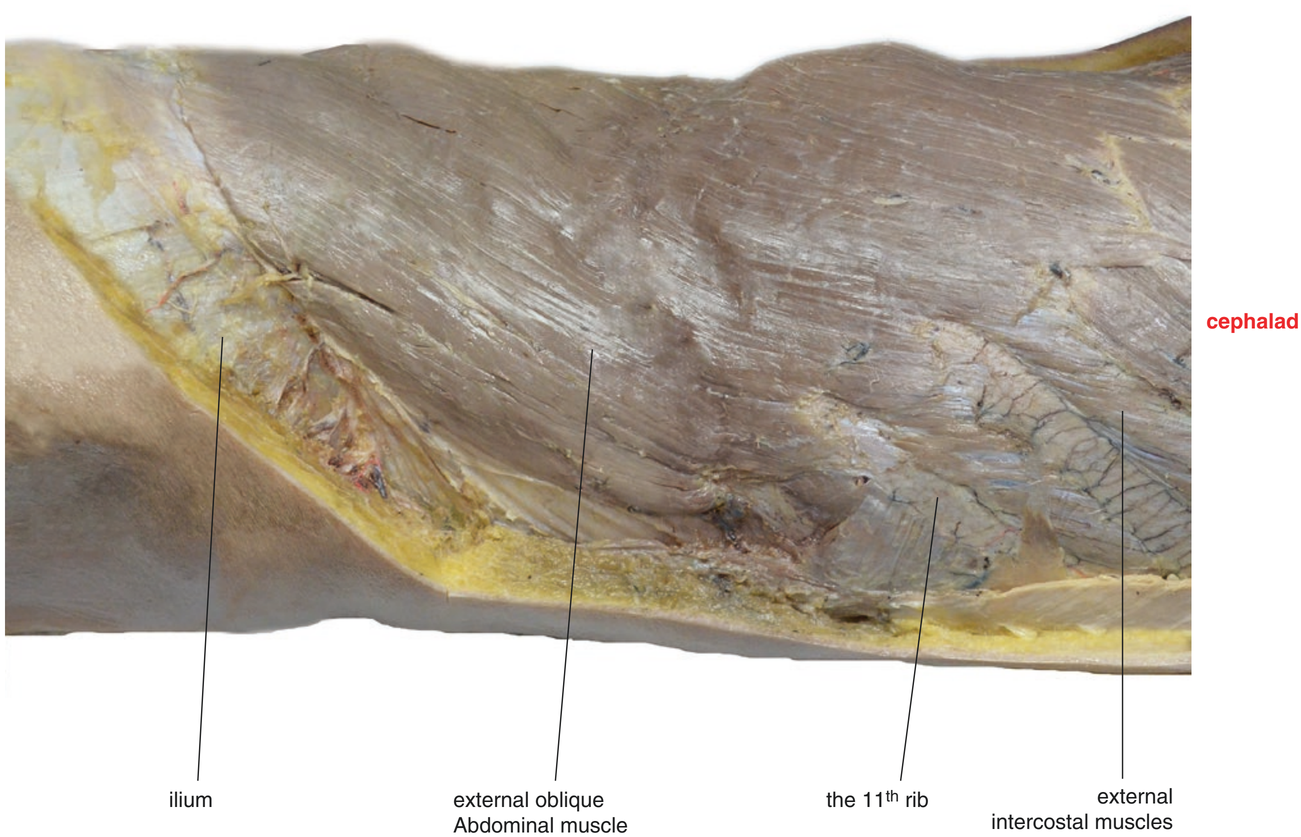


Fig. 4.9 Anatomy related to the lateral abdominal wall (external oblique muscle of the abdomen)

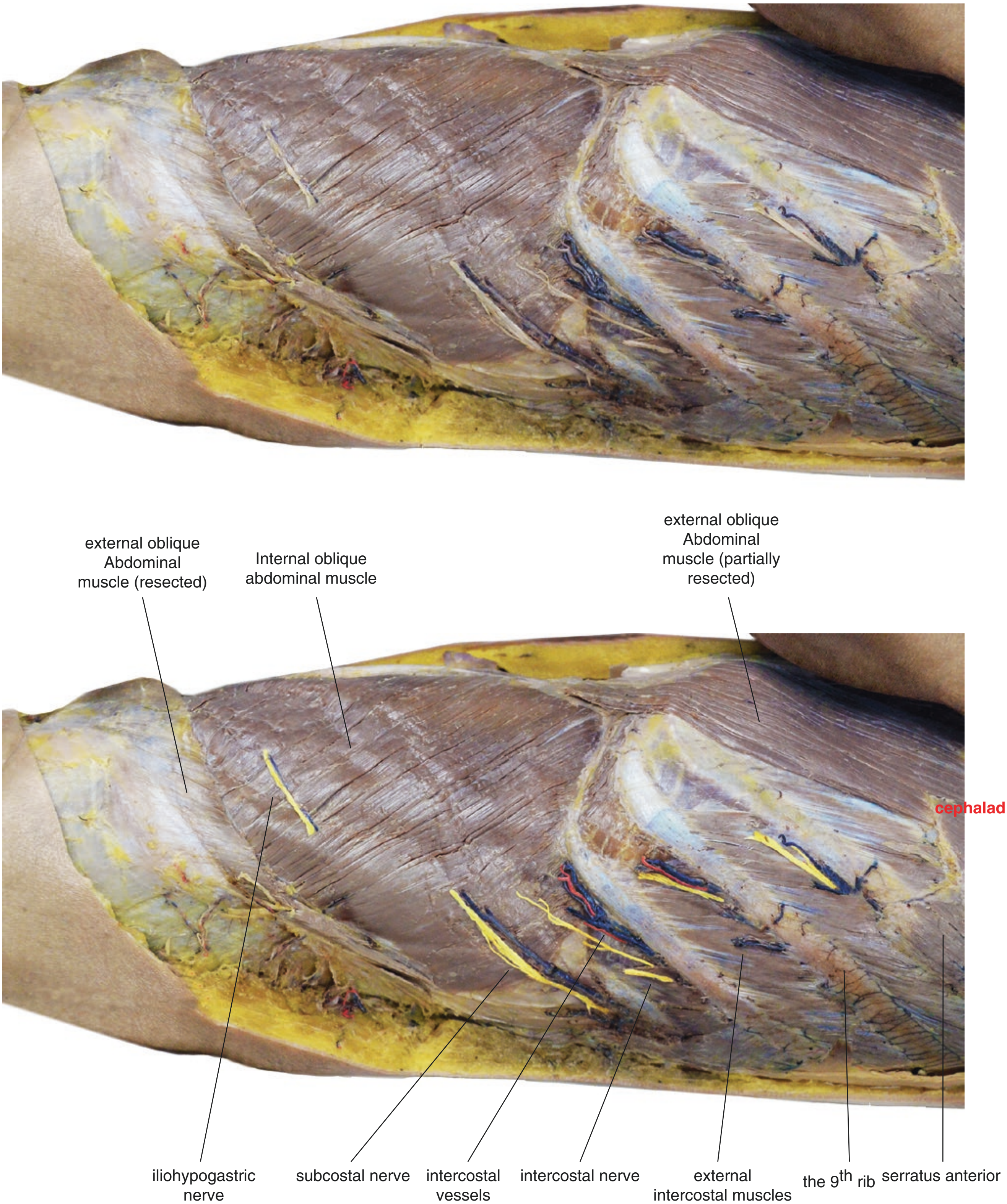


Fig. 4.10 Anatomy of the internal oblique muscle of the abdomen (the external oblique muscle of the abdomen has been removed)

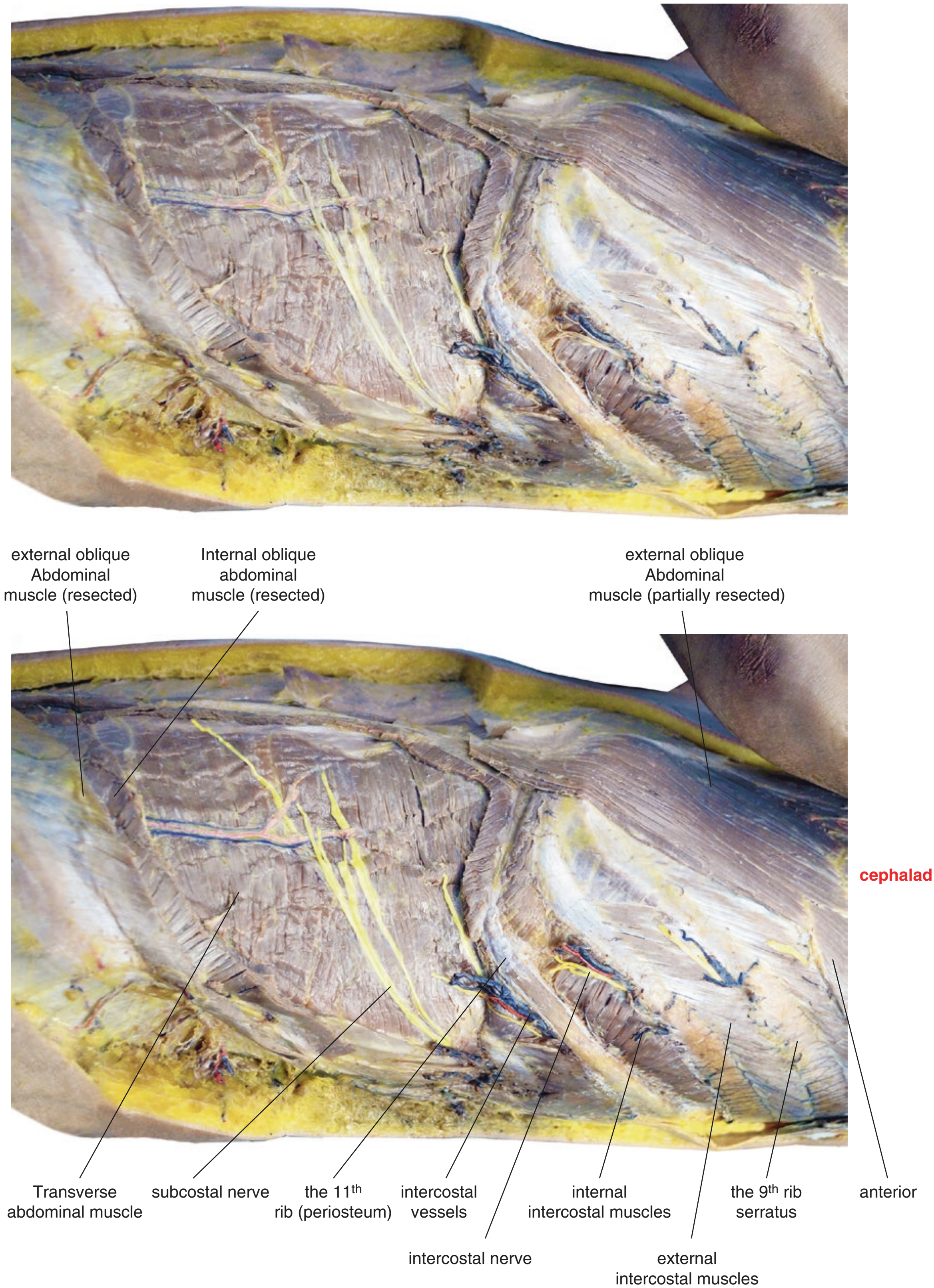


Fig. 4.11 Anatomy of the transverse abdominal muscle (the external oblique muscle of the abdomen and the internal oblique muscle of the abdomen have been removed)

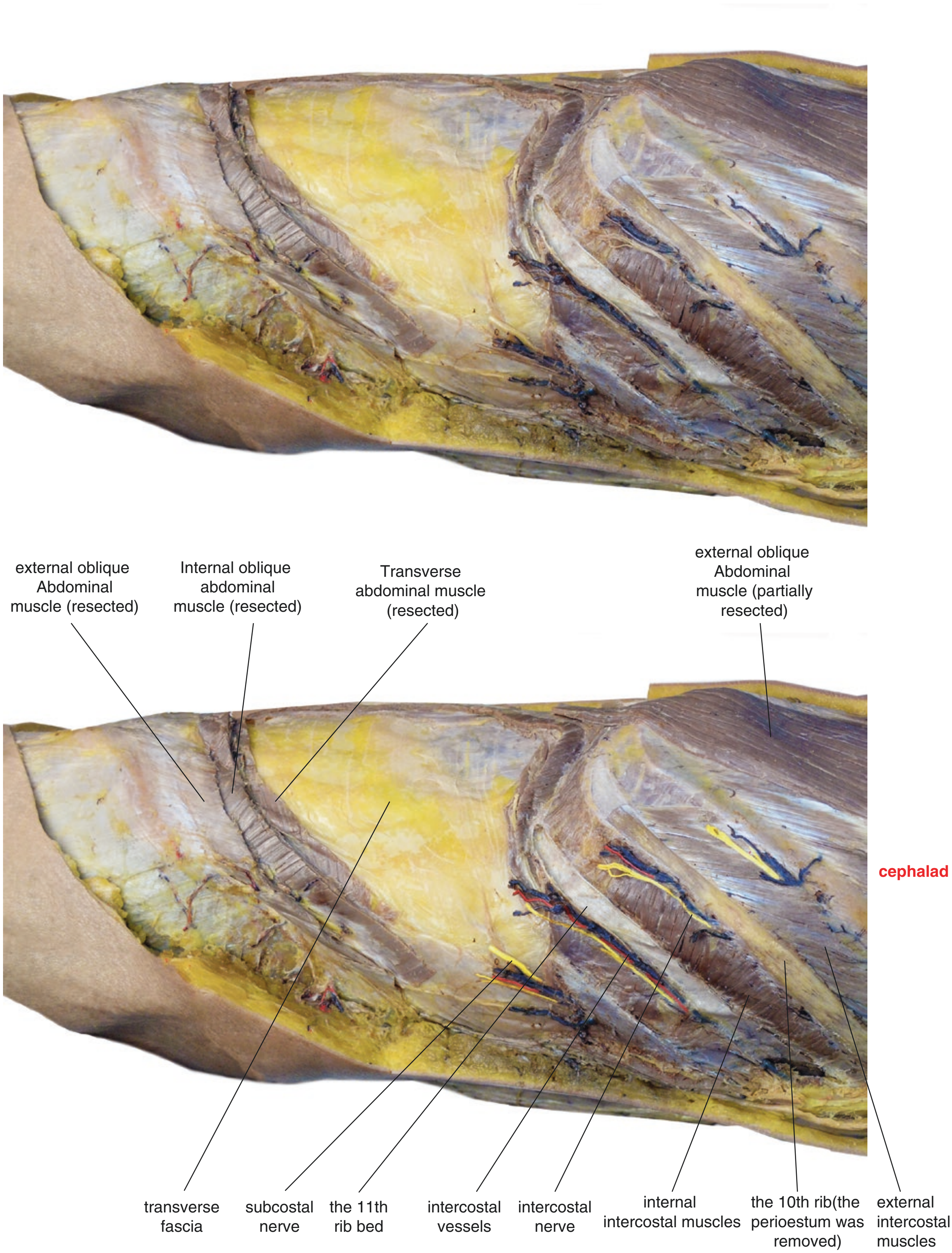


Fig. 4.12 Anatomy of the transverse fascia (the external oblique muscle of the abdomen and the internal oblique muscle of the abdomen have been removed)

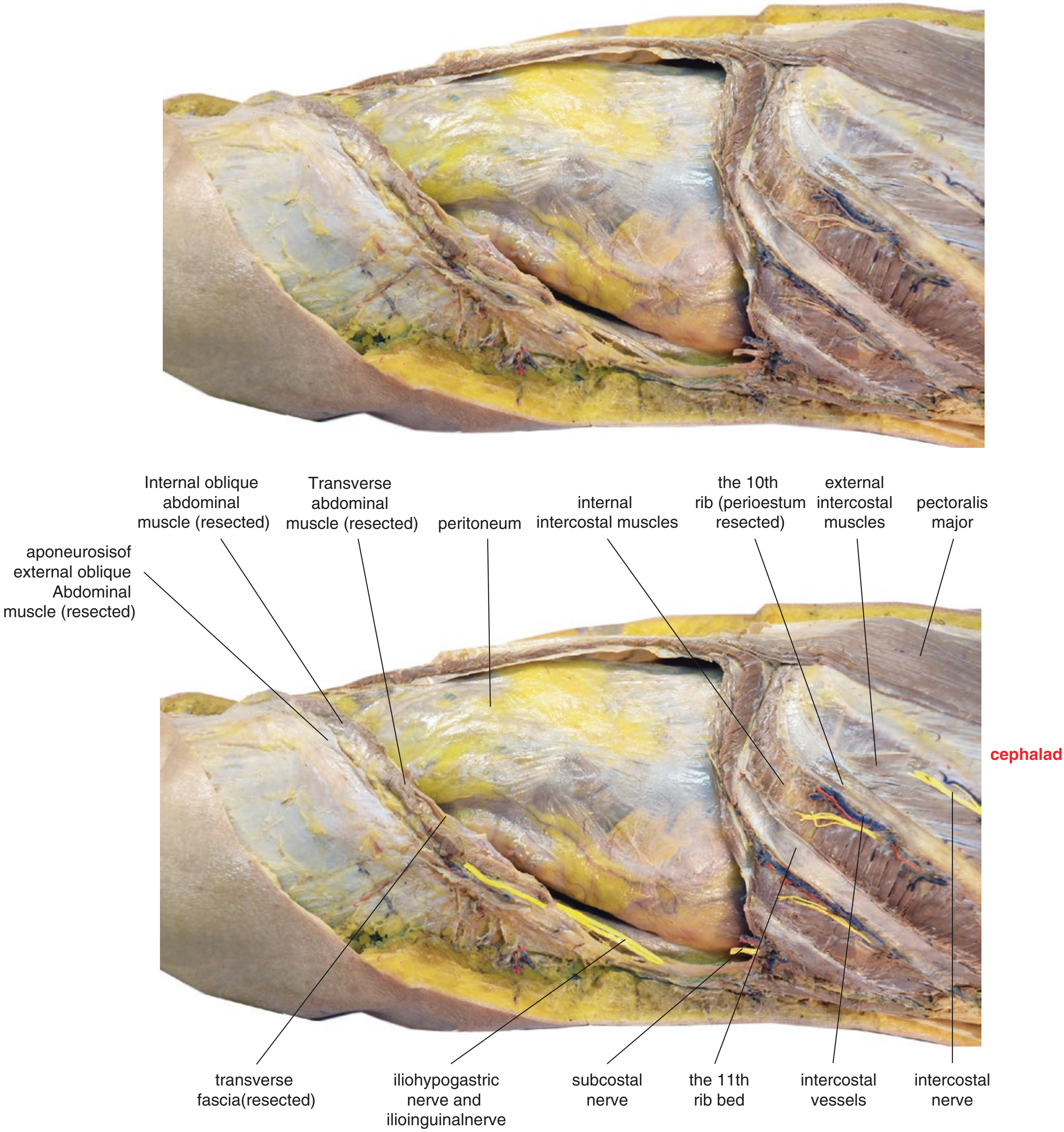


Fig. 4.13 Anatomy related to the lateral abdominal wall (parietal peritoneum)

1.4 Exposure

The psoas major muscle is exposed by retracting the peritoneum and visceral organ to the midline. The ureters which are located on the medial surface of the psoas major can be retracted medially to avoid injury.

The abdominal aorta and inferior vena cava should be protected with wet gauze pads, which are located above the superior L4 body.

The lateral vertebral body to lateral intervertebral disc can be exposed by dissecting the iliopsoas to the dorsal side. The lumbar artery and lumbar vein on the lateral vertebral body surface can be seen at the middle part of the lumbar vertebral body (Fig. 4.14).

If the L5 vertebral body and L4–L5 intervertebral disc need to be exposed, left iliac blood vessels are retracted to the opposite side (Fig. 4.16).

The lumbar artery and lumbar vein on the target vertebral body are ligated. The connective tissue of the vertebral body and intervertebral disc surface should be carefully identified, separated, and then incised to avoid bleeding.

The duration of compression on the iliac artery and iliac vein should not be too long to avoid formation and rupture of thrombus.

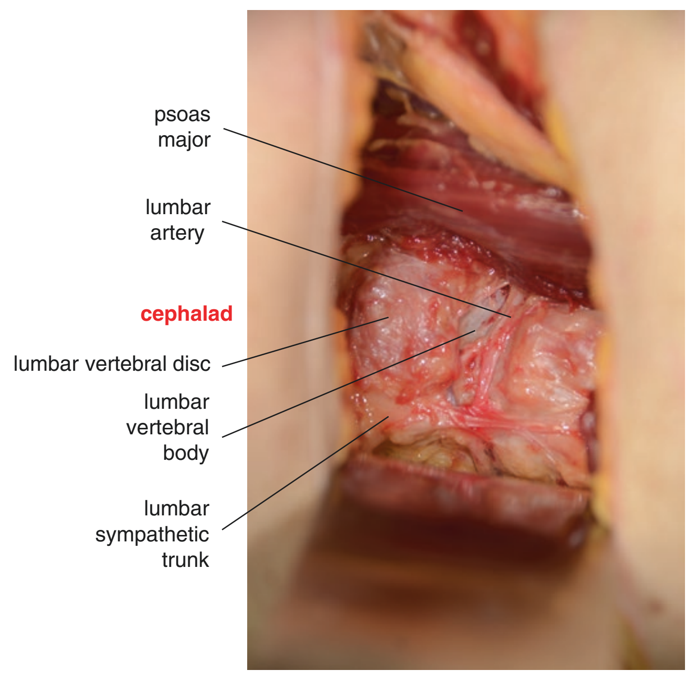


Fig. 4.14 Exposure of vertebral bodies

Retroperitoneal space: it is located between the retroperitoneal peritoneum and the intra-abdominal fascia, and it ranges up from the diaphragm and down the superior pelvic aperture. The space connects to mediastinal tissues through the retroperitoneal fascia on each side and upward to the lumbocostal triangle and down communicates with the retroperitoneal space of the pelvic cavity. So the space infection is easily spread; aseptic condition should be strictly kept during the surgery to avoid the infection in the retroperitoneal space. The contents of retroperitoneal space include the kidneys, adrenal glands, abdominal portion of the ureters, great vessels (such as the abdominal aorta, inferior vena cava, and its branches), nerve, and lymph node duct (Fig. 4.15).

Ureter: with a total length of 25–30 cm and a diameter of 4–7 mm, it is located in the medial aspect of the psoas major fascia surface. The adjacent structures around the abdominal portion of ureters are different on each side. Flexura duodenojejunalis is to the left front, crossed by the left colic artery, left testicular vessel (ovarian vessel for female), and sigmoid mesocolon. The descending portion of the duodenum, right colon, ileocolic vessel, radix of mesentery, and right testicular vessel cross in front of the right ureter from top to bottom. The blood of the abdominal portion of the ureter is supplied by the renal artery, testicular (or ovarian) artery, abdominal aorta, and iliac artery, and these vessels are mostly located in the medial aspect of the ureter (Fig. 4.15).

Lumbar sympathetic trunk (Fig. 4.16): it is composed of 3–5 ganglions, located between the vertebral column and psoas major muscle and covered by the prevertebral fascia. It is adjacent to the abdominal aorta on the left side and covered by the inferior vena cava on the right side. The number of ganglions is variable, and the location of ganglions at L2 and L4 is more stable because they are covered by the medial arcuate ligament and common iliac artery, respectively, and they serve as anatomic landmarks in clinical practice. Transverse ramus communicant is connected to the left and right sympathetic trunks. Injury to the sympathetic trunks may cause retrograde ejaculation or sexual dysfunction, so they should be identified and protected during surgery.

Lumbar artery (Fig. 4.16): lumbar arteries are branches of the abdominal aorta. The four pairs of branches symmetrically arise from each side of the posterior abdominal aorta and cross over lateral aspects of the lumbar vertebral body along with the lumbar vein toward the intervertebral foramen and then divide into the dorsal branch and ventral branch at the medial psoas major border. Dorsal branch is distributed in the muscle and skin of the back. Ventral branch is distributed in the abdominal wall and connects with other arteries in the anterolateral abdominal wall.

Abdominal aorta: it is located in the left front of T12–L4 and arises from the diaphragmatic aortic hiatus, connecting the thoracic aorta above and dividing into left and right common iliac arteries at L4 level. The abdominal aorta is 14–15 cm in length and about 3 cm in diameter. In front of it, there is the pancreas, a horizontal portion of the duodenum and radix mesenterii; L1–L4 vertebral bodies and intervertebral discs are on the posterior side of it; the inferior vena cava is on the right side of it; the left lumbar sympathetic trunk is on the left side of it (Fig. 4.17).

Inferior vena cava: it is located at the L4–L5 level and receives drainage from the convergence of left and right common iliac veins. It runs upward along the right side of the abdominal aorta in front of the vertebral column, crosses the vena caval foramen of the diaphragm, then enters the thoracic cavity. In front of the inferior vena cava, there are the liver, caput pancreas, horizontal portion of the duodenum, right testicular (or ovary) artery, and (small) radix mesenterii. Behind the inferior vena cava, there are the lumbar vertebral body, the right crura of the diaphragm, and the right lumbar sympathetic trunk. The abdominal aorta is to its left, and the right psoas major muscle, right ureter, right kidney, and right adrenal gland are to the right of the inferior vena cava.

Celiac plexus: it is the biggest plexus of the visceral nerve. It is located in front of the left and right crura of the diaphragm and the upper portion of the abdominal aorta, between both sides of the adrenal gland. It surrounds the coeliac trunk and the root of the superior mesenteric artery.

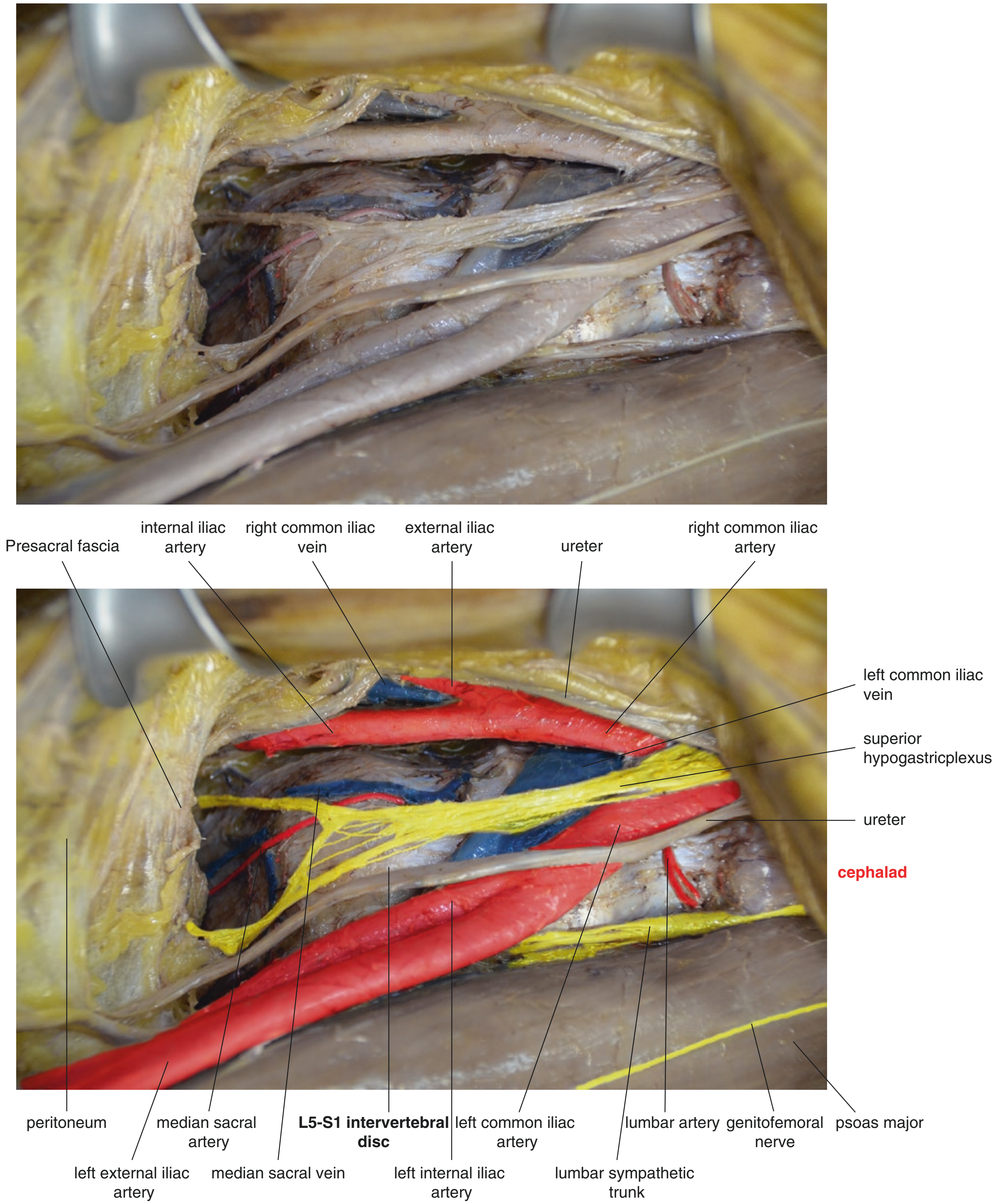
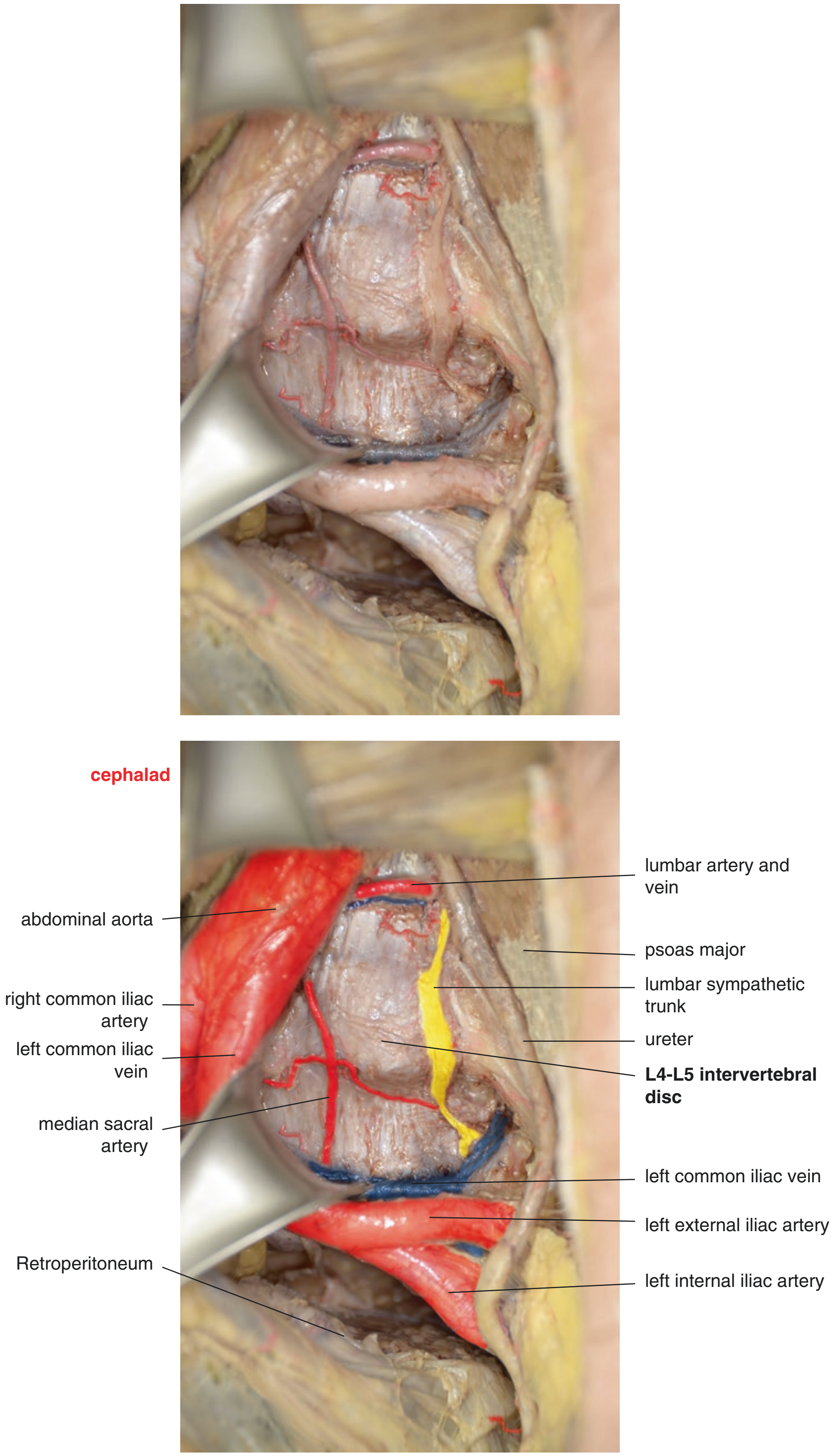


Fig. 4.15 Anatomy related to the retroperitoneum

Fig. 4.16 Lumbar sympathetic trunks



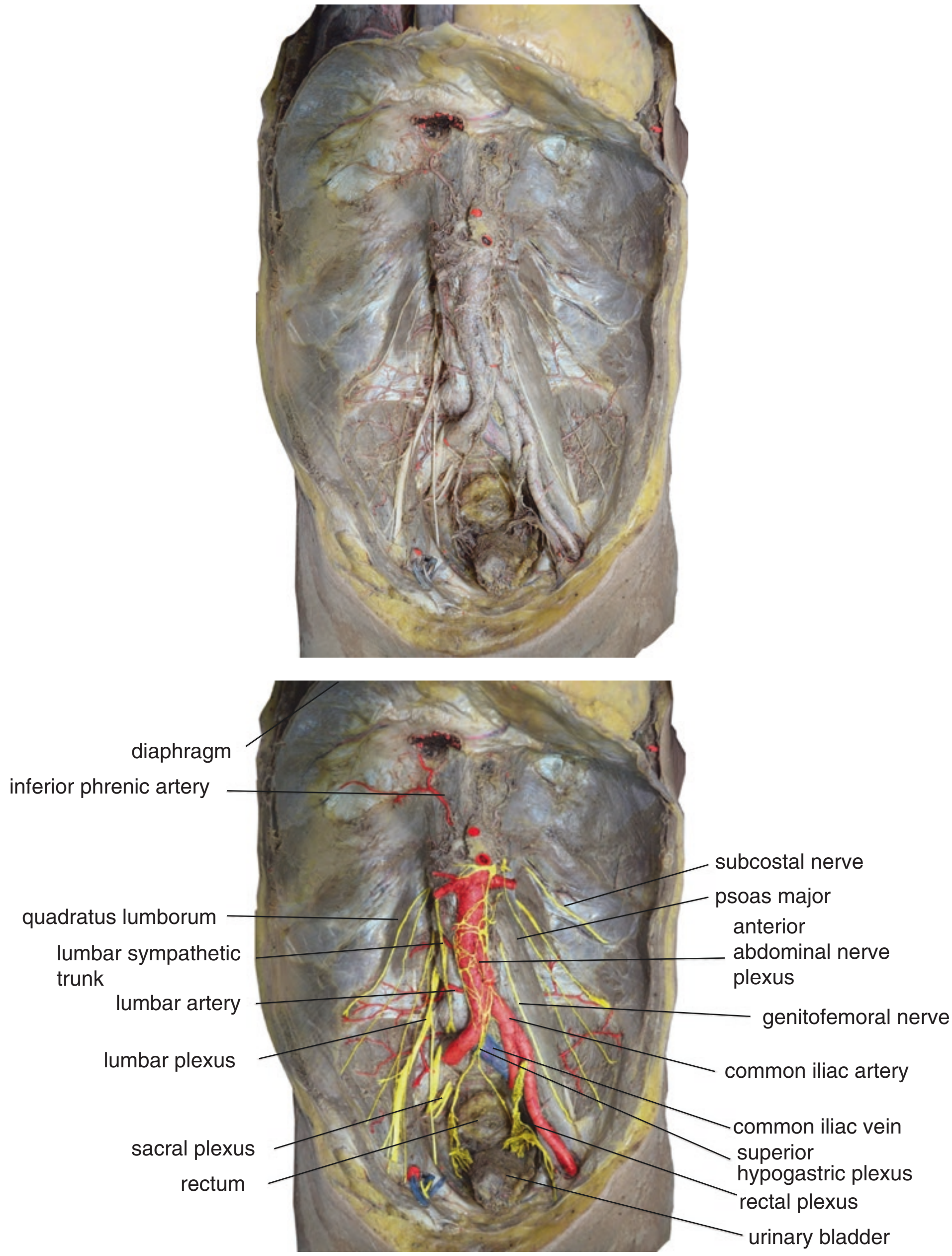


Fig. 4.17 Neurovascular structures in retroperitoneal space

2 Posterior Lumbar Spinal Exposure and Transforaminal Lumbar Interbody Fusion

2.1 Overview

Posterior approaches to the lumbar spine are mainly used for posterior column lesions such as lesions of the vertebral pedicle, transverse process, facet joint and spinous process, and spinal canal as well as central column lesions such as lesions of the intervertebral disc, posterior longitudinal ligament, and posterior vertebral body. The Wiltse approach (a paraspinal intermuscular approach) has advantages involving simple surgical route, minor soft tissue injury, short duration of surgery, less blood loss, and fast recovery.

In 1982, Harms et al. proposed transforaminal lumbar interbody fusion (TLIF). TLIF is an approach mainly via Kambin's triangle to expose the intervertebral space, which can make the dural sac or nerve roots suffer the minimum retraction during interbody fusion and which only weakens the unilateral structures of the posterior lumbar spine. But traditionally, TLIF has relatively narrow indications, because it does not allow complete decompression on the dural sac and nerve root. It is mainly indicated for lumbar degenerative disease without or with unilateral radiolopathy. Hence, modified TLIF was then developed, in which the operating area is shifted more medially than that in traditional TLIF; unilateral facet joints and vertebral plates are partially resected; and thorough decompression is performed around the traversing nerve root and preserving posterior ligamentous complex between spinous processes.

2.2 Position

Patients are usually placed in the prone position after general anesthesia (Fig. 4.18). Keep enough abdominal space to avoid impacts on respiration and meanwhile help decrease compression on venous drainage to reduce intraoperative bleeding.

2.3 Exposure

Make a posterior midline incision along the spinous processes according to the involved levels (Fig. 4.19).

Incision on the skin and subcutaneous tissue is made to expose the lumbodorsal fascia.

Incise the lumbodorsal fascia (Fig. 4.21) to expose the dorsal muscle.

Fig. 4.18 Position for posterior lumbar spinal exposure

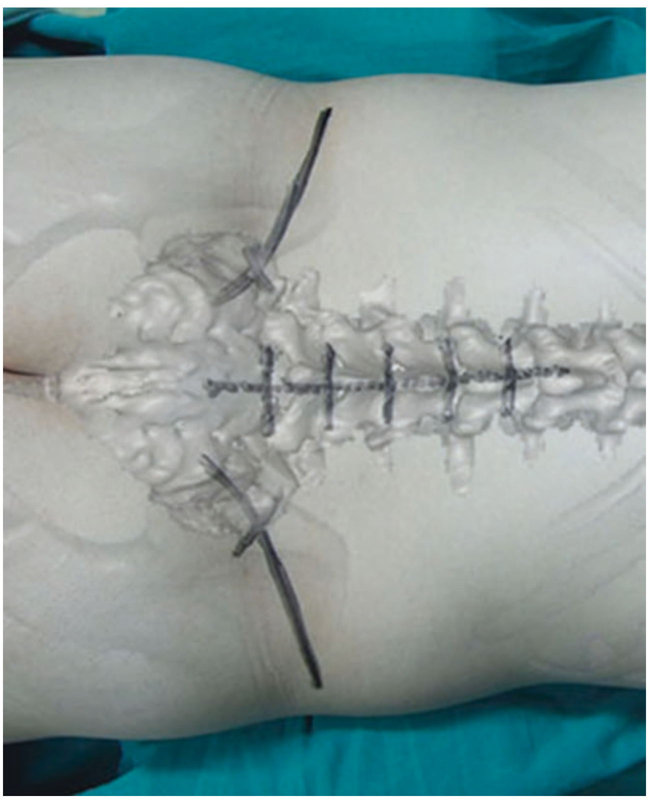


Fig. 4.19 Incision for posterior lumbar spinal exposure

Lumbodorsal fascia, also known as thoracolumbar fascia (Fig. 4.20): the main function of the thoracolumbar fascia is to support and wrap erector spinae muscles. The lumbodorsal fascia originates from the thorax and ends at the sacrum. The lumbodorsal fascia becomes thicker around the lumbar transverse process. In the L4–S1 segments, its transverse fiber is closely connected to the midline structures.

Supraspinous ligament: the supraspinous ligament originates from the C7 spinous process and ends at the median sacral crest. The supraspinous ligament and interspinous ligament are innervated by the terminal of the dorsal rami of the spinal nerves (Figs. 4.21 and 4.22).

Interspinous ligament: it is located between adjacent spinous processes, with the anterior border connected to the ligamentum flavum and the posterior border continuous with the supraspinous ligament. Injury to the interspinous ligament can cause chronical low back pain (Fig. 4.22).

The innervation of the facet joint of a lumbar spine: each lumbar facet joint is innervated by medial branches of the dorsal ramus. The medial branches course caudally under the base of the superior articular process after they split off of the dorsal ramus. They continue in a groove between the superior articular process and transverse process underneath the mamillo-accessory ligament. The medial branches then give off two branches to the adjacent facet joints, the ascending and descending articular branches. The lumbar facet joints have dual innervation from the medial branch of each respective level and the level above (Fig. 4.23).

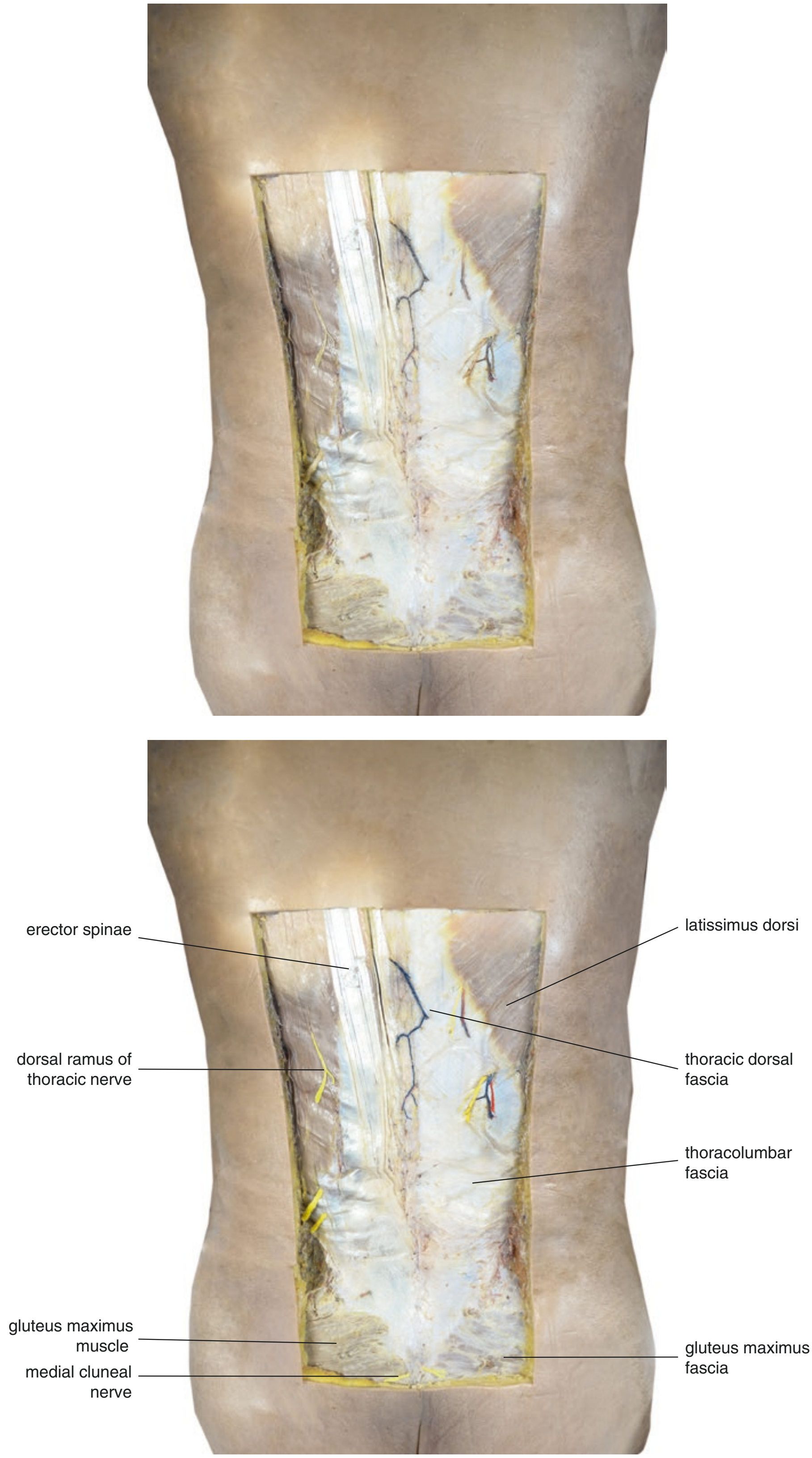


Fig. 4.20 Anatomy related to the posterior approach to the lumbar spine

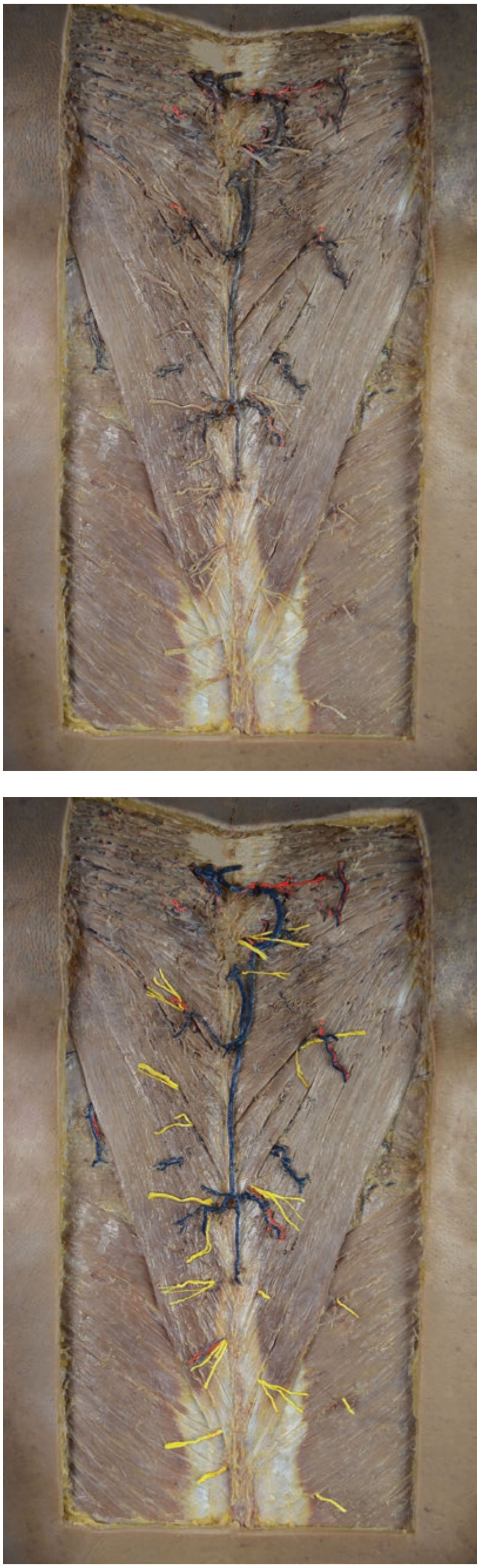


Fig. 4.21 Anatomy related to the posterior approach to the lumbar spine

Subperiosteal dissection is performed along each side of the spinous processes. Attention should be paid to preserving the supraspinous ligaments and interspinous ligaments.

Expose the facet joints on both sides and then use an automatic retractor to expose the posterior structure of the lumbar spine (Fig. 4.24).

Connecting rods are installed on the contralateral screws to the fusion side to help temporarily fix the spine and spread out the intervertebral spaces of the target segments (Figs. 4.25 and 4.26).

The inferior facet of the superior vertebra is removed with an osteotome.

The superior facet and ligamentum flavum are removed with Kerrison rongeur to expose the lateral recess and intervertebral disc (Fig. 4.27).

Expose the lateral spinal canal, dural sac, intervertebral foramen, and traversing nerve root. Superior nerve root exists from the intervertebral foramen beneath the superior vertebral pedicle.

Protect the existing nerve root and traversing nerve root with nerve root retractor.

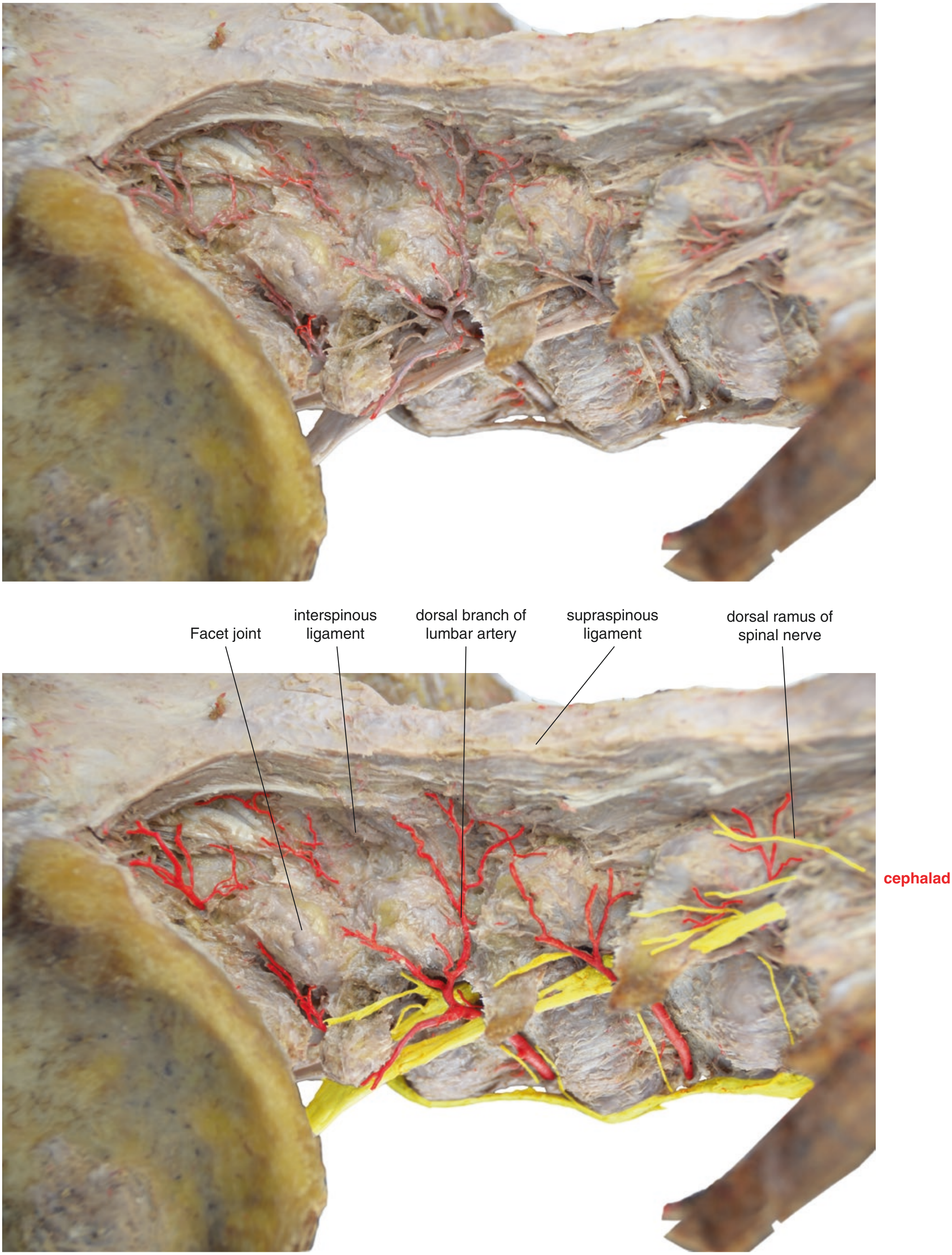
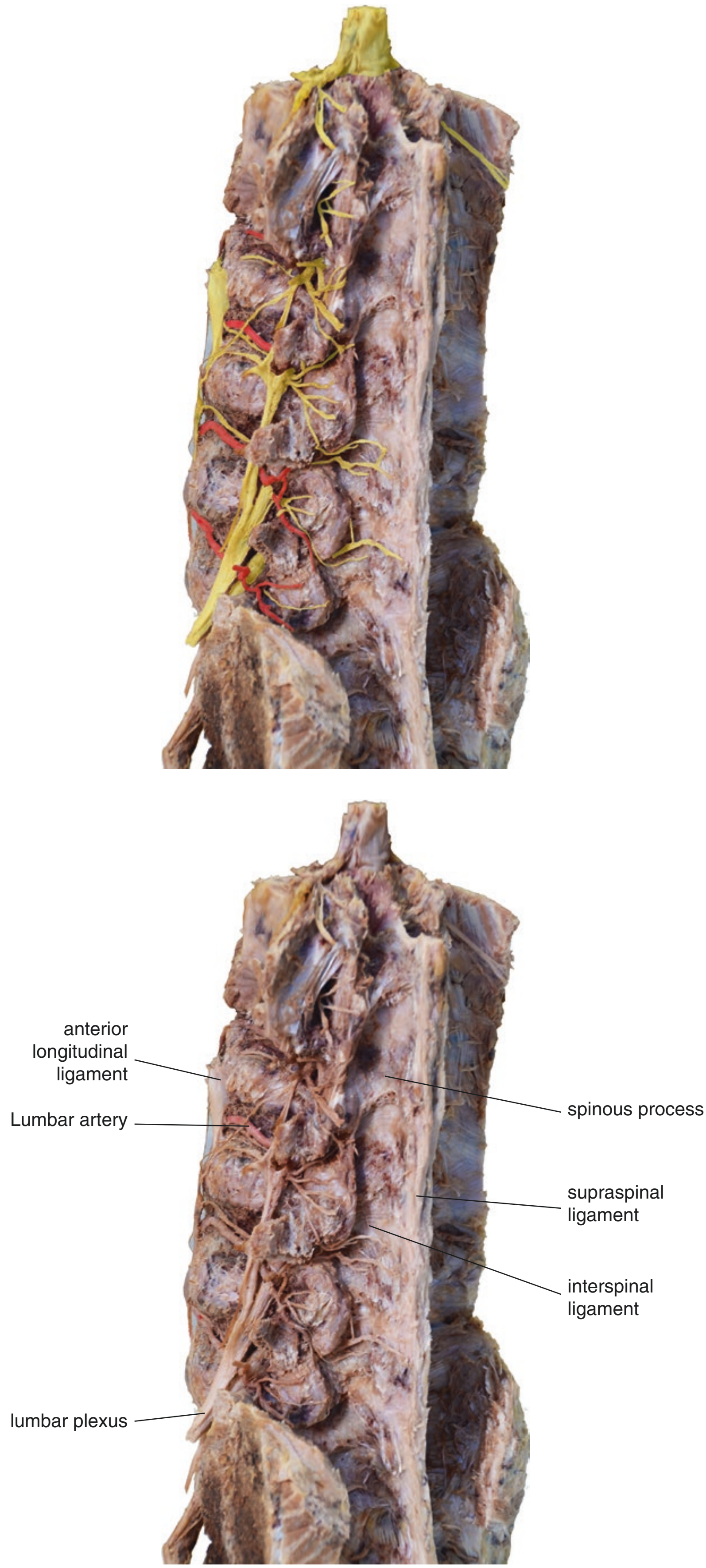


Fig. 4.22 Posterior lumbar ligaments, vessels, and nerves

Fig. 4.23 The innervation of the facet joint of a lumbar spine



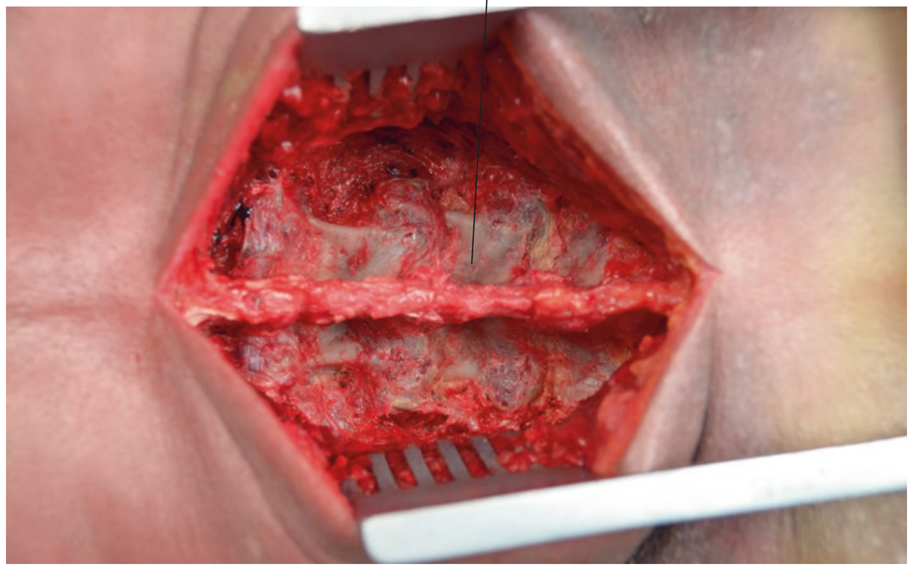


Fig. 4.24 Exposure of the posterior structure of the lumbar spine

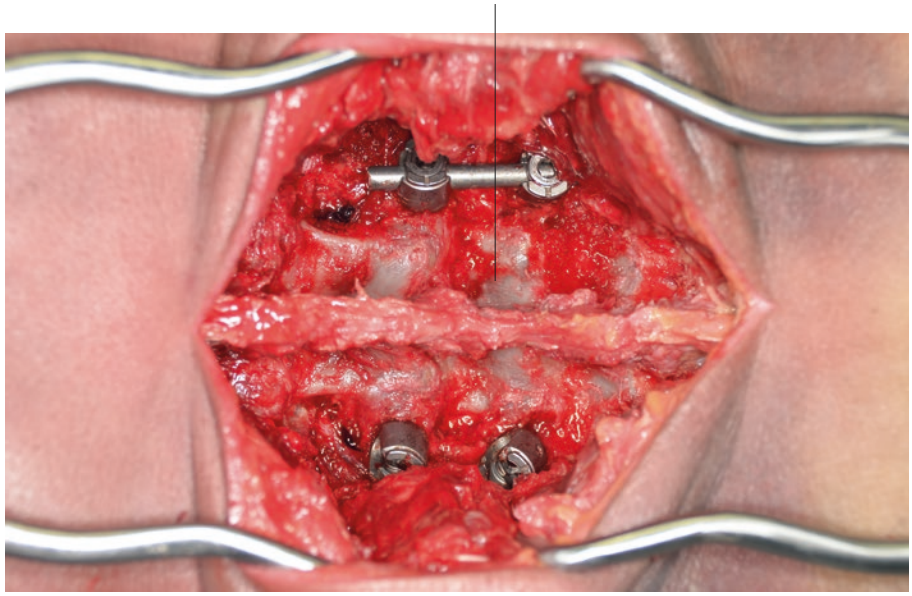


Fig. 4.25 Temporarily stabilizing the involved segments by installing connecting rod

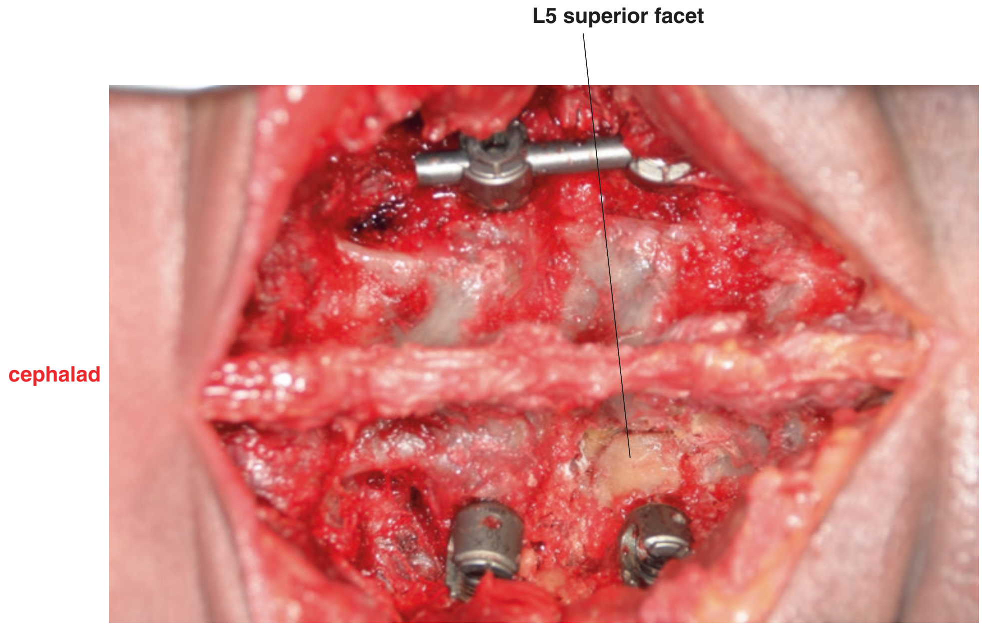


Fig. 4.26 The inferior facet of the superior vertebra is resected with an osteotome

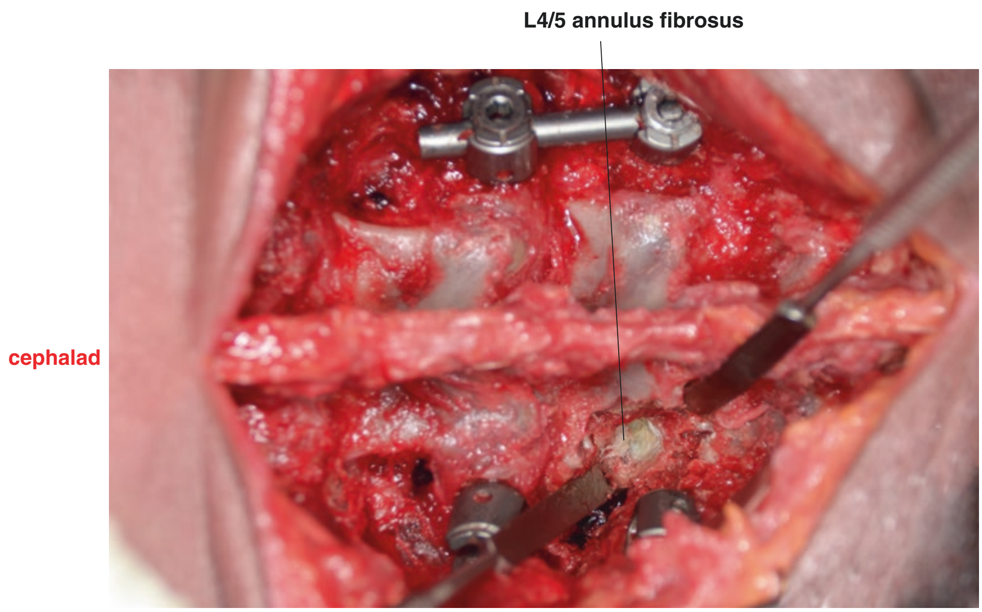
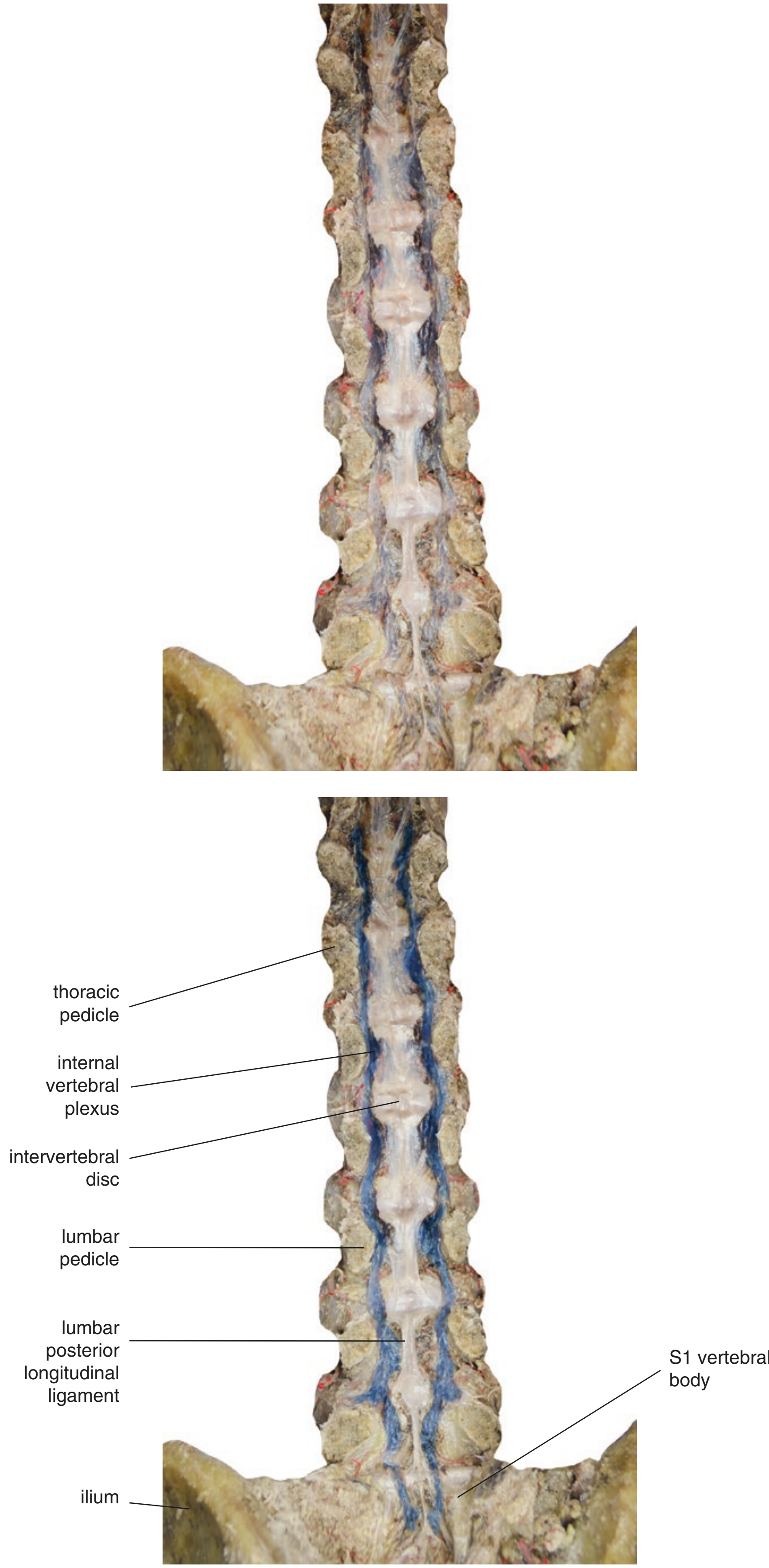


Fig. 4.27 Exposure of the lateral recess and intervertebral disc

Internal vertebral venous plexus: the internal vertebral venous plexus is located in the spinal canal, distributed between the vertebral periosteum and the dural sac. The greatest venous density of internal vertebral venous plexus is the posterior to the vertebral bodies and intervertebral discs, which form two longitudinal veins on both sides of the posterior longitudinal ligament. The posterior plexus is located in the vertebral arch and the deep layer of the ligamentum flavum. The internal vertebral venous plexus receives drainage from the vertebral bodies and communicates superiorly with the dural venous sinuses and through the intervertebral foramina by way of the intervertebral veins at all levels (Fig. 4.28).

Fig. 4.28 Anatomy of the posterior aspect of spinal column



Decompression: perform decompression of the inferior nerve root and dural sac by removing the inferior and superior facets, ligamentum flavum, and intervertebral disc.

Prior to intervertebral fusion, explore the nerve root canal to make sure there are no obstruction and compression (Fig. 4.29).

The triangle space formed by the inferior vertebral pedicle, dural sac, and exiting nerve root is termed as a “safety triangle” or “Kambin’s triangle” (Figs. 4.30, 4.31, 4.32, 4.33, 4.34, and 4.35).

The dural sac is retracted medially with a nerve root retractor. The annulus fibrosus is incised with a scalpel. Remove the nucleus pulposus and nucleus of the intervertebral disc with pituitary rongeurs, curettes, and shavers, respectively (Fig. 4.36).

Care must be taken to avoid damage to the subchondral bone of the end plates during disc space preparation.

In intervertebral fusion cage, a suitable size is placed into the anterior central portion of the intervertebral space, and the location is verified by intraoperative fluoroscopy (Fig. 4.37).

The C-arm fluoroscopy shows the pedicle screw and intervertebral fusion cage are located well (Figs. 4.38 and 4.39).

Place the connecting rod on the fusion side and compress the intervertebral space. Compression on the intervertebral space not only promotes intervertebral fusion and restoration of lumbar lordosis (Fig. 4.40).

cephalad

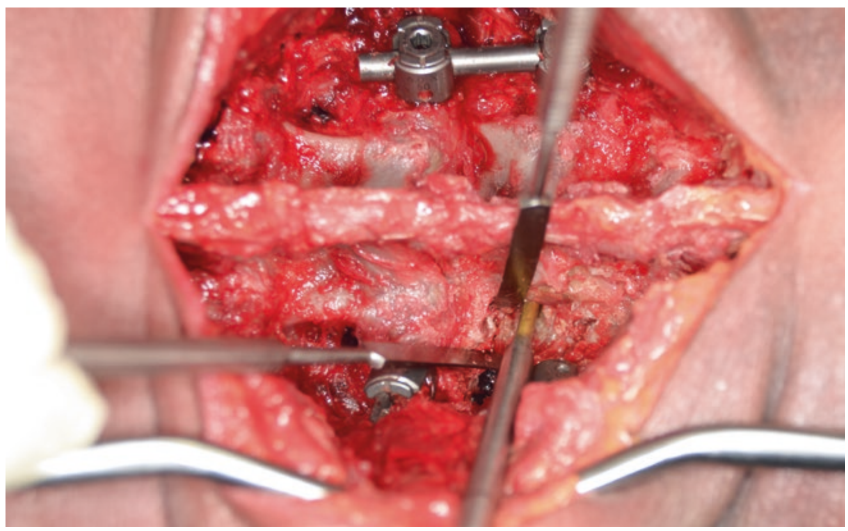


Fig. 4.29 Treatment of the intervertebral space

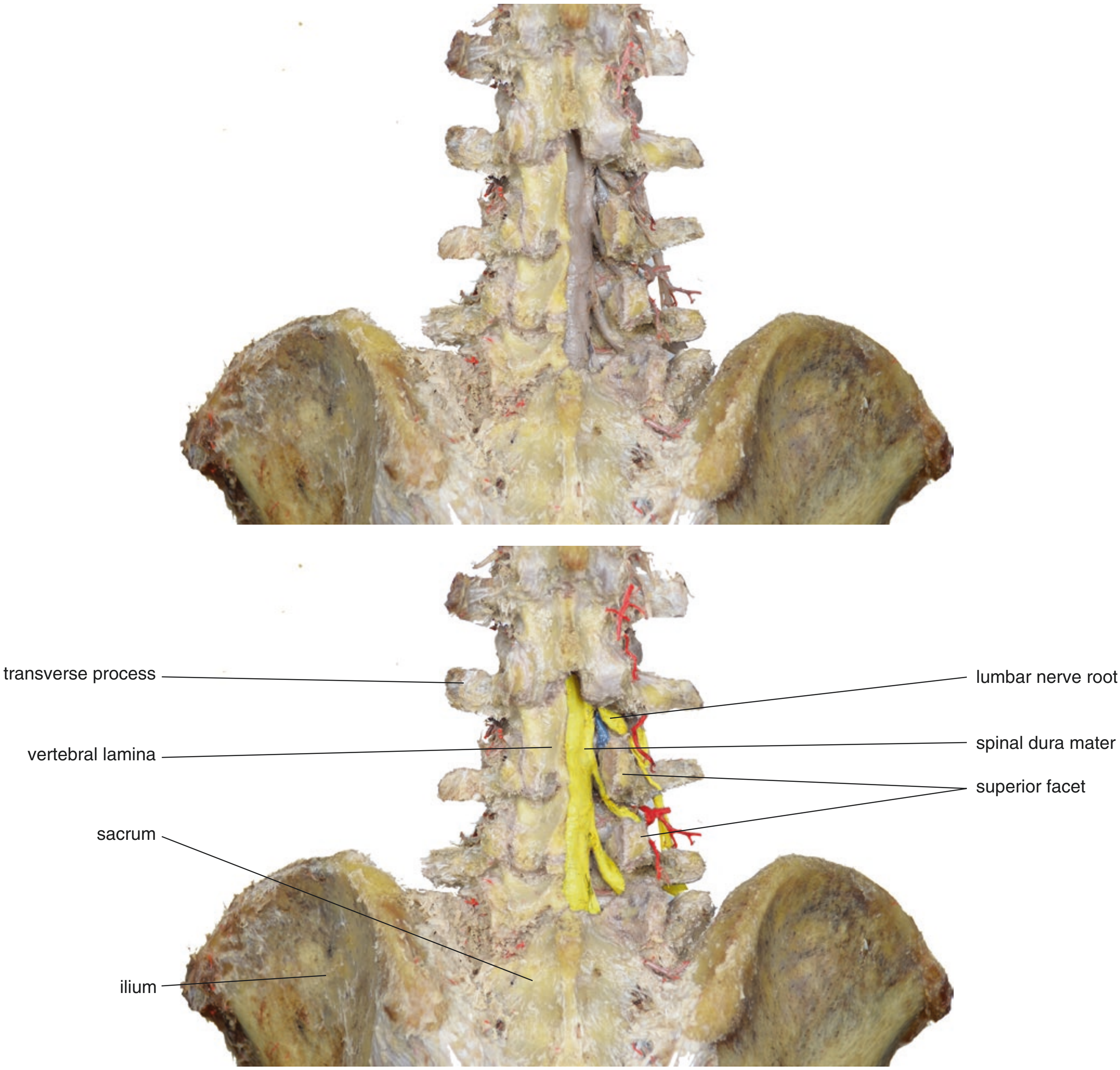


Fig. 4.30 Posterior view of relationship among the lumbar nerve root, intervertebral disc, and bony structure (posterior bony elements partially removed)

Fig. 4.31 Posterior view of relationship among the lumbar nerve roots, intervertebral discs, and bony structure (posterior bony elements partially removed)

Fig. 4.32 Posterior view of relationship among the lumbar nerve roots, intervertebral discs, and bony structure (posterior bony elements partially removed)

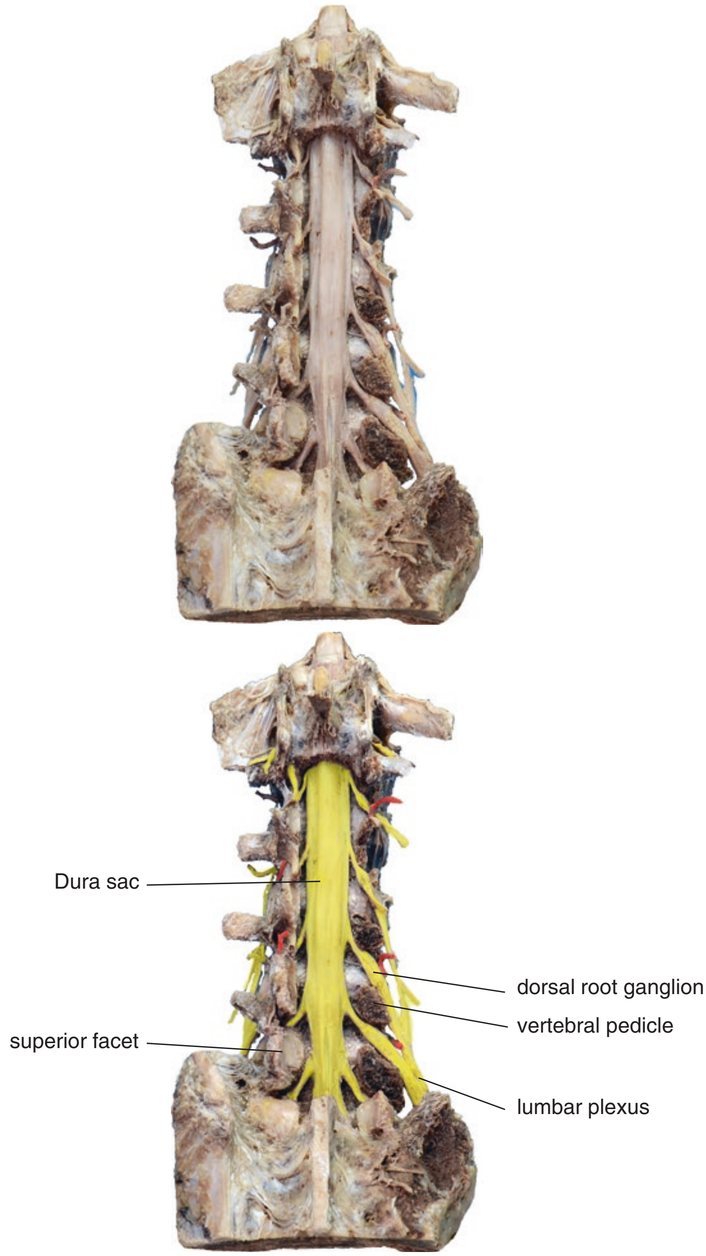
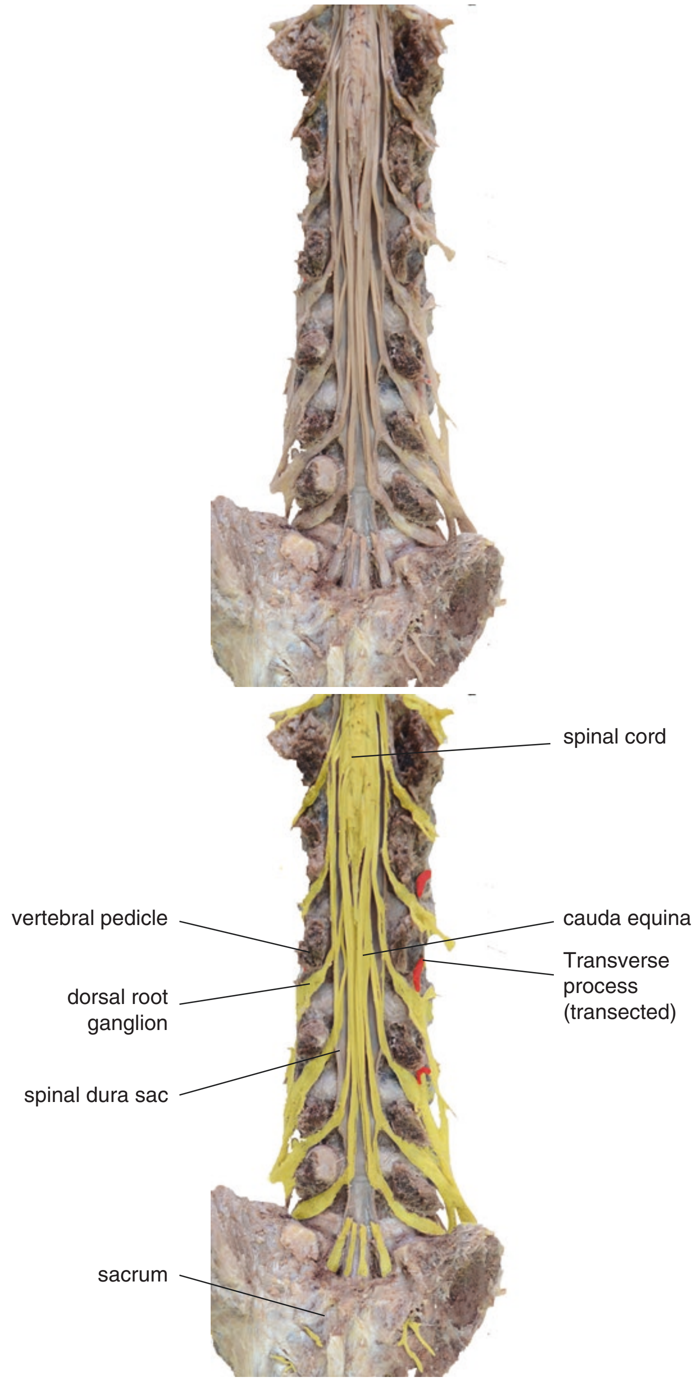


Fig. 4.33 Posterior view of relationship among the lumbar nerve roots, intervertebral discs, and bony structure (posterior bony elements and dural sac removed)



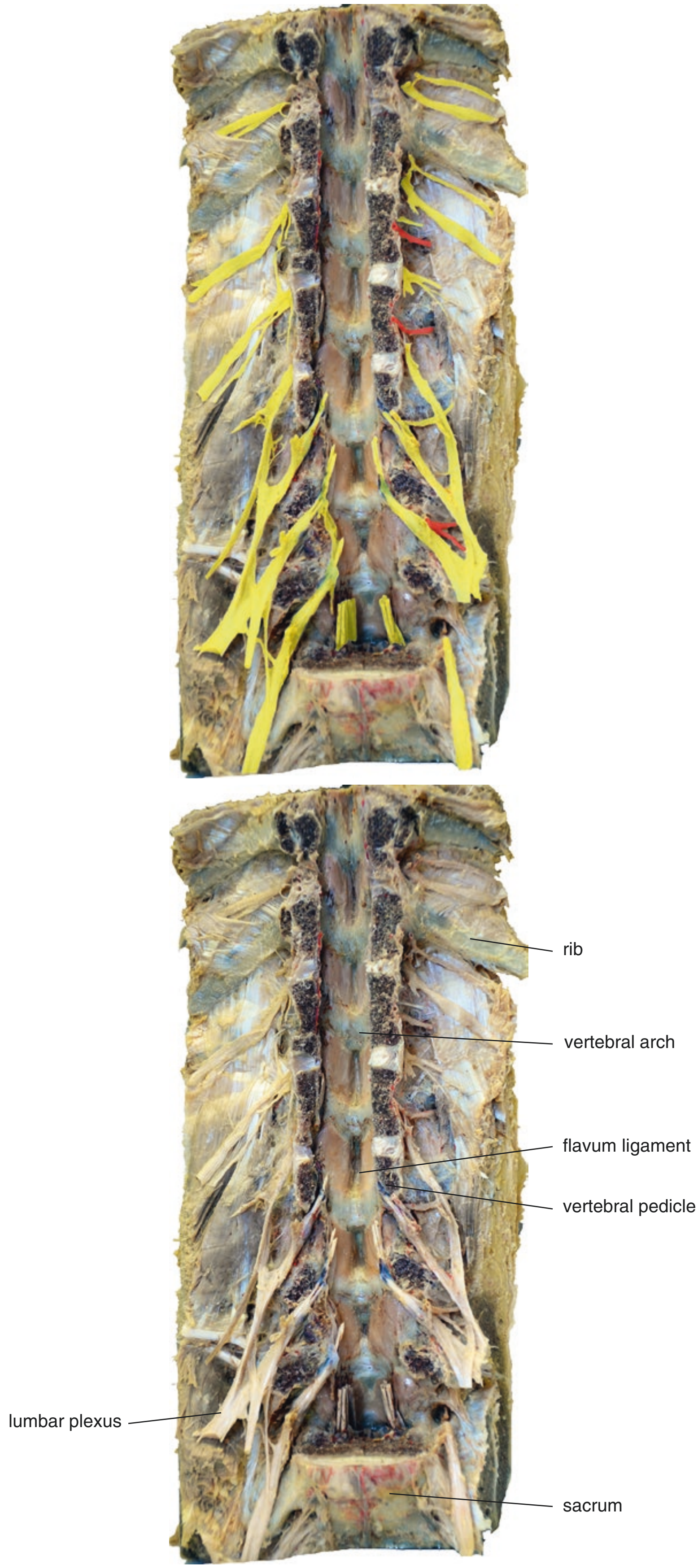
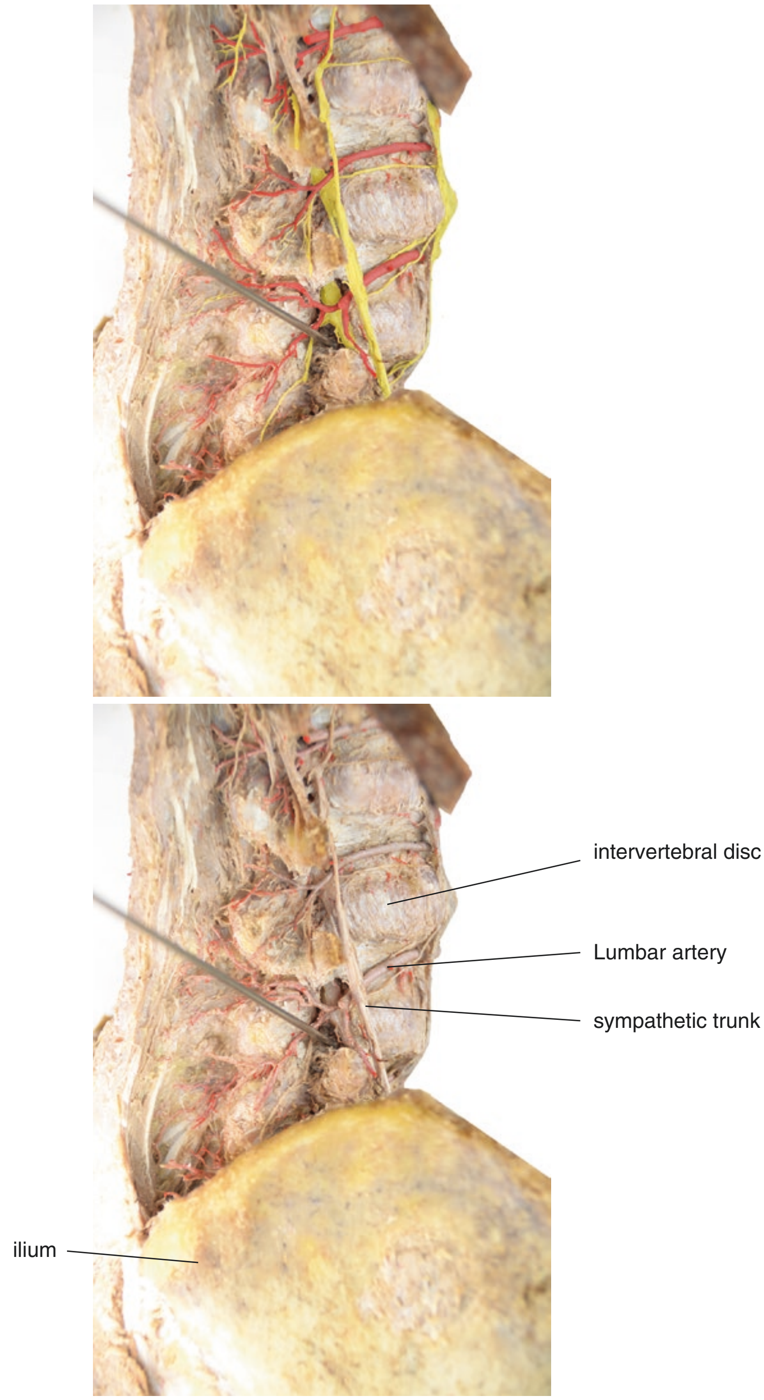


Fig. 4.34 Anterior view of relationship among the lumbar nerve roots, ligamentum flavum, and bony structure (spinal column removed)

Fig. 4.35 Kambin's triangle



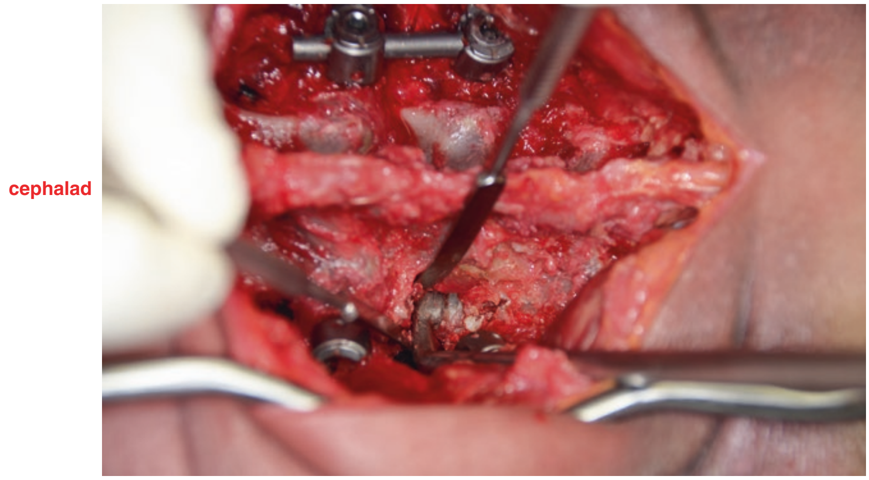


Fig. 4.36 Graft bed preparation

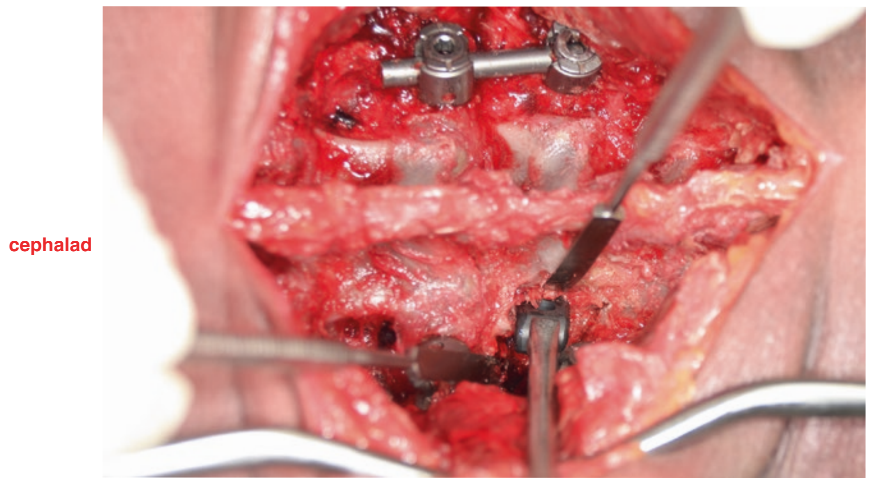


Fig. 4.37 Placement of an intervertebral fusion cage

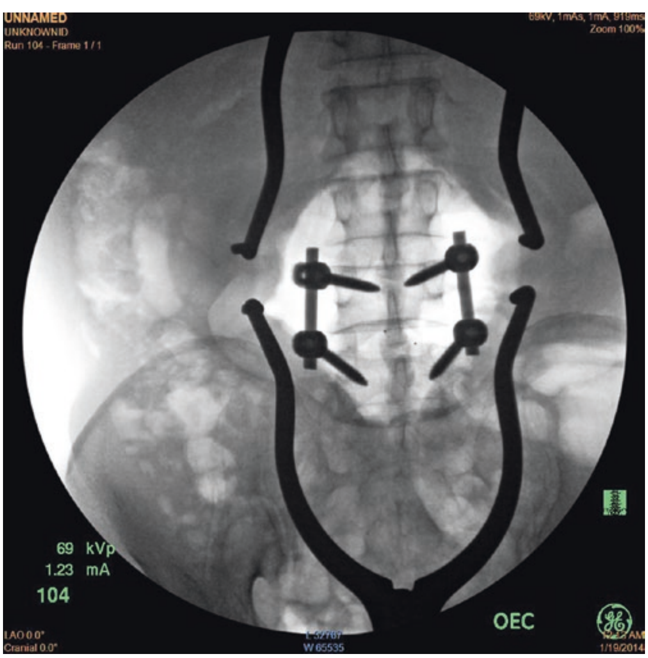


Fig. 4.38 Placement of an intervertebral fusion cage (anteroposterior C-arm fluoroscopy)

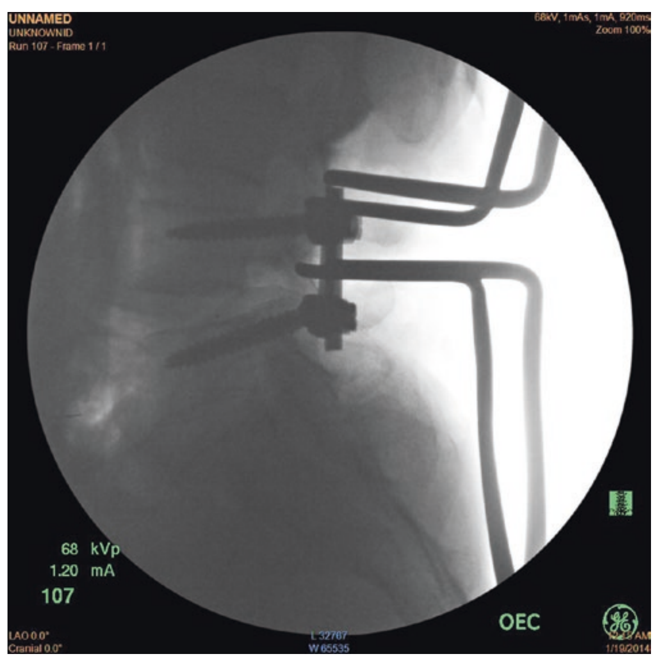
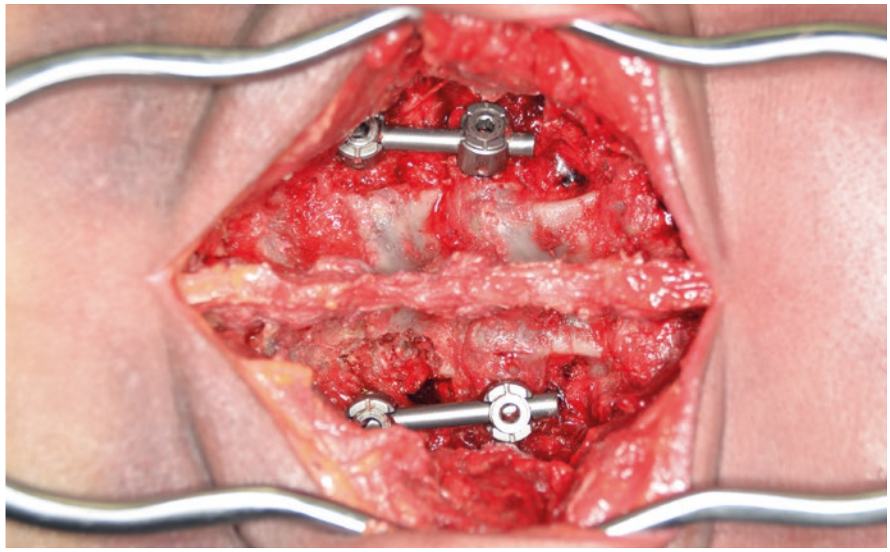


Fig. 4.39 Placement of an intervertebral fusion cage (lateral C-arm fluoroscopy)

Fig. 4.40 Place the connecting rod on the fusion side and compress the intervertebral space

cephalad



2.4 Minimally Invasive TLIF

Incision for minimally invasive TLIF (Fig. 4.41).

Wiltse approach or subperiosteal dissection is used to expose the facet joint of the target level.

Pedicle screws are placed via the Wiltse approach or percutaneously on the opposite side.

The skin, subcutaneous tissue, and superficial fascia are incised to expose the lumbodorsal fascia. Palpate the facet joint to identify the intermuscular space (Fig. 4.42).

Longitudinally incise the lumbodorsal fascia. Blunt dissection is performed along the intermuscular space of the longissimus and multifidus muscles to expose the facet joint and the transverse process (Fig. 4.43).

Screws are placed in the pedicles in the superior and inferior vertebra of the involved disc (Fig. 4.44).

The anteroposterior C-arm fluoroscopy shows the pedicle screw is located well (Fig. 4.45).

The lateral C-arm fluoroscopy shows pedicle screw is located well (Fig. 4.46).

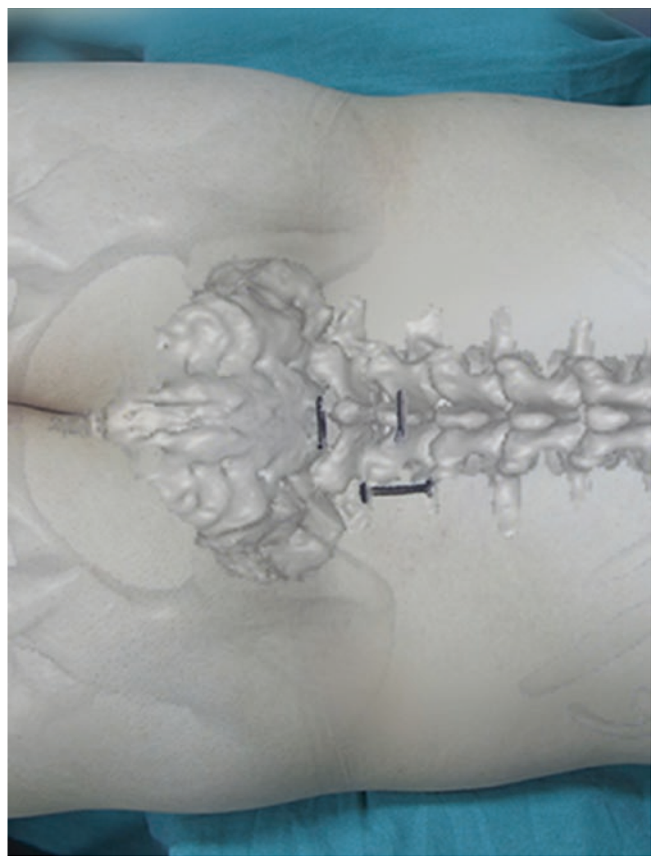


Fig. 4.41 Incision for minimally invasive TLIF

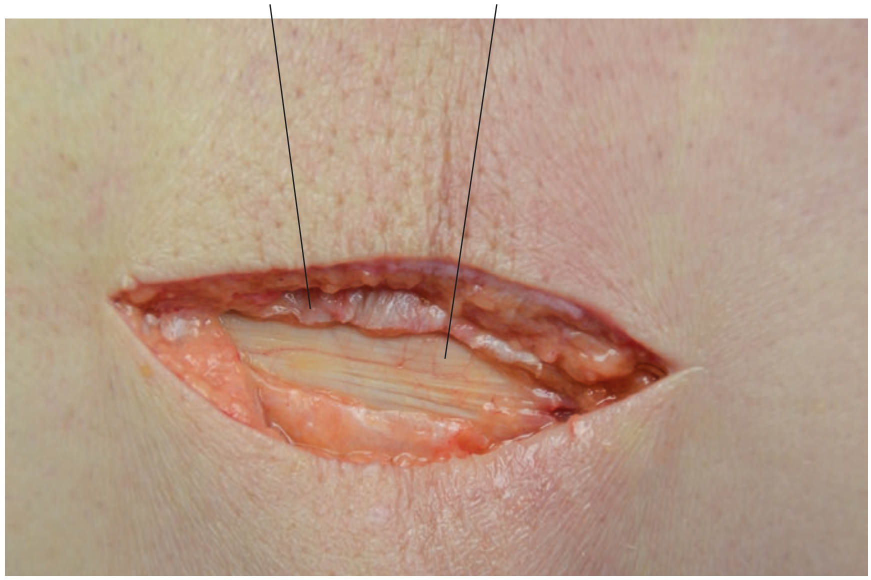


Fig. 4.42 Incision for minimally invasive TLIF

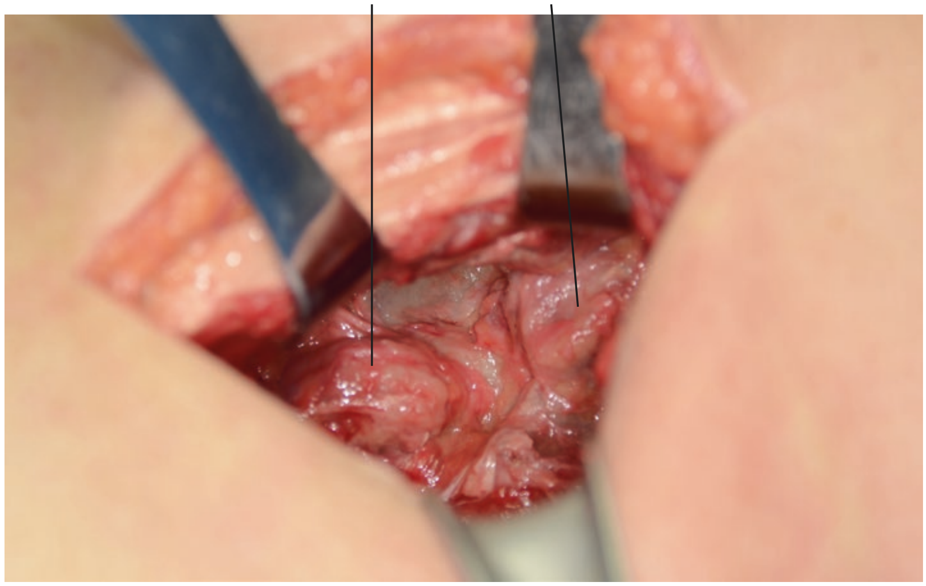


Fig. 4.43 Minimally invasive TLIF exposure

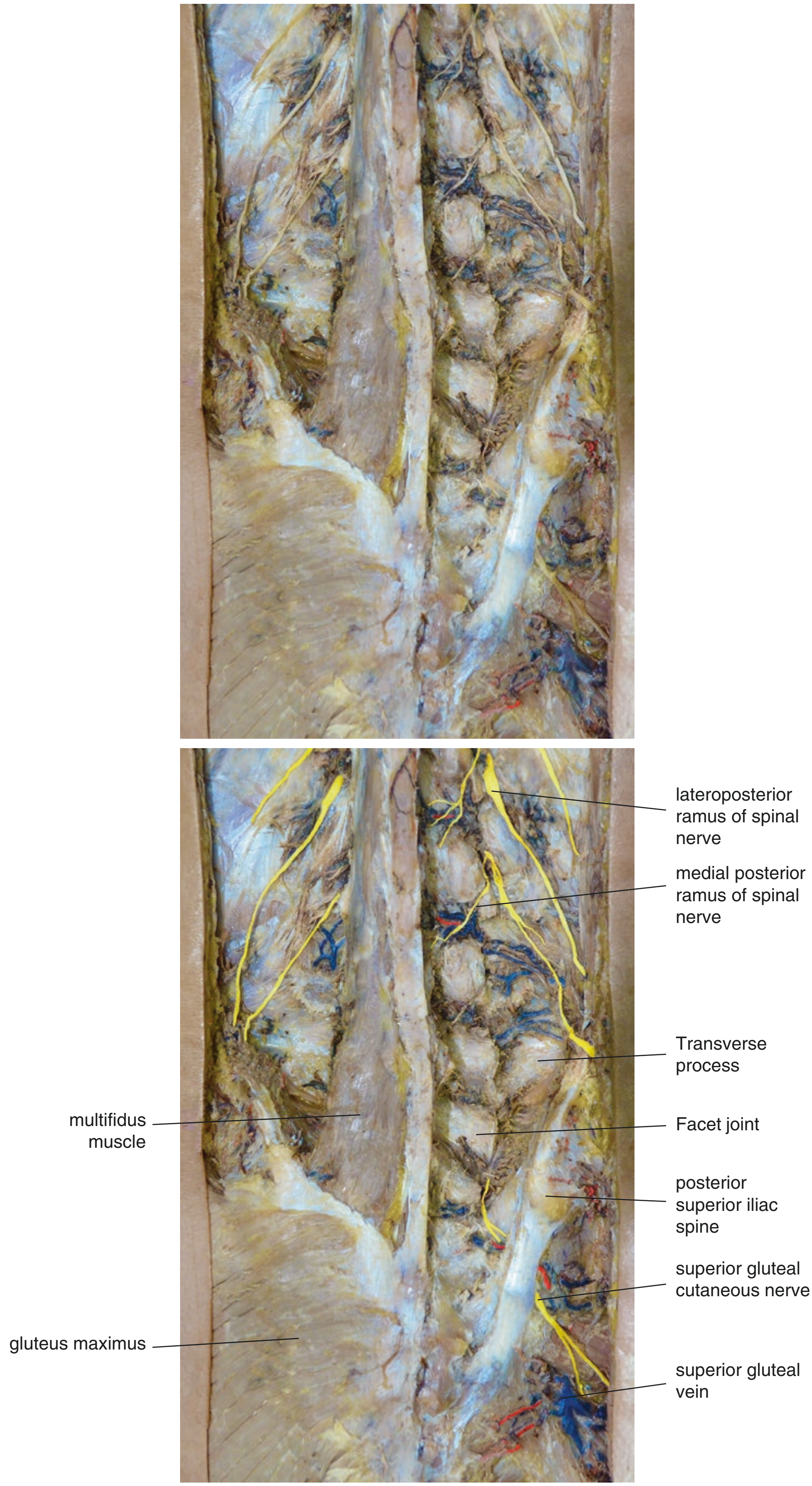


Fig. 4.44 Relationship among the transverse processes, multifidus muscle, and facets

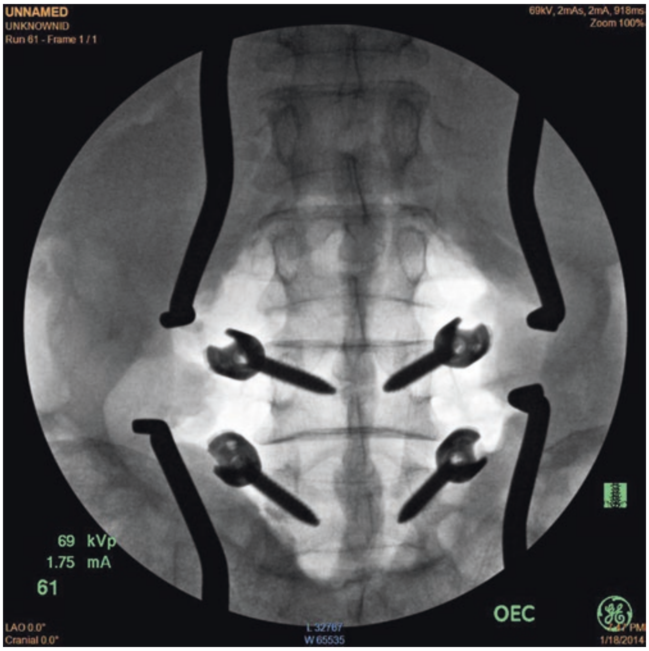


Fig. 4.45 Placement of the pedicle screws (anteroposterior C-arm fluoroscopy)

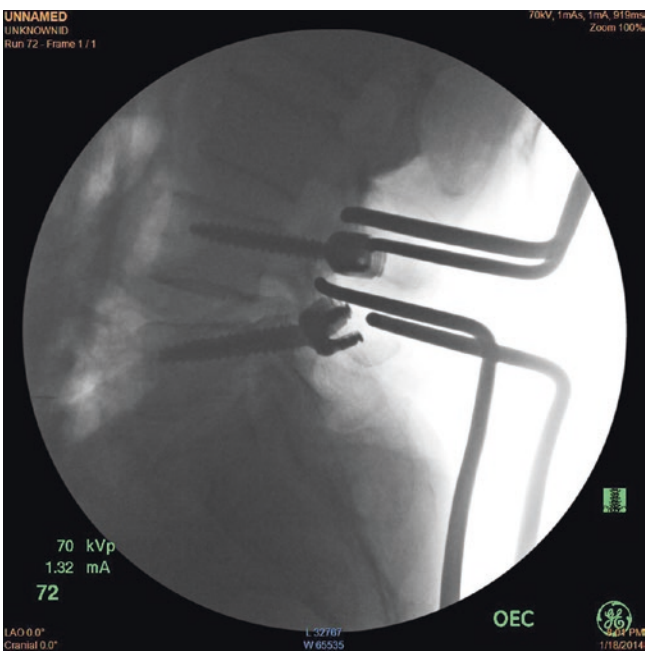


Fig. 4.46 Placement of the pedicle screws (lateral C-arm fluoroscopy)

3 Pedicle Subtraction Osteotomy

3.1 Overview

In 1985, Thomasen put forward pedicle subtraction osteotomy (PSO) to treat kyphosis in ankylosing spondylitis. PSO is mainly applied to correct spinal deformity in the sagittal plane. Such technique is a closing wedge osteotomy, in which the vertebral plate and the pedicle in the posterior spine are resected; then the anterior vertebral body undergoes wedge-shaped resection; next, posterior elements of the spine are closed to achieve bony contact between the anterior column and the middle column; finally, the C7 plumb line is allowed to fall to the posterior part or the posterior-superior border of the S1 vertebral body so as to achieve the goal of balancing the spine in the sagittal plane. And meanwhile, the technique, to some extent, also can correct the imbalance of the coronal plane through the adjustment of osteotomy in the coronal plane. But if osteotomy is performed in the upper lumbar region and the posterior column is excessively shortened, it will cause spinal cord kinking or folds and then result in serious neural complications. Therefore, it is generally believed that PSO is mainly indicated for those with serious kyphotic deformity, a Cobb angle of more than 40° rigid deformity in thoracolumbar joints and ligaments, who experience failure in nonsurgical treatment.

3.2 Position

After general anesthesia, patients are placed in a prone position (Figs. 4.47 and 4.48) on a jackknife table with appropriate padding.

During surgery, the jackknife table can be elevated to extend the lower extremities and chest to close the osteotomy.

Fig. 4.47 Position for PSO

Fig. 4.48 Jackknife table can be elevated to extend the lower extremities and chest to close the osteotomy

3.3 Exposure

A posterior midline incision is utilized (Fig. 4.49).

Subperiosteal dissection of the paraspinal muscles from the involved spine to the lateral margin of the transverse process.

Pedicle screws are placed in one segment above and two segments below (or two segments, respectively, above and below) the osteotomy segment (Figs. 4.50 and 4.51).

For cases in which there is difficulty in identifying bony landmarks, screw placement can be completed under the observation of a CT navigation system.

Pedicle screws and temporary rod are placed on one side (Fig. 4.52) so as to facilitate temporary stability and follow up closure of the bone surface when osteotomy is performed.

The range of osteotomy covers the inferior pole of the cephalad pedicles to the superior pole of the caudad pedicles (Fig. 4.53).

An asymmetric wedge resection can be carried out when a two-plane sagittal/coronal correction is acquired (Fig. 4.54).

The posterior lamina of the osteotomy segment, lower part of the spinous process, and vertebral plate of the superior segment are resected by a rongeur (Fig. 4.55).

An osteotome is used to remove the inferior facet of the superior segment. The inferior vertebral plate of the superior segment is removed with a Kerrison rongeur (Fig. 4.56).

A Kerrison rongeur is used to resect the vertebral plate, inferior facet, and ligamentum flavum in the osteotomy segment (Fig. 4.57).

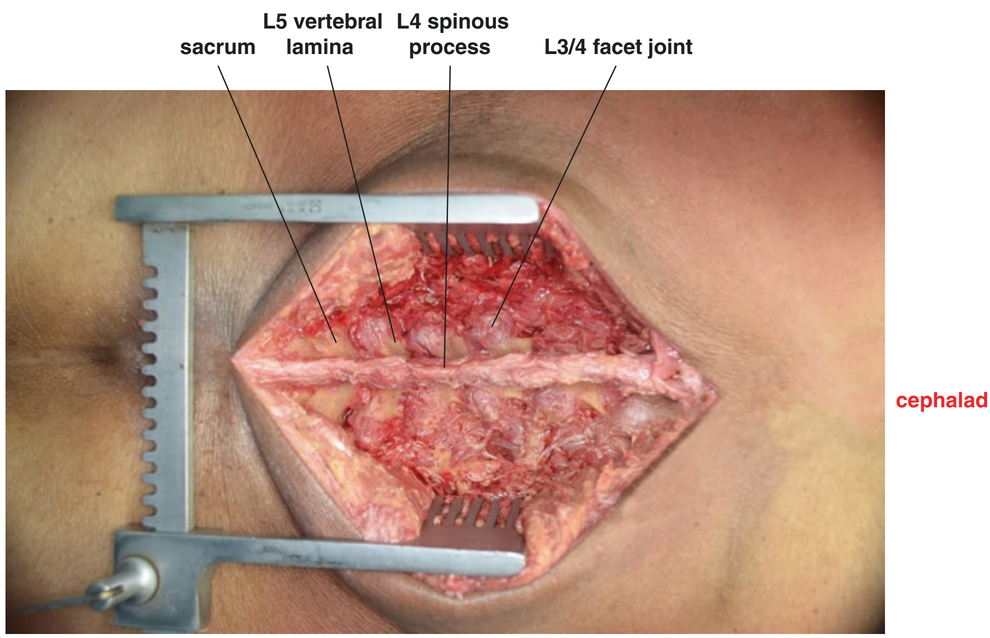


Fig. 4.49 Exposure of the involved spine for PSO

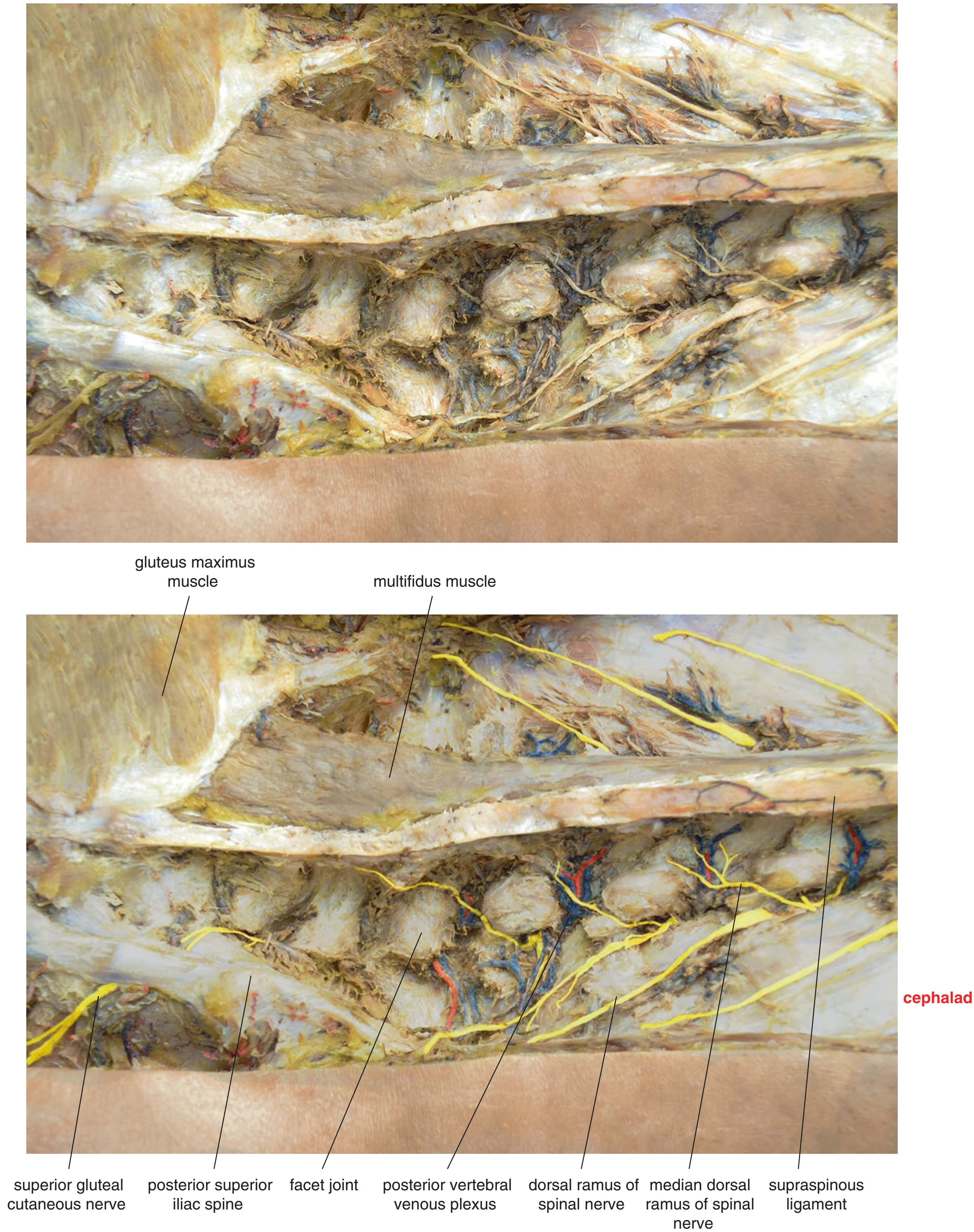


Fig. 4.50 Anatomy of the posterior lumbar spine

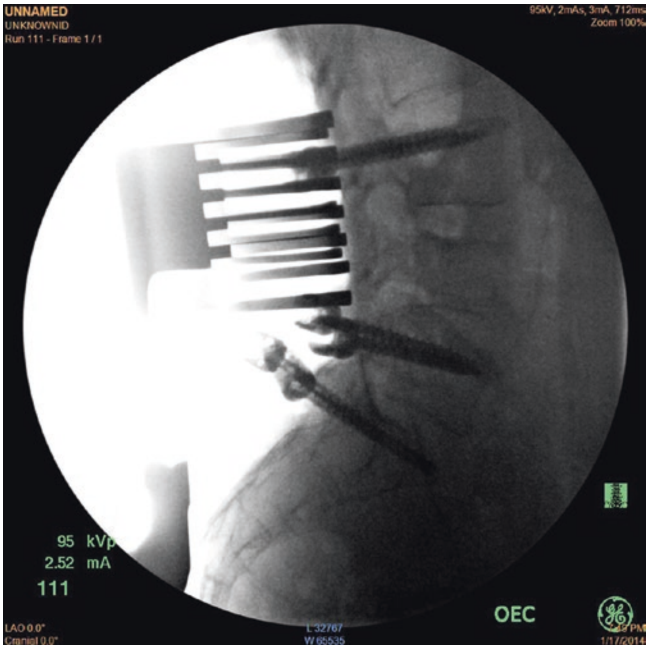


Fig. 4.51 Pedicle screw placement

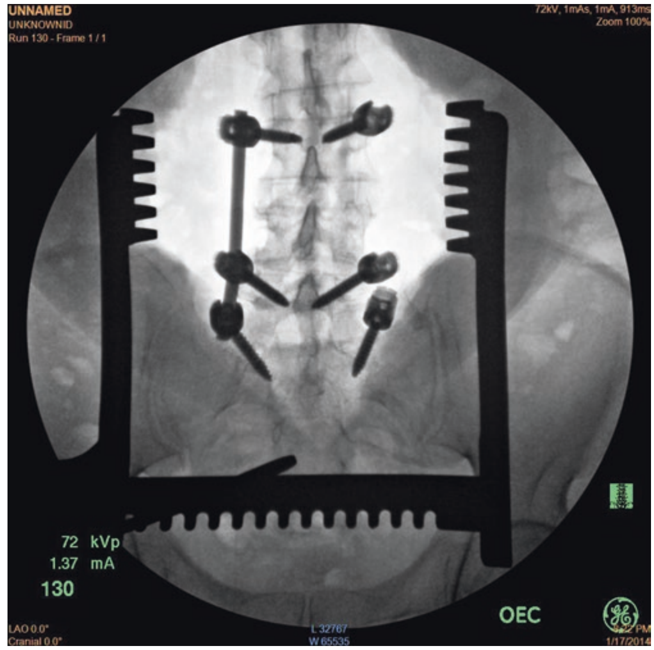


Fig. 4.53 Intraoperative anteroposterior fluoroscopy of temporary fixation of a titanium rod on one side

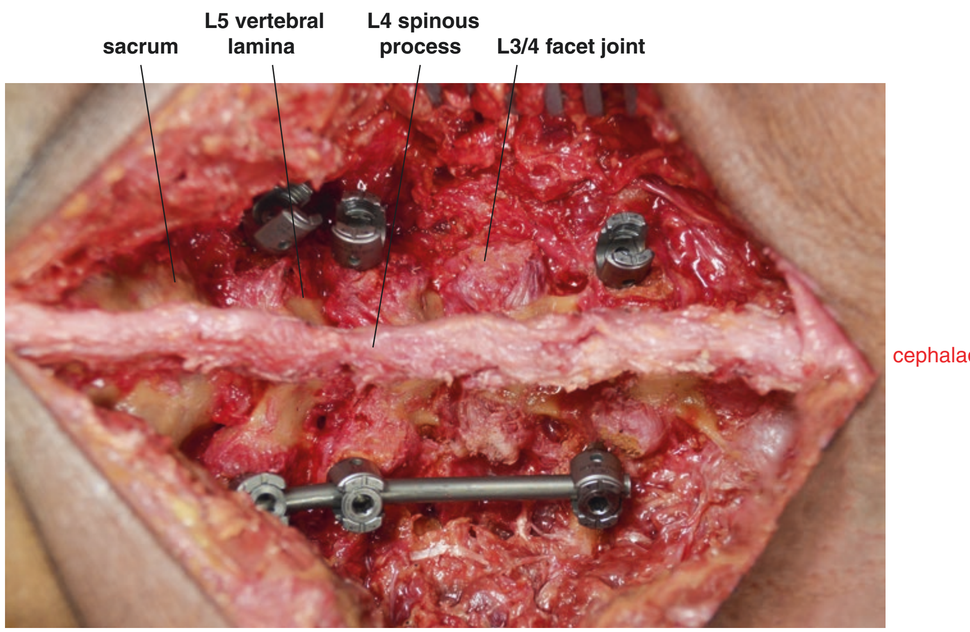


Fig. 4.52 Rod fixation on one side

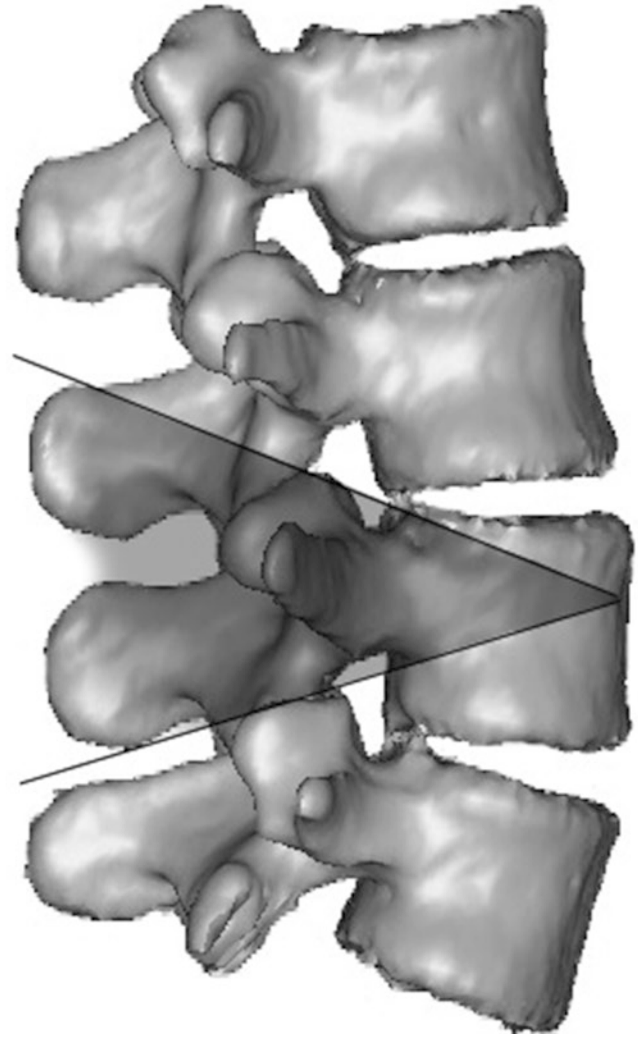


Fig. 4.54 Wedge-shaped fashion of PSO

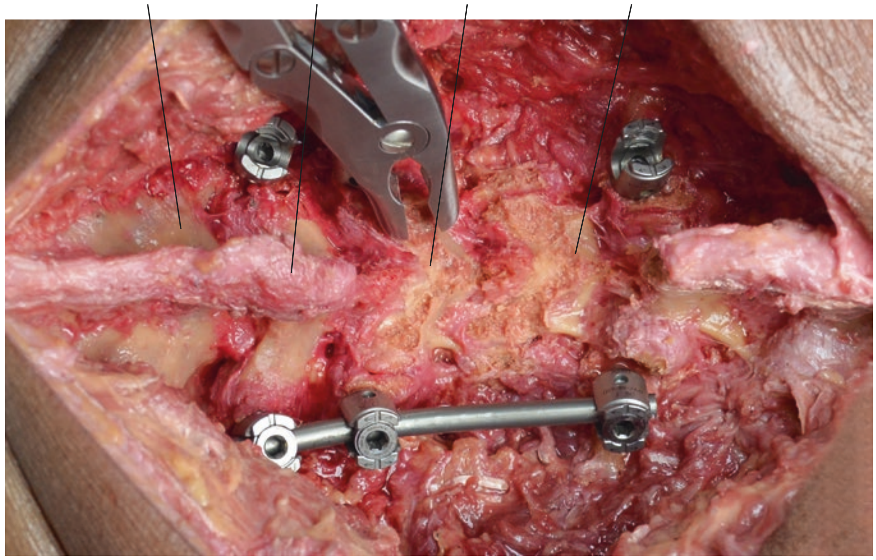


Fig. 4.55 Removal of the posterior lamina of the osteotomy segment, lower part of the spinous process, and vertebral plate of the superior segment

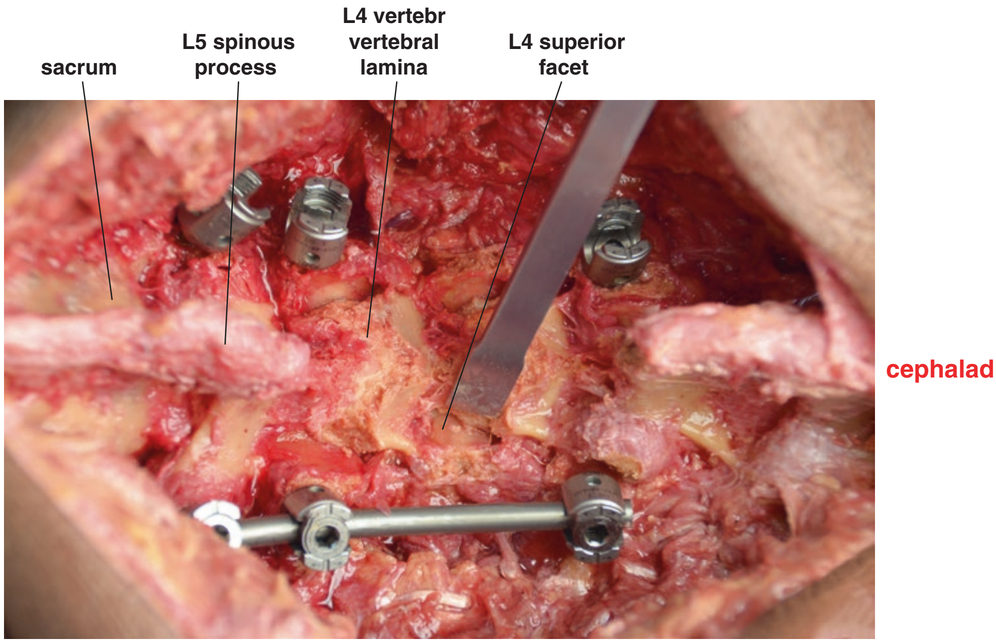


Fig. 4.56 Resection of the inferior facet of the superior segment

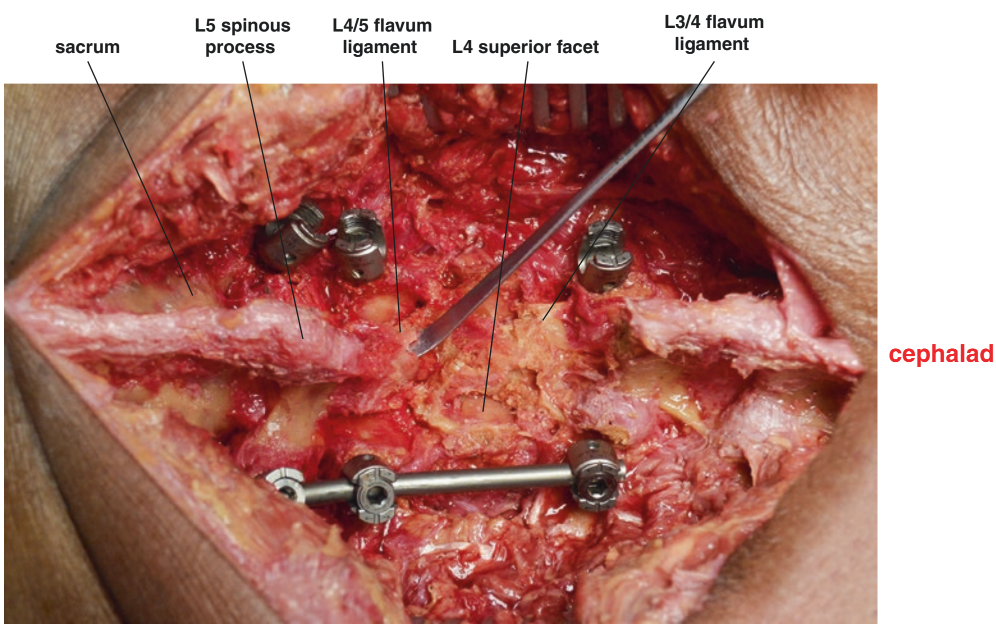


Fig. 4.57 Resection of the vertebral plate and ligamentum flavum in the osteotomy segment

Ligamentum flavum (Fig. 4.58) is connected to the lamina of adjacent vertebrae within the spinal canal. The ligamentum flavum is mainly composed of yellow elastic fibrous tissue, which is distributed vertically and goes downward from the anterior-inferior margin of the superior vertebral plate to reach the posterior-superior margin of the inferior vertebral plate. The ligamentum flavum in the lumbar spine is the thickest. It serves as an important landmark in the posterior approach for lumbar surgery.

Fig. 4.58 The lumbar ligamentum flavum

The ligamentum flavum is removed (Fig. 4.59) to expose the dural sac. In the procedure, the attention should be paid to avoid injury to the dural sac, which will cause cerebrospinal fluid leakage.

Use a nerve probe to detect the nerve root canals above and below the osteotomy pedicle and the exiting nerve roots, to avoid compression on the nerve roots during osteotomy and closure of the osteotomy (Fig. 4.60).

Remove the superior facet in the osteotomy segment with an osteotome and rongeurs to expose the pedicle.

Use the nerve root retractor to separate the dural sac and nerve roots from the intravertebral fat and venous plexus (Figs. 4.61 and 4.62).

The cancellous bone within the osteotomy level pedicle is removed with different size of curettes (Fig. 4.63).

The epidural bleeding encountered is dealt with bipolar electrocautery, hemostatic agents, and cottonoids sponges.

Under the protection of the nerve retractors, the residual pedicle cortical bone is dissected by Kerrison rongeurs (Fig. 4.64).

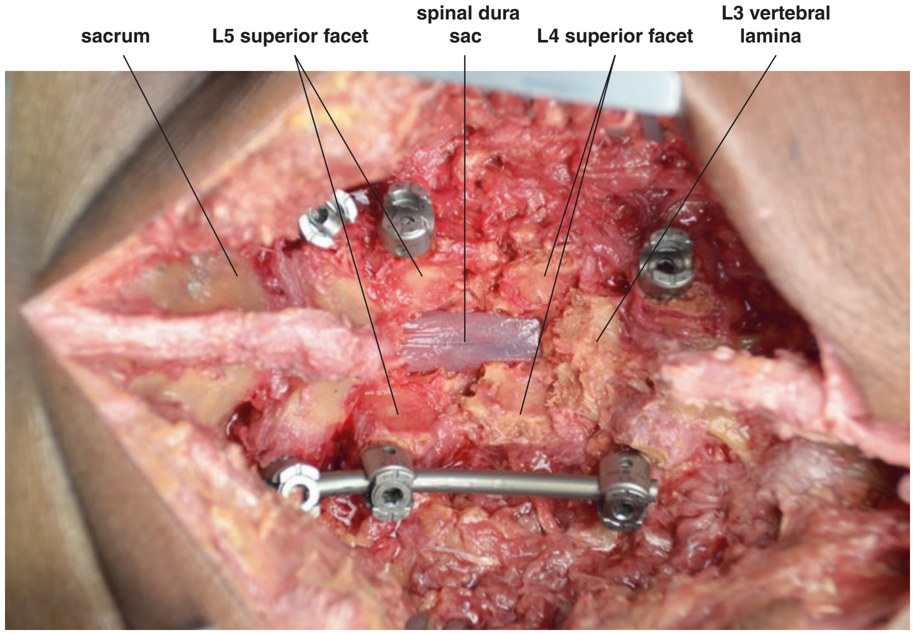


Fig. 4.59 Removal of the ligamentum flavum

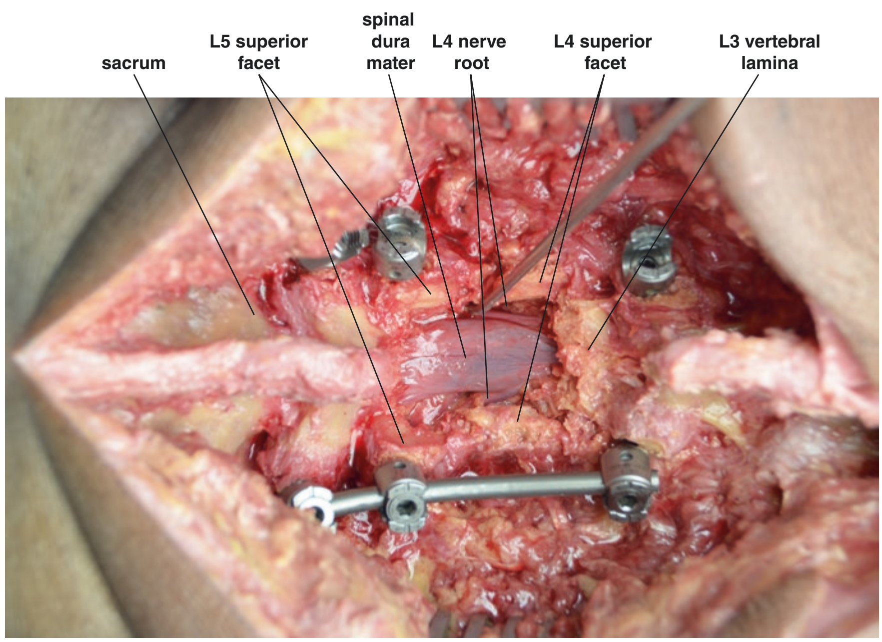


Fig. 4.60 Decompression of the nerve root in the osteotomy segment

Fig. 4.61 Pedicles, traversing nerve roots, and the exiting nerve roots

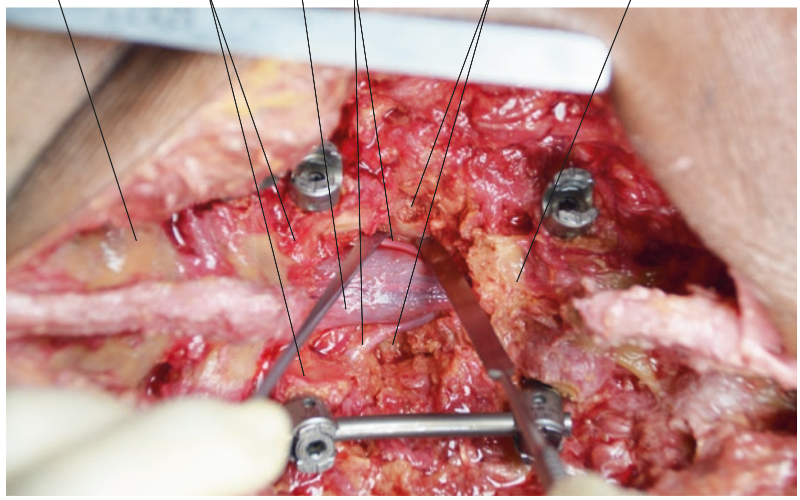


Fig. 4.62 The nerve root beside the osteotomy level pedicle is retracted and protected

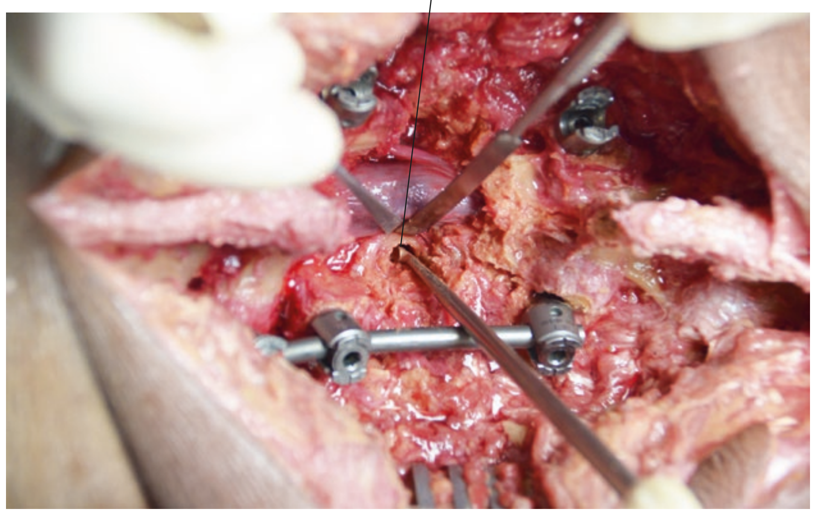


Fig. 4.63 Remove the cancellous bone within the pedicle with curettes

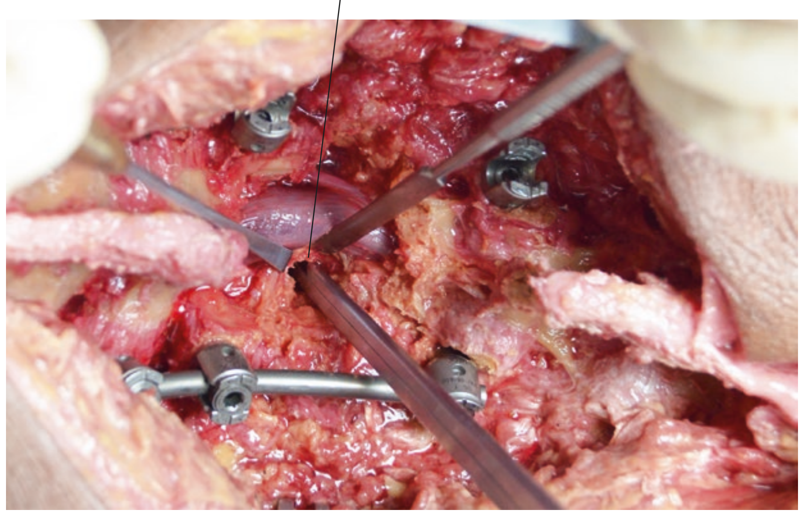


Fig. 4.64 Osteotomy of the pedicle

Intervertebral foramen of the lumbar spine: it is the area where the lumbar nerve root exits out of the spinal canal, and it has a "light bulb" appearance. The intervertebral foramen is a route connecting the vertebral canal and the retroperitoneal space for segmental vessels and nerves. The anterior wall of the intervertebral foramen is formed by the lower aspect of the body of the upper vertebra above, by the intervertebral disc in the middle and lower part, and by the small upper portion of the back of the body of the lower vertebra at the lowest level. The posterior wall, on the other hand, is formed by the lower portion of the pars interarticularis of the lamina of the higher vertebra superiorly and the superior articular process of the lower vertebra inferiorly. Most nerve roots exiting out of the intervertebral foramen are within the superior one fourth of the foramen (Fig. 4.65).

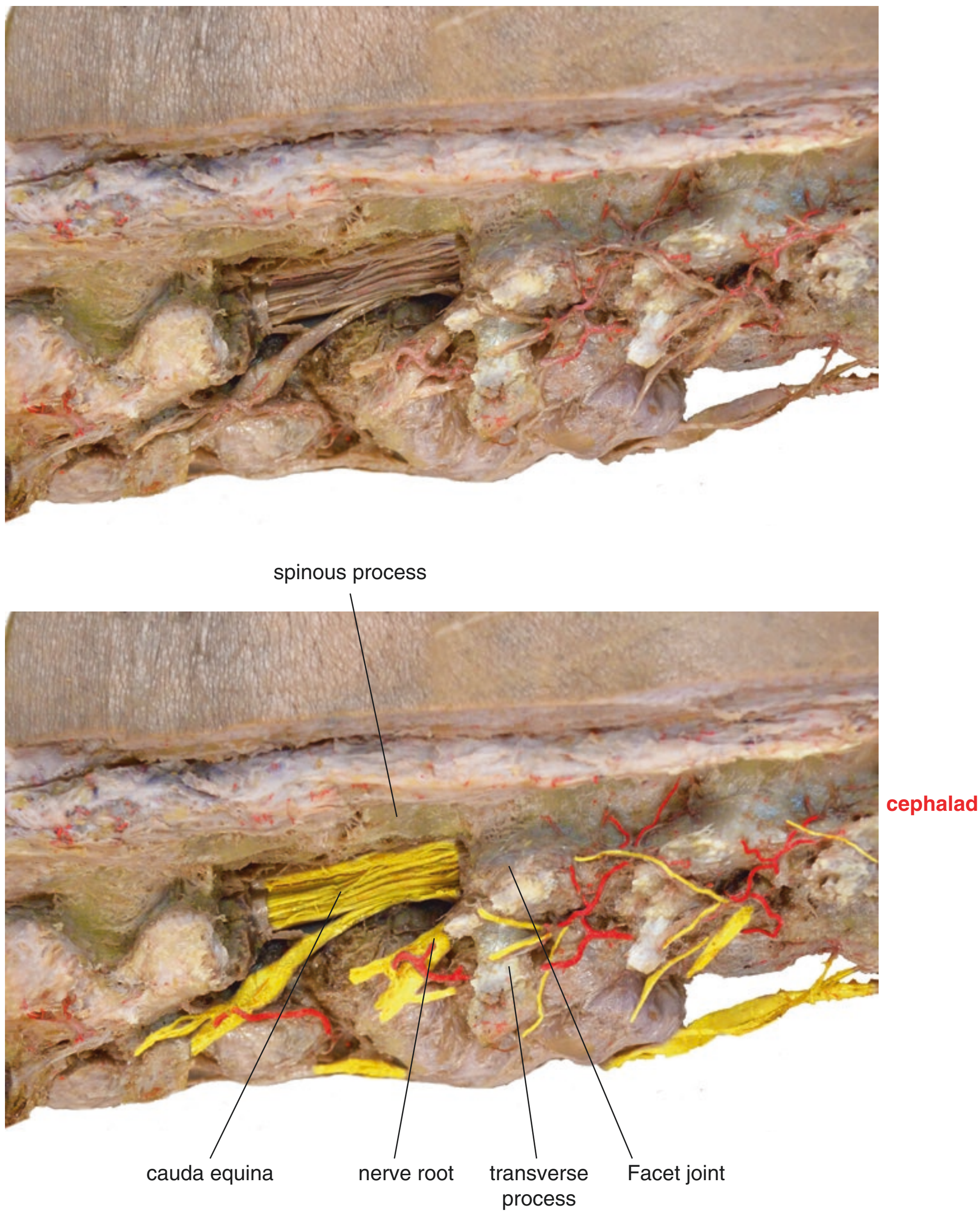


Fig. 4.65 Relationship among the nerve root, cauda equina, and bony structure (the posterior bony structures are removed on the right side of the target level for PSO)

The same osteotomy is done to the opposite side (Fig. 4.66).

Medial retraction of the dural sac and nerve root should be limited not further than midline.

The figure shows the relationships among the vertebral body, nerve roots, sympathetic trunk, and segmental vessels (Fig. 4.67).

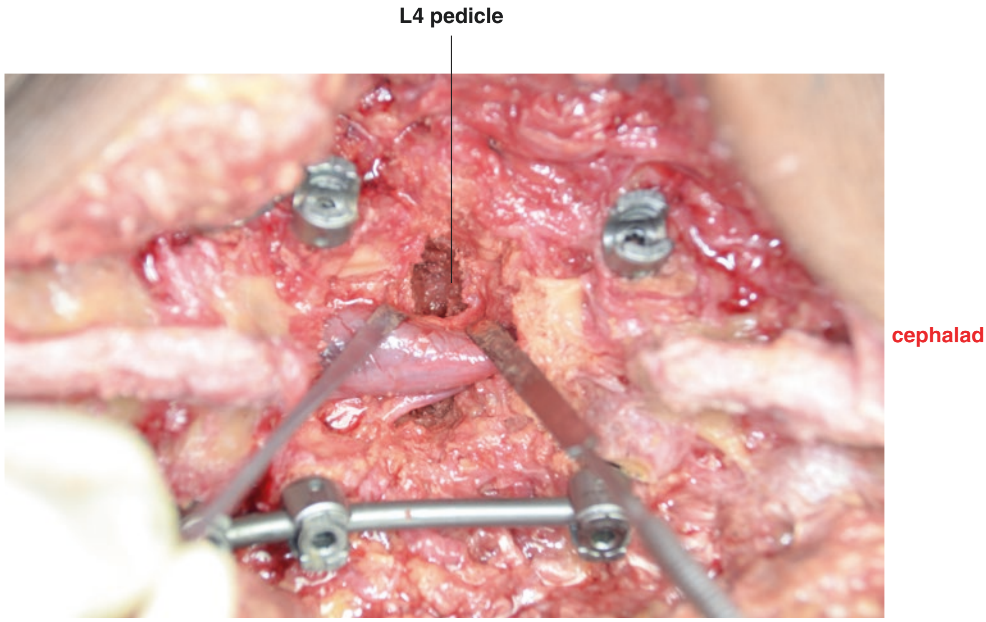
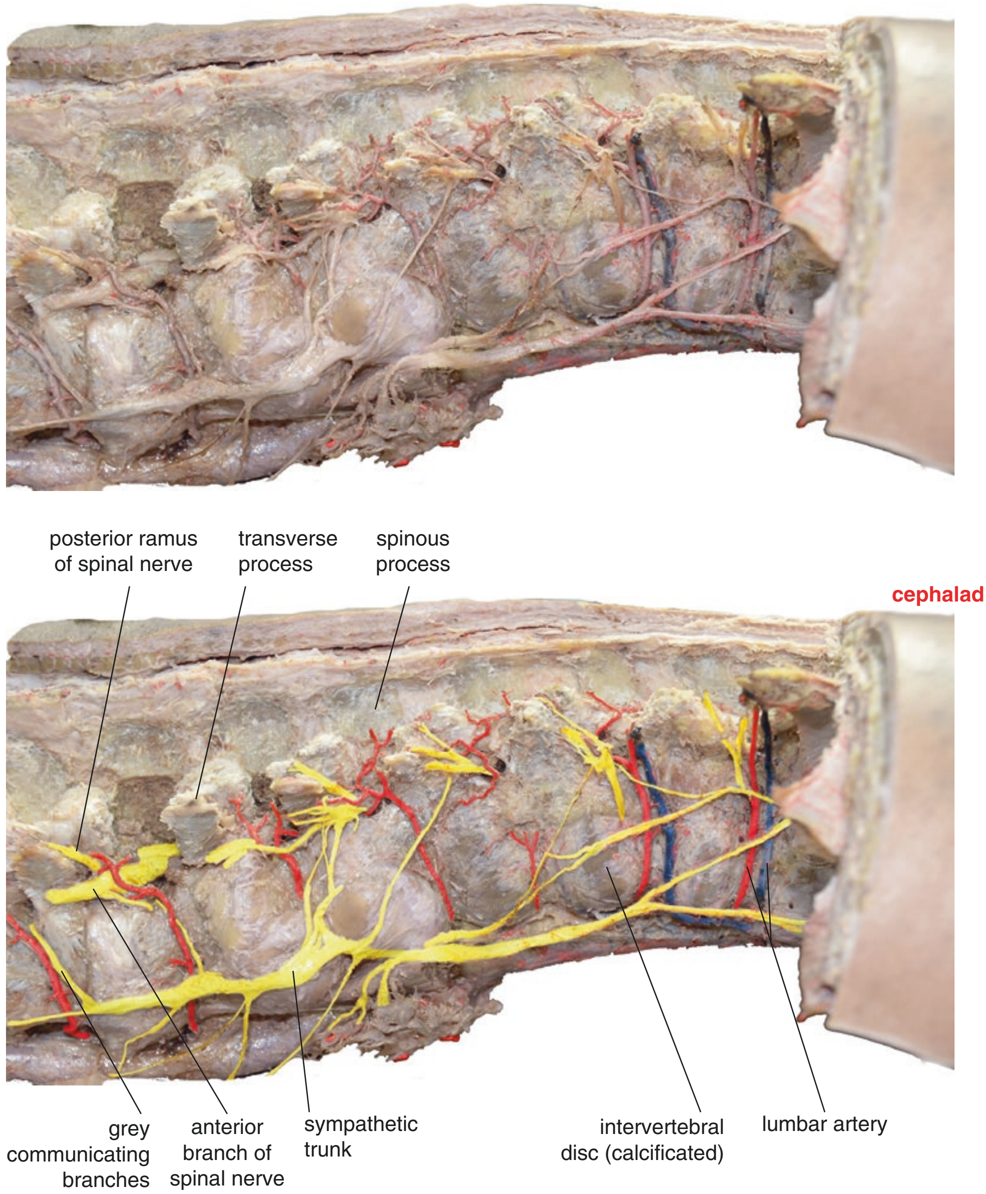


Fig. 4.66 Osteotomy of the vertebral body

Fig. 4.67 Neurovascular structures around the lumbar spine



Place a foot-shaped posterior wall impactor into the ventral part of the dural sac, and then impact the posterior vertebral wall down into the vertebral body defect (Figs. 4.68 and 4.69).

Use a rongeur to remove the partial bone in the posterior wall of the vertebral body of osteotomy edge in both ends to avoid compression on the dural sac.

An osteotome is used to perform wedge-shape resection of the lateral vertebral body. A curette is used to remove cancellous bone in the vertebral body to make the osteotomy in a wedge-shaped fashion.

Determine whether the resection depth and area in the anterior part of the vertebral body meet the requirements by observing the C-arm fluoroscopy image (Figs. 4.70 and 4.71).

A compressor is used to apply force to the pedicle screws bilaterally in the osteotomy segment and close the osteotomy (Fig. 4.72).

A jackknife bed that can break in the middle can also be used to facilitate the closure of the osteotomy. The lumbar of the patient can be hyperextended by placing the table into V shape during the correction procedure.

In the process of closing the osteotomy, it should be rechecked that there is no compression on the neural elements of the osteotomy segment (Fig. 4.73).

Use the nerve root probe to inspect the intervertebral foramen (Fig. 4.74), and remove the excessive bone or soft tissue that will cause compression on the nerve root or dural sac.

Fluoroscopy shows the osteotomy is closed and the implants are in good position (Figs. 4.75 and 4.76).

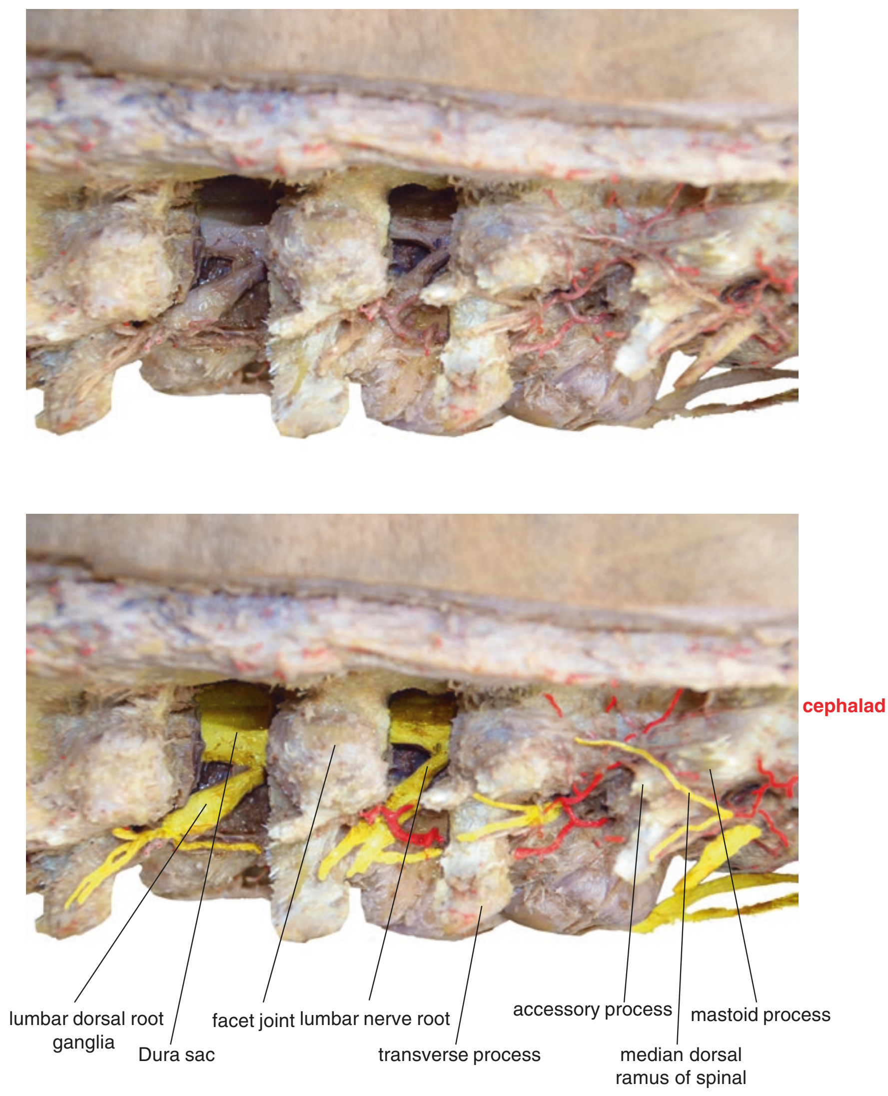


Fig. 4.68 Relationships among the dural sac, nerve roots, and vertebral body (vertebral plates are partially resected)

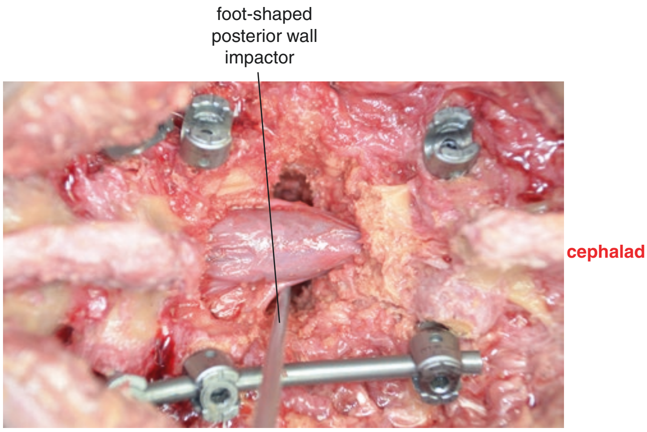


Fig. 4.69 Vertebral osteotomy

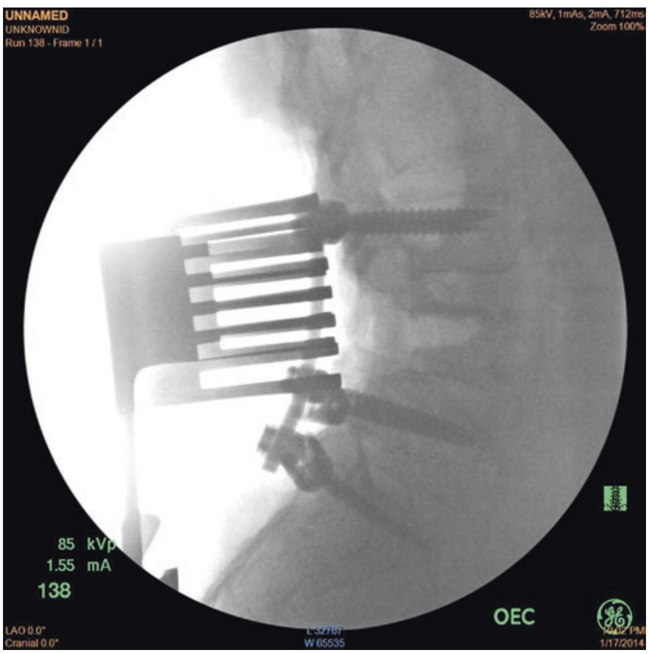


Fig. 4.70 Lateral C-arm fluoroscopy of PSO

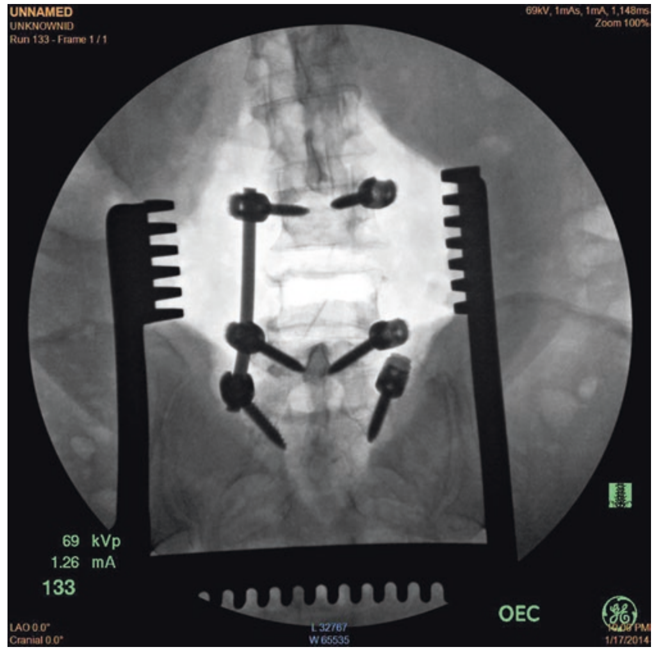


Fig. 4.71 Anteroposterior C-arm fluoroscopy of PSO

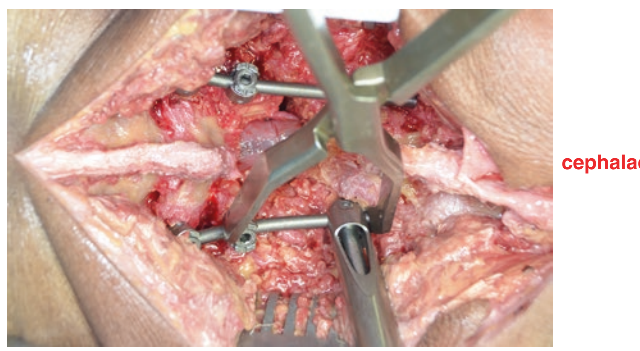


Fig. 4.72 A compressor is used to apply force to the pedicle screws to facilitate the closure of the osteotomy

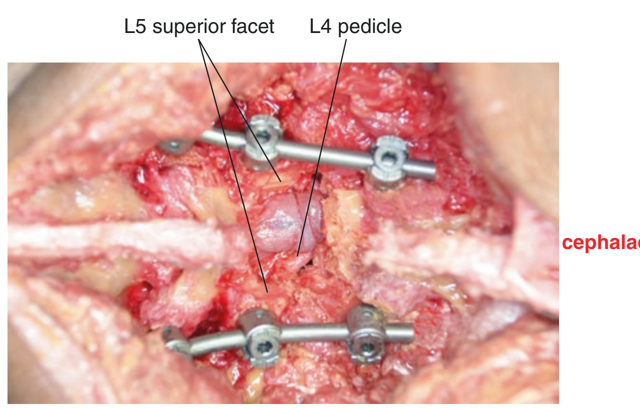


Fig. 4.73 The osteotomy is closed

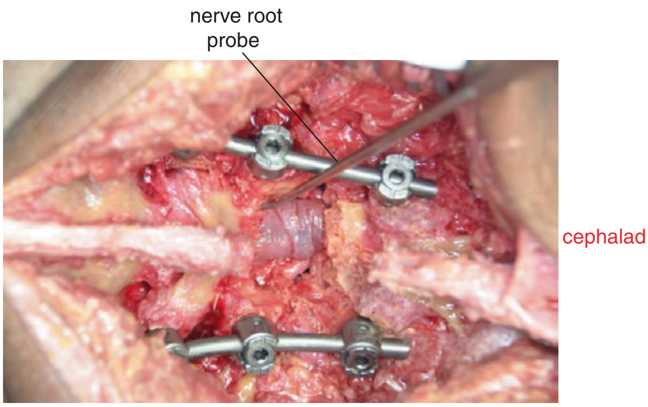


Fig. 4.74 Inspect the intervertebral foramen to check if compression exists on the nerve root

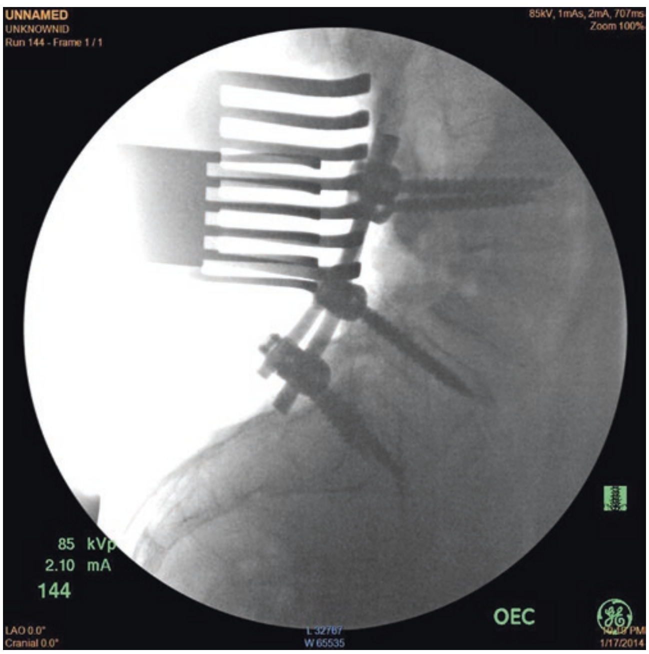


Fig. 4.75 Lateral fluoroscopy of the closed osteotomy

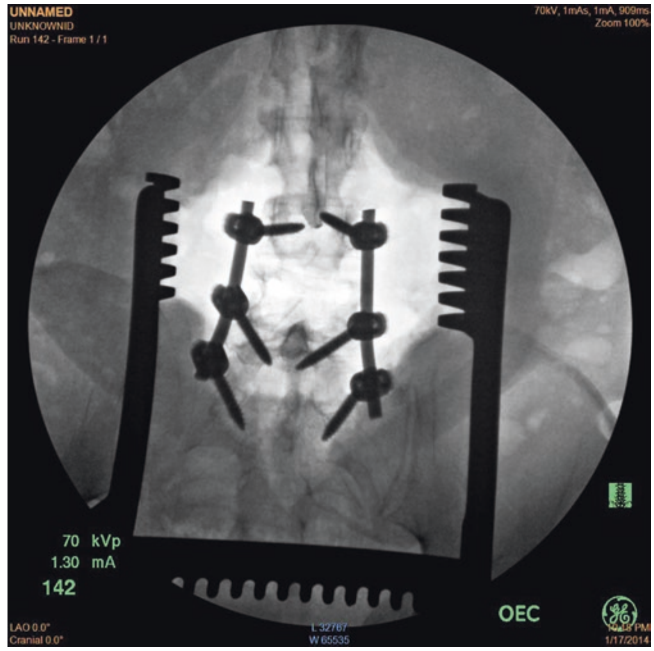


Fig. 4.76 Anteroposterior fluoroscopy of the closed osteotomy

4 Extreme Lateral Interbody Fusion (XLIF)

4.1 Overview

Extreme lateral interbody fusion (XLIF), firstly reported by Neilwright in 2003, is a new minimally invasive technique for intervertebral fusion reaching the lumbar spine through the retroperitoneal space and psoas major muscle. As a novel lateral retroperitoneal approach for the lumbar spine, XLIF has its special advantages over PLIF and TLIF. This approach can remain the integrity of anterior and posterior longitudinal ligaments and allow implanting a bigger interbody fusion cage with a larger fusion area, which could have better biomechanical stability and fusion rate.

The principle of XLIF lies in indirect decompression, which is achieved by restoring the height of the intervertebral space, and thus achieves the following results: (1) increasing the area of the intervertebral foramen, (2) extending the thickened ligamentum flavum and posterior longitudinal ligament that protrude into the spinal canal, and (3) correcting the alignment of the vertebral column. The successful establishment of the operation route passing through the retroperitoneum and psoas major muscle is the key to the success of the procedure. Surgical indications of XLIF are as follows: discogenic low back pain or intervertebral disc degenerative disease with lumbar instability and recurrent intervertebral disc herniation; grade 1–2 spondylolisthesis; mild degenerative lumbar vertebra scoliosis; replacement and repair for artificial lumbar intervertebral discs; and revision surgery for previous posterior lumbar interbody fusion which includes pseudarthrosis and adjacent segment degeneration.

4.2 Position

The patient is placed in the lateral decubitus position (Figs. 4.77 and 4.78) after intubation. The kidney rest is elevated to gain maximum opening of the space between the ribs and the iliac crest to facilitate the access to the target disc.

The bolsters and generous padding are used to position the patient. Tapes are used to secure the patient in position.

To avoid damage to the liver or inferior vena cava, the right lateral position and left-sided approach are usually adopted.

In cases with degenerative scoliosis with a right-sided lumbar curve, the left lateral position and right approach can facilitate exposure to the intervertebral space of the wedging variable and close side.

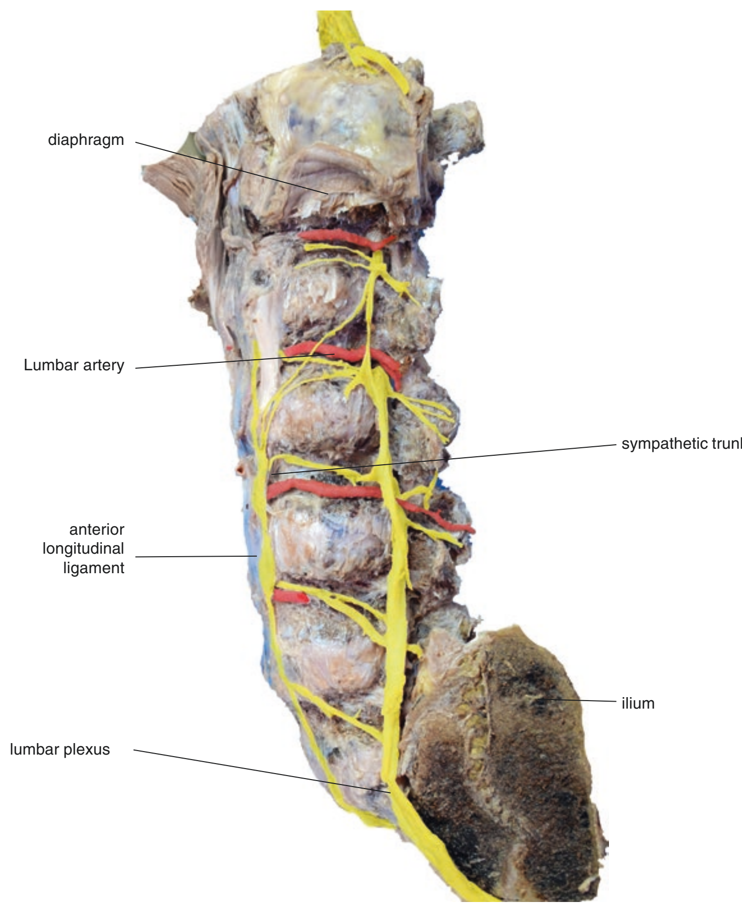
Both hip joints are placed in inflection position to relax the psoas major muscle.

The attachment point of midaxillary line of diaphragm muscle lied between the inferior edge of the 10th rib and the superior edge of the 12th rib. The attachments on both sides of the vertebral column are mainly located between the upper edge of T12 vertebra and L1–L2 disc (Figs. 4.79 and 4.80).

Fig. 4.77 Position of lumbar XLIF

Fig. 4.78 Position of lumbar XLIF

Fig. 4.79 The attachment point of the diaphragm muscle on the left side



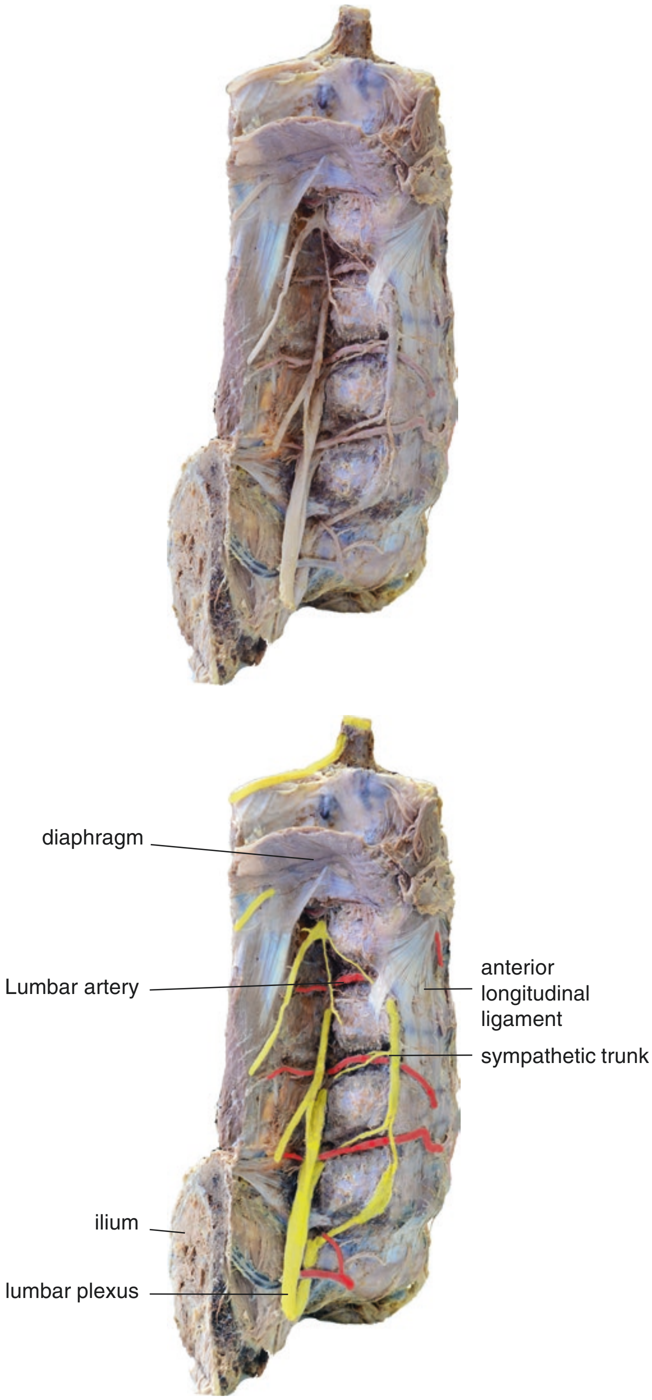


Fig. 4.80 The attachment point of the diaphragm muscle on the right side

A transthoracic approach should be considered when the target level was above T12 vertebrae, whereas a retroperitoneal approach should be chosen when target level was below L1–L2 disc. If the target level is located between T12 and L1–L2 disc, whether via transthoracic, retropleural, or retroperitoneal approach should be determined according to the conditions of patients and the skill and experience of the surgeon.

Incision should be made above the 10th rib for the transthoracic approach and below the 12th rib for the retroperitoneal approach.

True lateral image is performed and the table is tilted to adjust the position and obtain a true lateral view of the target disc. A true lateral view of the target disc is critical in XLIF procedure, for it allows a safe trajectory directly perpendicular to the floor and a better sense for the surgeon of the intraoperative spinal anatomy (Figs. 4.81 and 4.82).

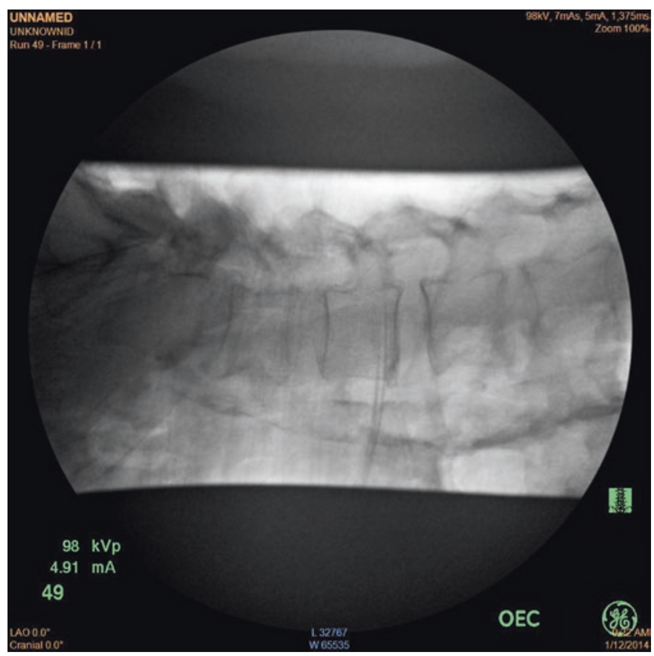


Fig. 4.81 True lateral image is performed during the placement of the patient to gain a true lateral view of the target disc

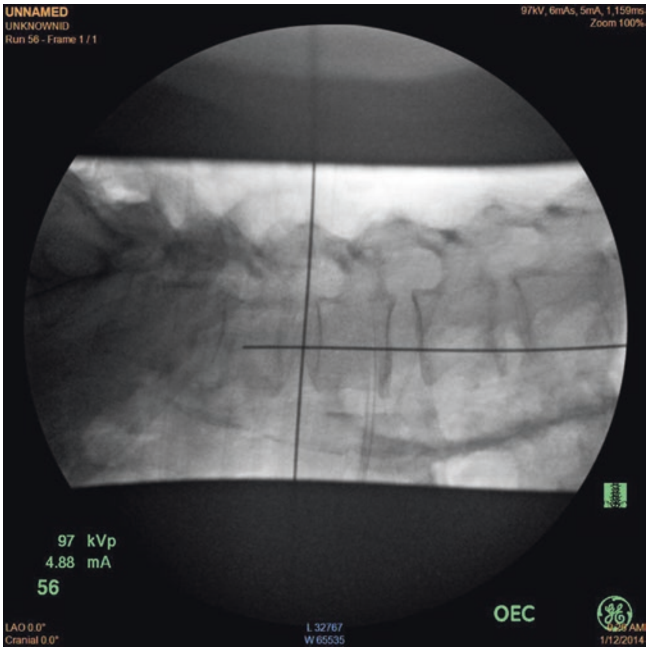


Fig. 4.82 Locate the target disc under fluoroscopy

4.3 Exposure

Longitudinally, incision is made on the skin, and the obliquus externus abdominis, obliquus internus abdominis, and musculus transversus abdominis are bluntly dissected.

Make sure there is no peritoneum underneath the abdominal transverse fascia before incising the transverse fascia.

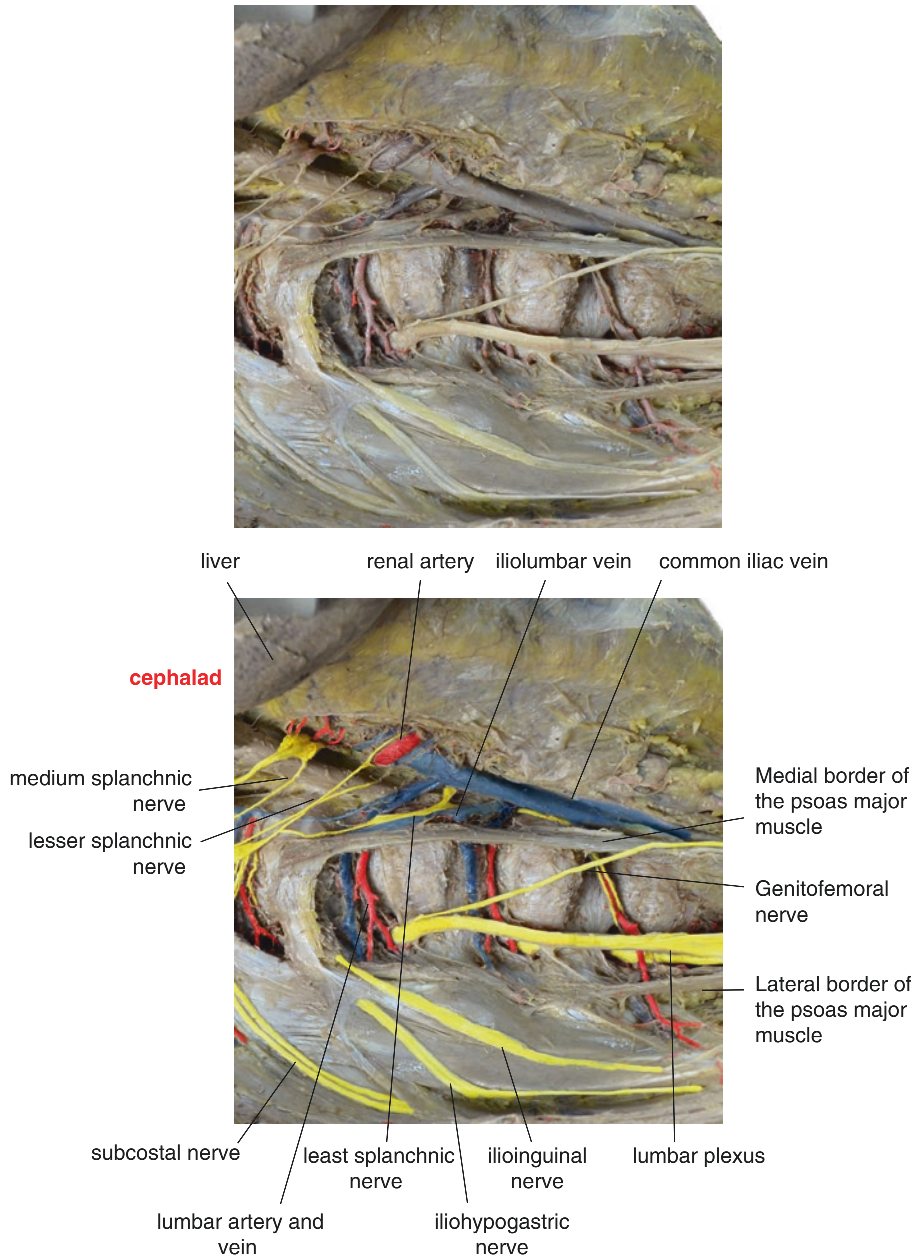
The surgeon uses his or her finger to perform blunt dissection and create a retroperitoneal space. Then a guide wire is placed along the finger into position directly over the psoas muscle.

The psoas major fiber is bluntly dissected till the intervertebral disc with initial dilatator. The blunt dissection proceeds from the anterior part of the vertebral body to avoid injury to the lumbar plexus and nerve roots.

Psoas major muscle: the psoas major muscle is a long fusiform muscle located on the side of the lumbar region of the vertebral column. The psoas major is divided into two parts. The deep part originates from the transverse processes of L1–L5. The superficial part originates from the lateral surfaces and neighboring intervertebral discs of the T12–L4. The lumbar plexus lies between the two layers. The psoas major serves as an important anatomic landmark in XLIF (Fig. 4.83).

Genitofemoral nerve: a nerve originating from the ventral rami of the L1–L2 nerve roots. It penetrates the surface of the psoas major muscle at the L3–L4 level and runs downwardly on the surface of the psoas major muscle. It diverges into the ramus genitalis and ramus femoralis above the inguinal ligament, of which the former enters the inguinal canal deep ring and is distributed in the cremaster and scrotum and the latter runs across the crural sheath and femoral fascia and is distributed in the skin of femoral triangle. During the approach of XLIF, entry point of the initial dilator should avoid the genitofemoral nerve (Fig. 4.83).

Fig. 4.83 Structures related to psoas major (psoas major resected with the boundary retained)



Make sure that the dilator is placed slightly anterior to the center of the target intervertebral space under fluoroscopy (Figs. 4.84 and 4.85).

A guide wire is gently introduced through the initial dilator into the intervertebral space, and then the location is confirmed by fluoroscopy (Fig. 4.86).

Dilators are then introduced sequentially through the psoas muscle with lateral fluoroscopic image confirming the position and depth (Figs. 4.87 and 4.88).

The retractors are placed along the dilators (Fig. 4.89).

The surgical field is exposed after opening the retractor blades, the tissue over the disc space is cleaned with a penfield dissector, and the nerve within the field can be swept dorsally and placed behind the retractor blade (Figs. 4.90 and 4.91).

The retractors are then adjusted into the proper place and locked to the bed with a retractor articulating arm (Figs. 4.92 and 4.93).

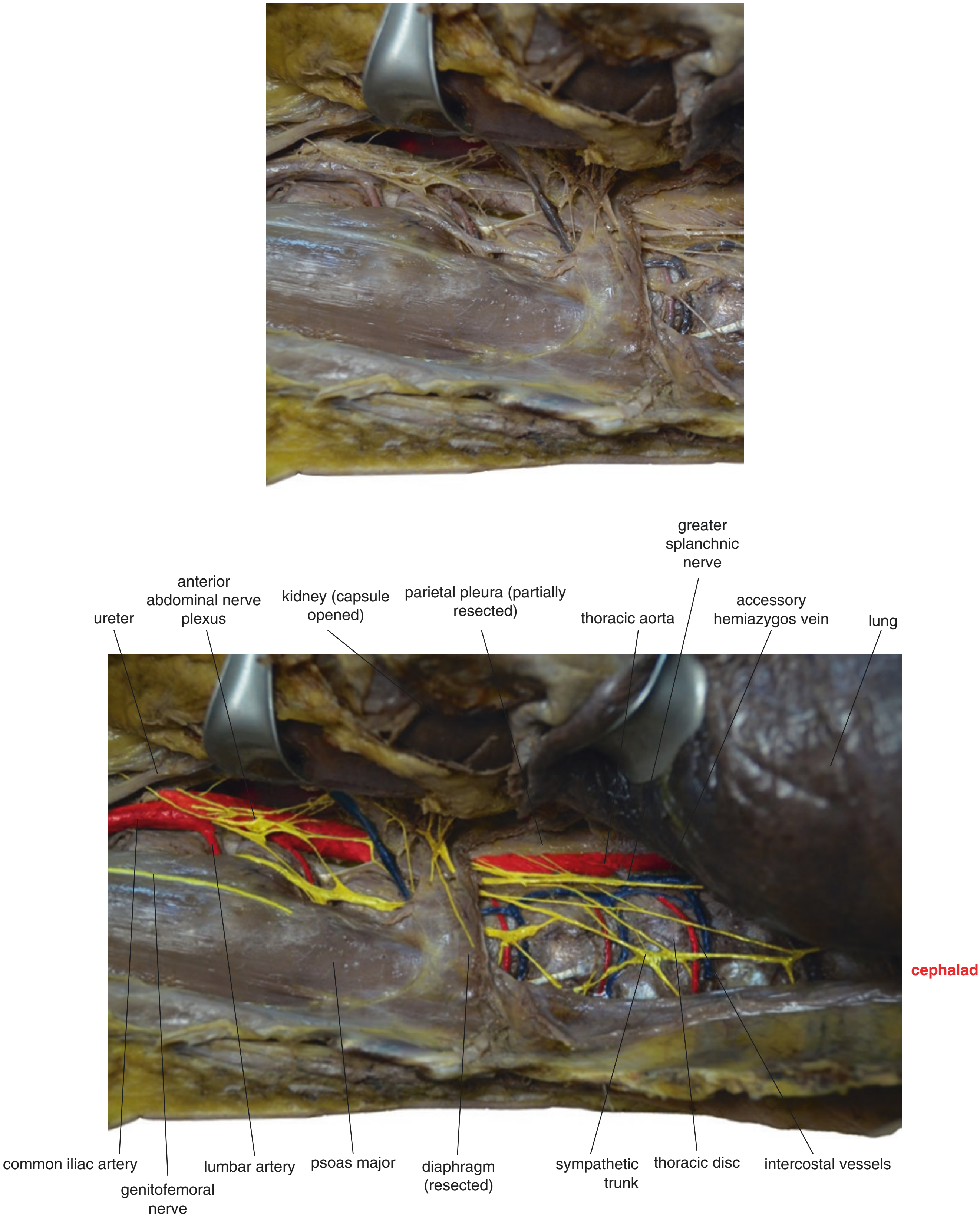


Fig. 4.84 Anatomy related to the psoas major muscle

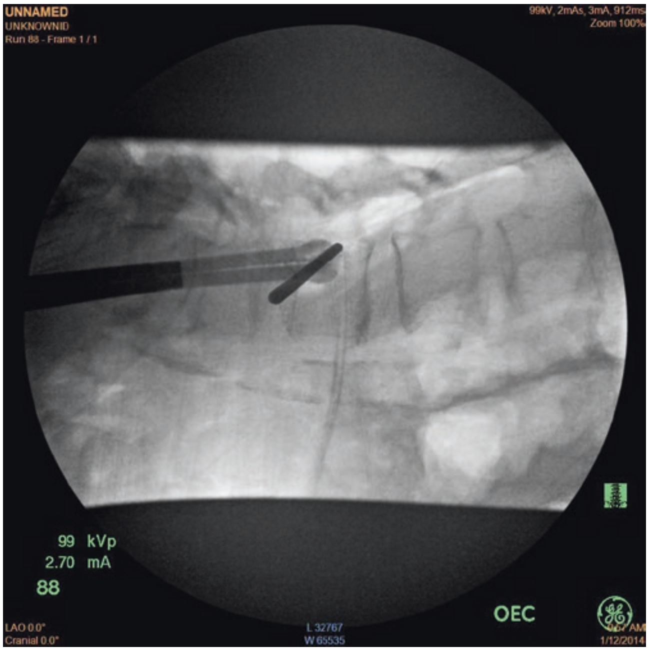


Fig. 4.85 Location of the L3–L4 intervertebral space

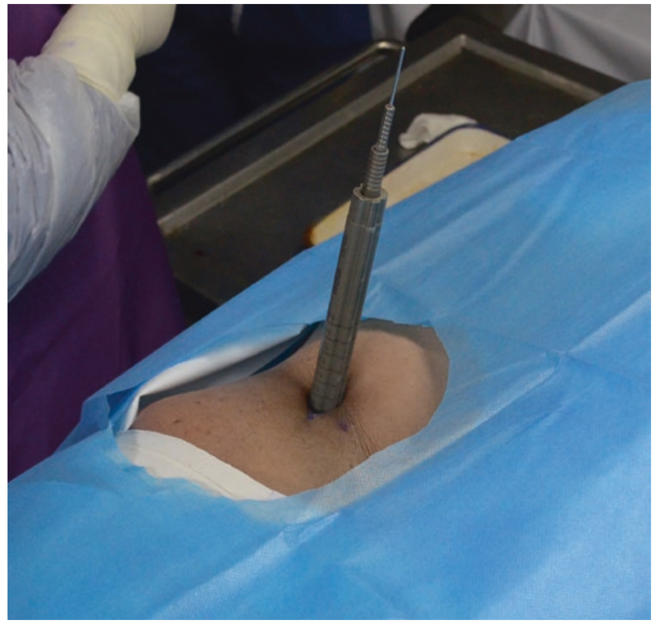


Fig. 4.87 Dilators are introduced sequentially through the psoas muscle

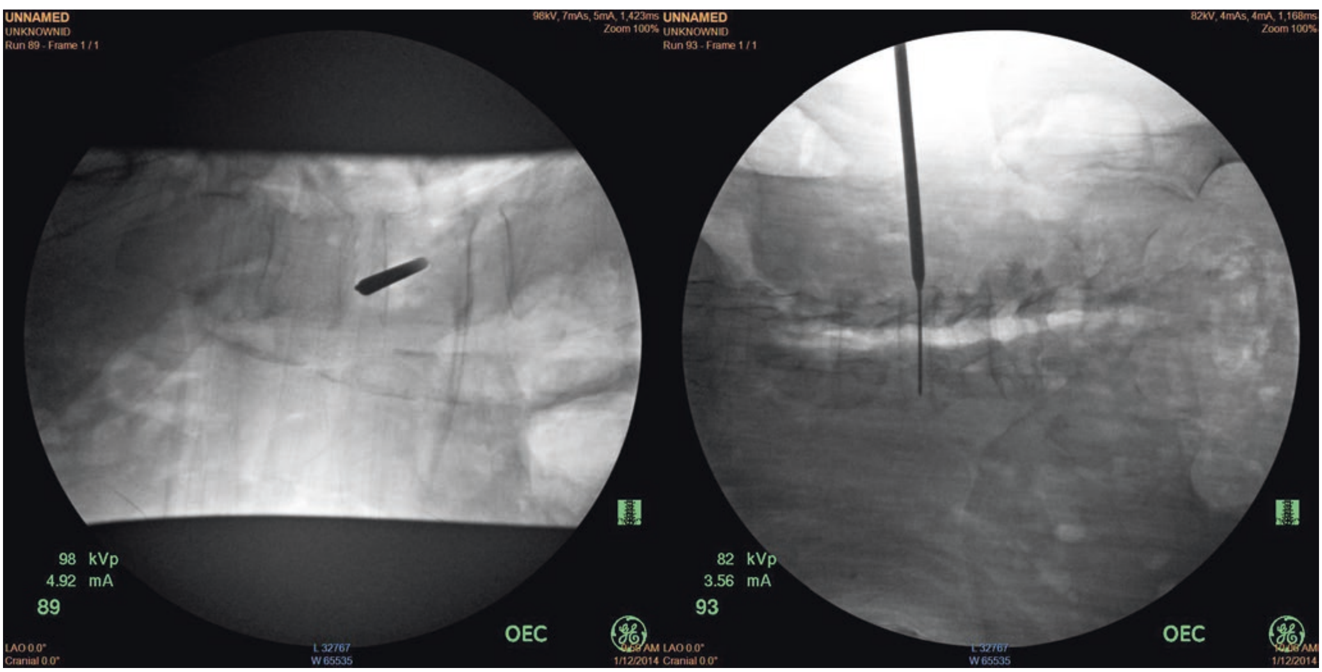


Fig. 4.86 The position and depth of guide wire are confirmed by fluoroscopy

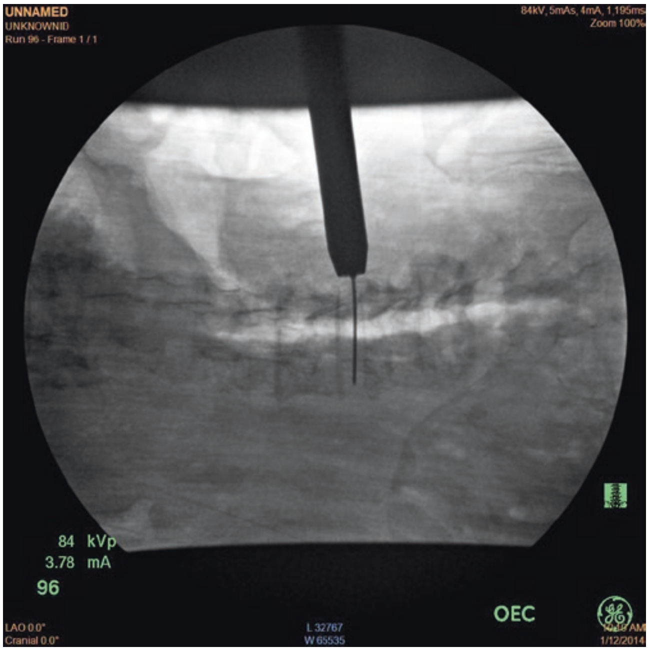


Fig. 4.88 Lateral fluoroscopic image showing dilators expanding the psoas major muscle to the intervertebral disc surface

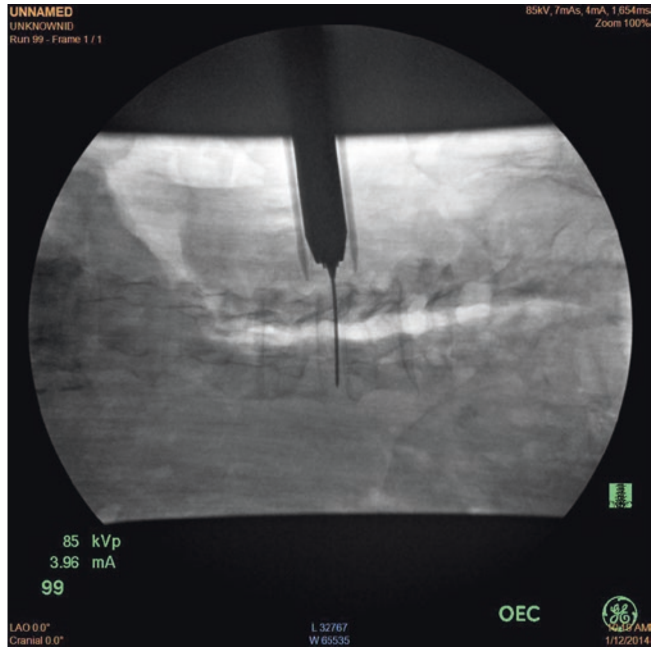


Fig. 4.90 The retractor blades are confirmed in location on lateral fluoroscopy; pins can be placed into the vertebral body to fix the retractor blades in place

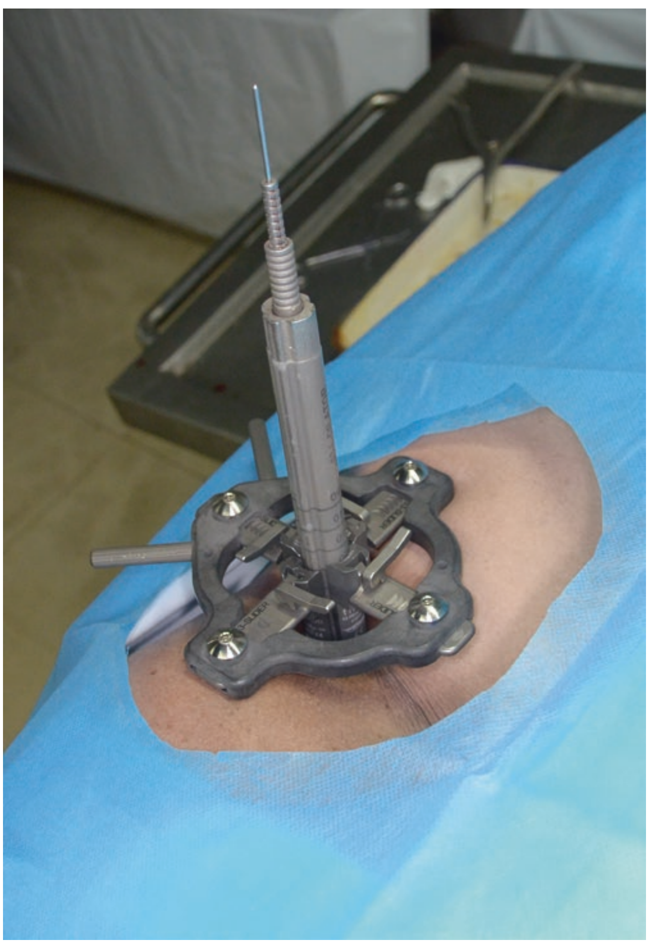


Fig. 4.89 Placement of the retractors

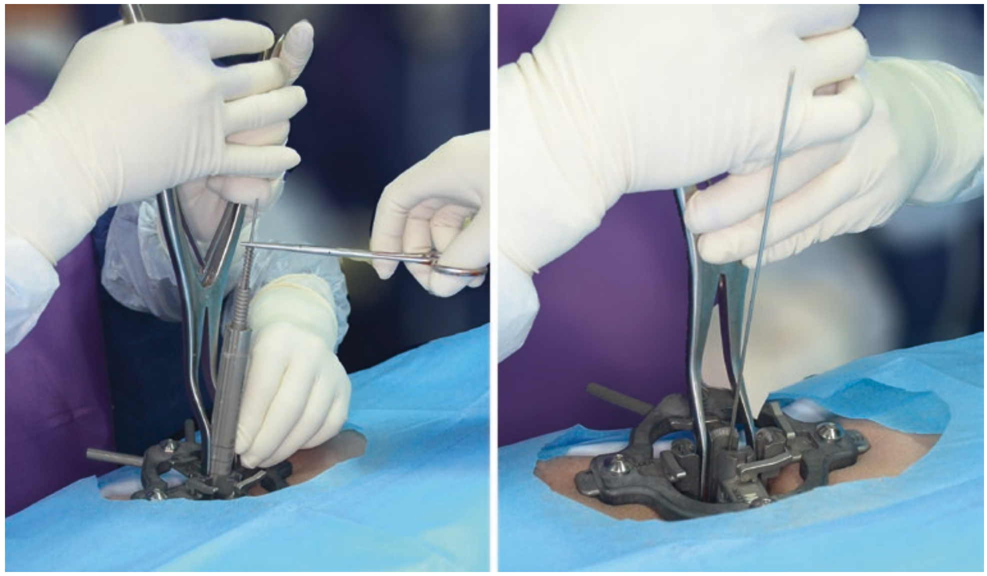


Fig. 4.91 Open the retractor blades with a dilator to expose the surgical field

Fig. 4.92 Fix the retractor on the bed

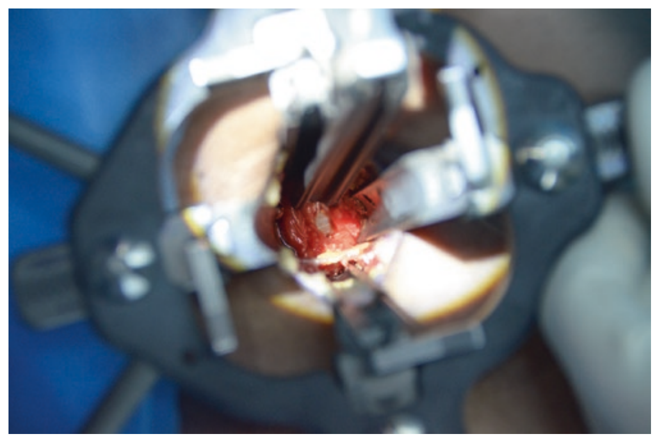


Fig. 4.93 Direct view of the intervertebral disc through the retractor

4.4 Discectomy

A blade is used to incise the anterior two thirds of the disc space. Pituitary rongeurs are used to remove nucleus pulposus.

The disc spaces and end plates are prepared with curettes, reamers, shavers, and rasps.

During surgery, keep the position of the patient unchanged to avoid trajectory bias and an increase in the risk of injury to the major vessels or the lumbosacral plexus (Fig. 4.94).

The intervertebral reamer is used to release the annulus on the contralateral side and cross just beyond the disc space under fluoroscopy (Fig. 4.95).

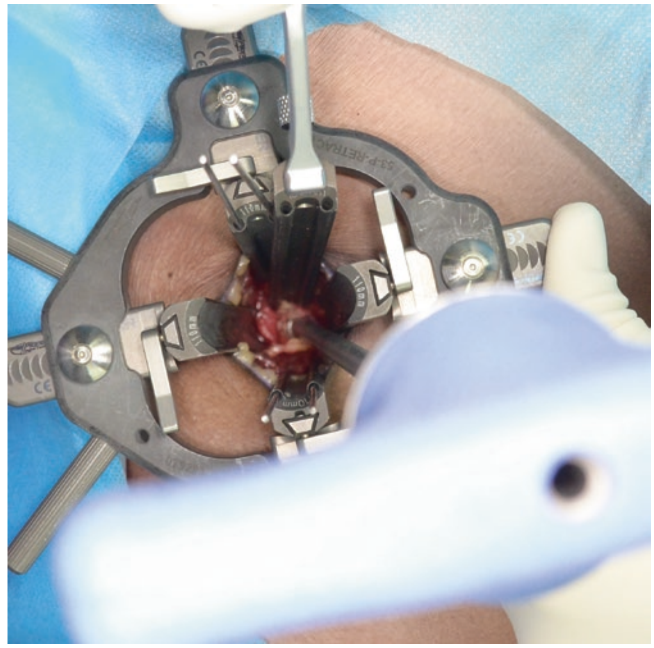


Fig. 4.94 Discectomy

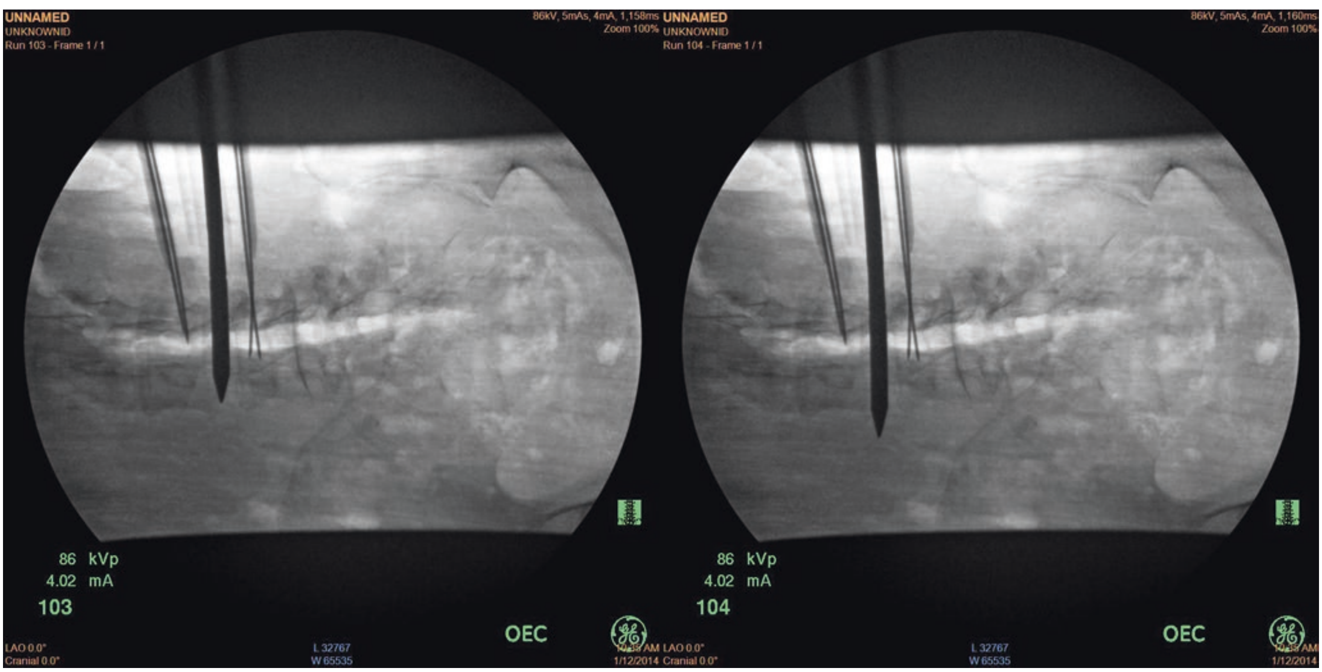


Fig. 4.95 Anteroposterior radiographic image shows intervertebral reamer to the contralateral side

The lumbar plexus (Figs. 4.96 and 4.97) is located posterior to the psoas major muscle and anterior to the lumbar transverse process, consisting of the ventral rami of L1–L3 nerve roots and most fiber of the ventral rami of L4 nerve root. To help avoid damage to the lumbar plexus in the approach of XLIF, the psoas muscle can be divided into four zones based on the distance between the anterior (zone I) and posterior (zone IV) borders of the vertebral bodies. At the level above L3, the lumbar plexus and nerve roots were found posterior to zone III. The nerves were in zone III at L4–L5 (Figs. 4.97 and 4.98).

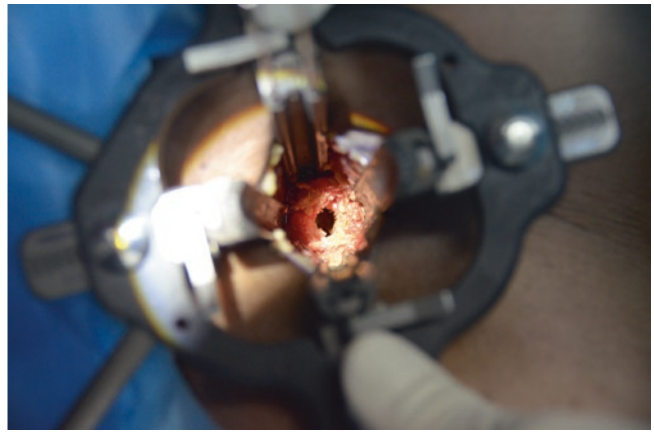
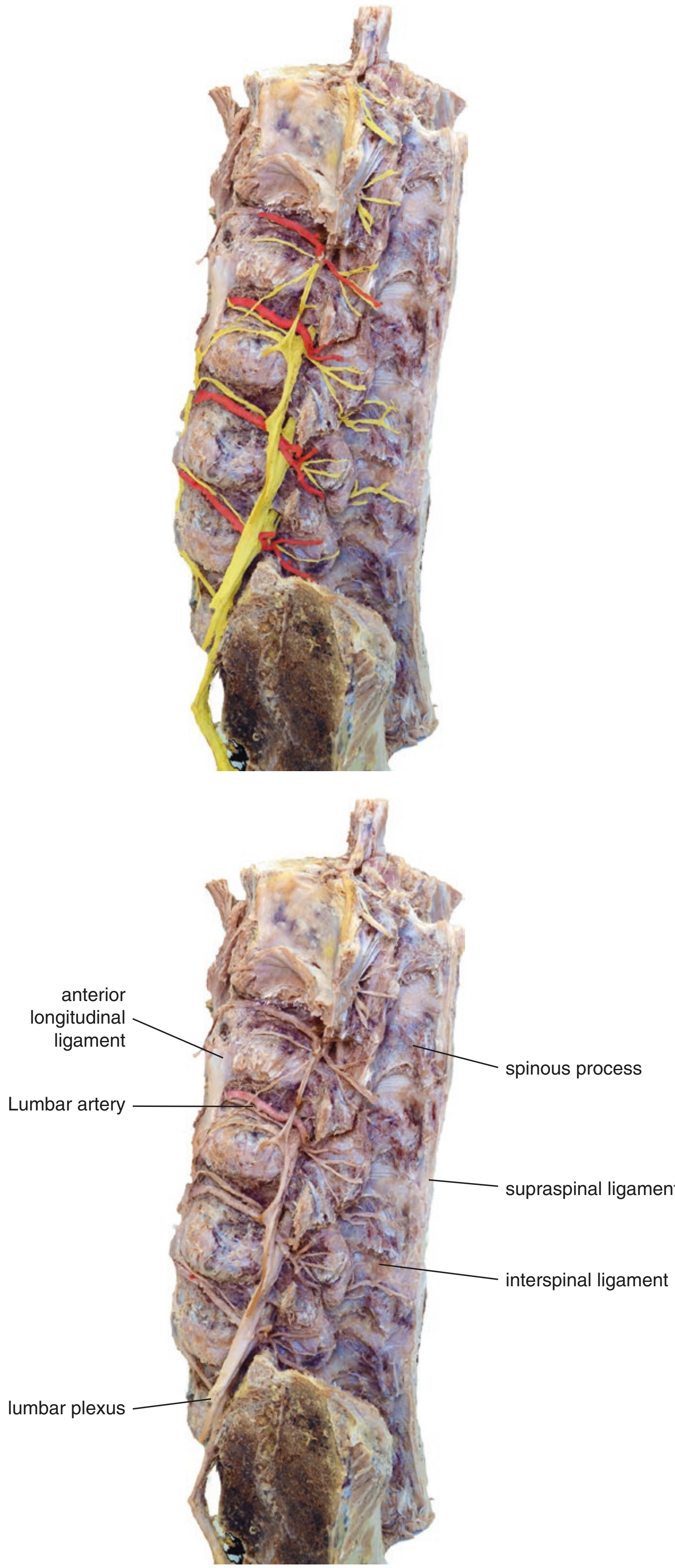


Fig. 4.96 Postdiscectomy

Fig. 4.97 Relationship among the vessel, nerve, and foramen intervertebrale



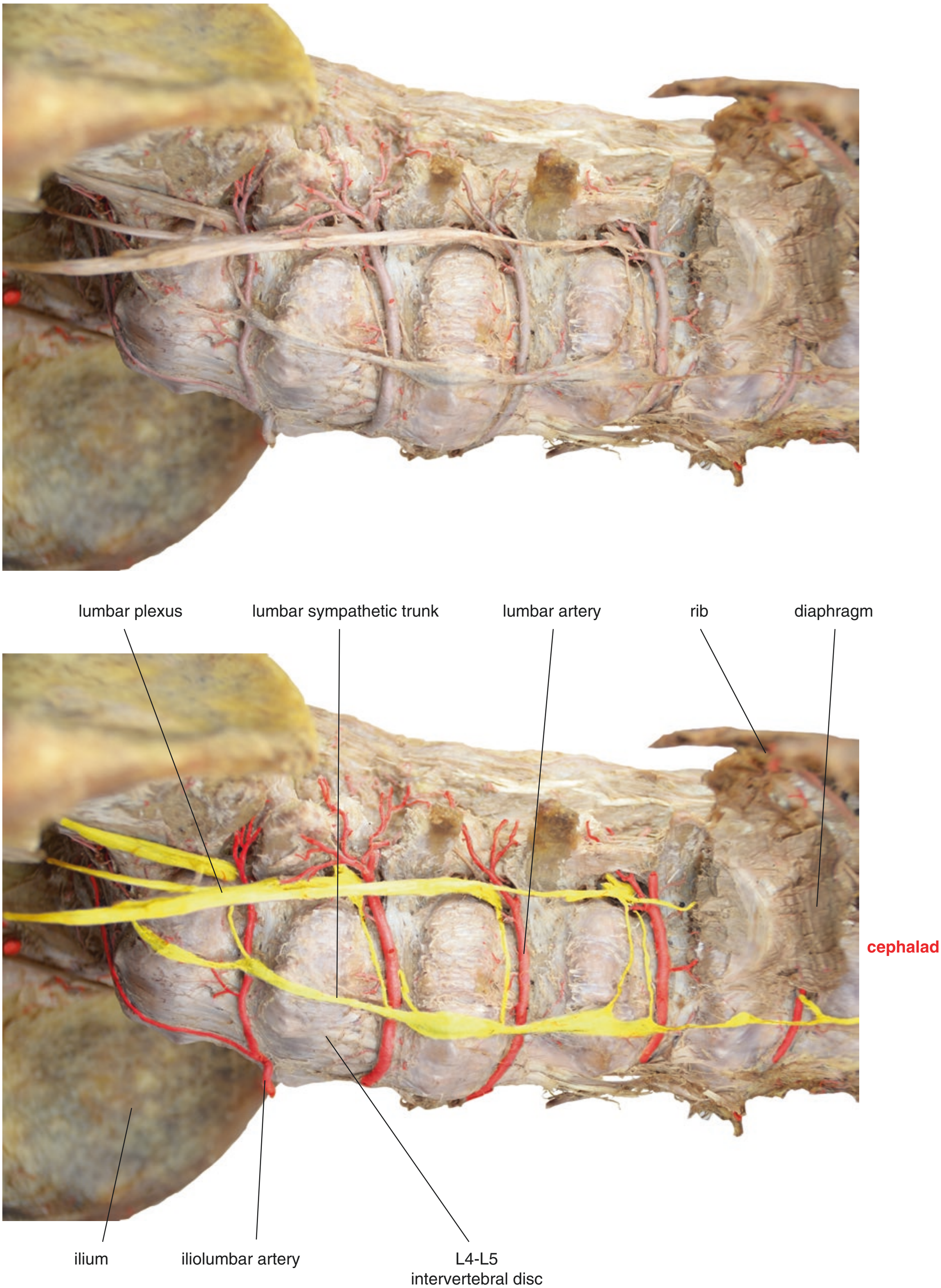


Fig. 4.98 Relationship among the vessel, nerve, and foramen intervertebrale

Trial spacers are used to determine the size and length of the implant (Fig. 4.99).

Place the intervertebral fusion cage filled with an autogenous bone or artificial bones into the intervertebral space (Fig. 4.100).

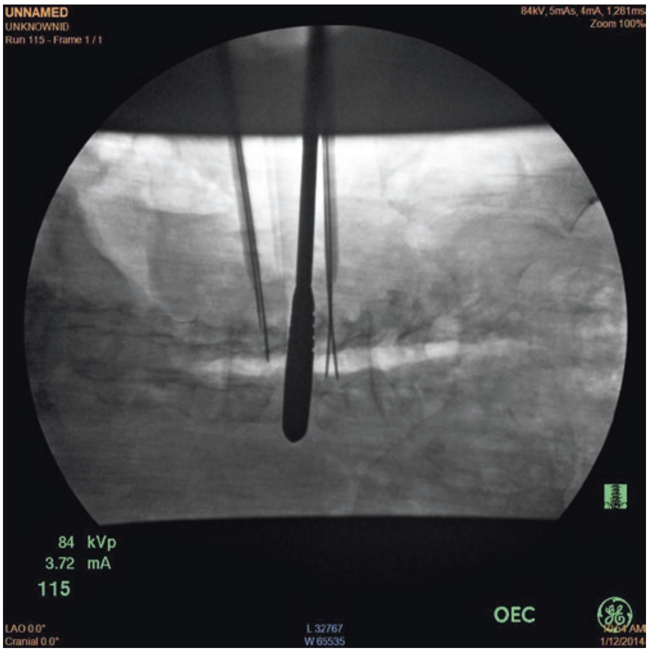


Fig. 4.99 Anteroposterior fluoroscopy shows a trial spacer to the contralateral side

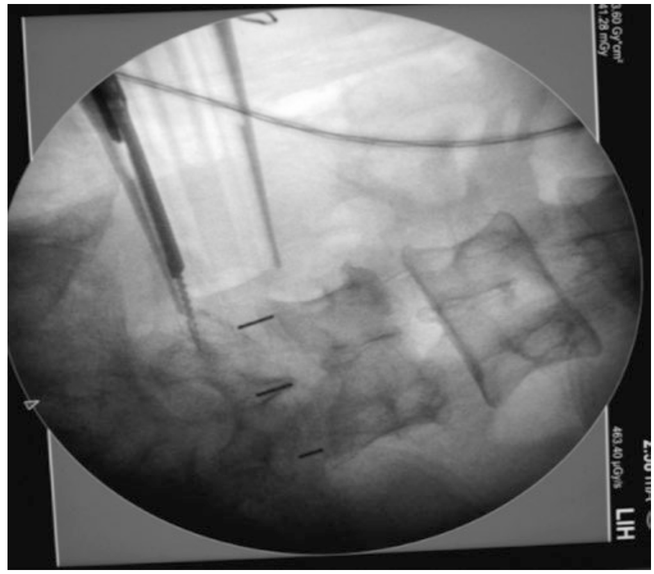


Fig. 4.100 Intraoperative fluoroscopy confirms that the intervertebral fusion cage is well located

5 Anterior Transperitoneal Approach to the Lumbar Spine

5.1 Overview

The anterior approach to the lumbosacral junction is used for the exposure of L4–S1 vertebral bodies and anterior intervertebral discs. It is indicated for surgery in this region, such as resection of infectious lesions (including tuberculosis) on the anterior of lumbar spine, excision of tumors of vertebral bodies, severe lumbar spondylolisthesis that indicates fusion via the anterior approach, and artificial intervertebral disc replacement. Intestinal paralysis can occur after surgery, so a stomach tube is placed before surgery to facilitate postoperative parenteral nutrition. Another complication of this approach is venous thrombus especially when exposure of L4–L5 intervertebral spaces is needed. Though the incision can be extended caudally to the ensisternum and intervertebral spaces above L4 can be exposed in this approach, it's easier to reach spaces above L4 via retroperitoneum approach. Thus, this approach isn't recommended for exposure above L4.

5.2 Position

Patients are placed in the supine position after general anesthesia (Fig. 4.101).

A towel is placed under the iliac crests to hyperextend the lumbar spine.

Generally, the L5/S1 disc is at the same level as the midpoint between the symphysis pubis and the umbilicus.

The L4/L5 disc space is located at the same level as the lower border of the umbilicus.

A transverse or midline vertical incision can be made for anterior transperitoneal approach to the lumbar spine.

The transverse incision is more cosmetic; however, it is mostly used for one level exposure.

The linea alba is incised in the midline to avoid opening the rectus sheath.

The rectus abdominis muscle (Figs. 4.102 and 4.103) is located on both sides of the linea alba with the sheath of the rectus abdominis muscle wrapping its superior and deep surfaces, and its bottom originates from the pubic symphysis to the crista pubica and ends at the 5th–7th costal cartilage. The rectus abdominis muscle is innervated by the inferior intercostal nerves and the subcostal nerve. The blood supply is from the superior epigastric artery and inferior epigastric artery.

The figure shows resection of a part of the rectus abdominis muscle and exposure of the inferior abdominal vessels, and dissection close to the linea alba can prevent injury to the vessels and segmental nerve (Fig. 4.104).

Inferior epigastric artery: originates from the external iliac artery posterior to the inguinal ligament. Along its course, it is accompanied by a similarly named vein, the inferior epigastric vein. Inferior epigastric artery curves forward in the subperitoneal tissue, ascends along the medial margin of the abdominal inguinal ring, then pierces the transversalis fascia, passes in front of the linea semicircularis, and ascends between the rectus abdominis and the posterior lamella of its sheath.

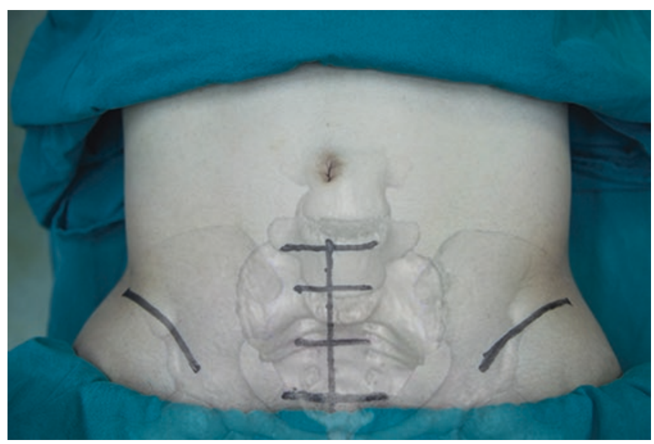


Fig. 4.101 Position and incision for anterior transperitoneal approach to the lumbar spine

Fig. 4.102 Anatomy of the superficial layer of the abdominal wall

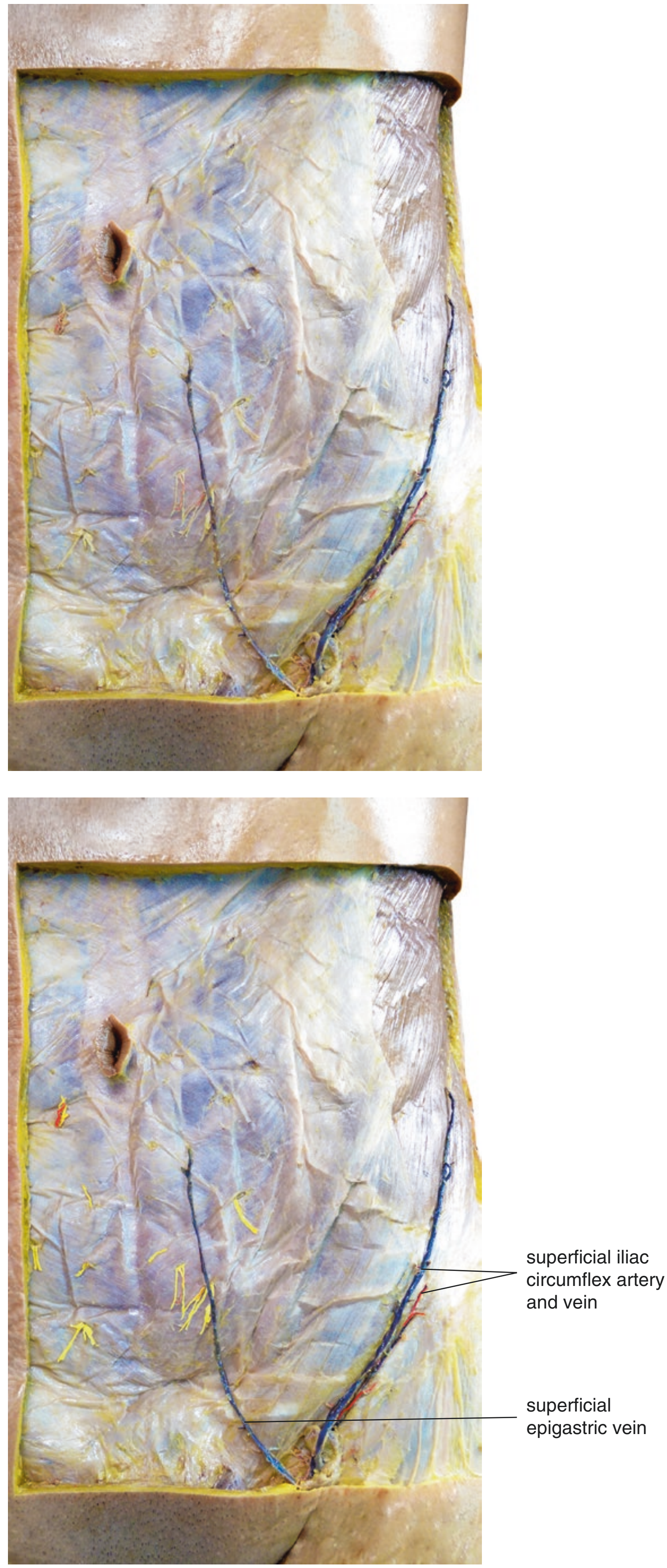


Fig. 4.103 Anatomy of the rectus abdominis muscle

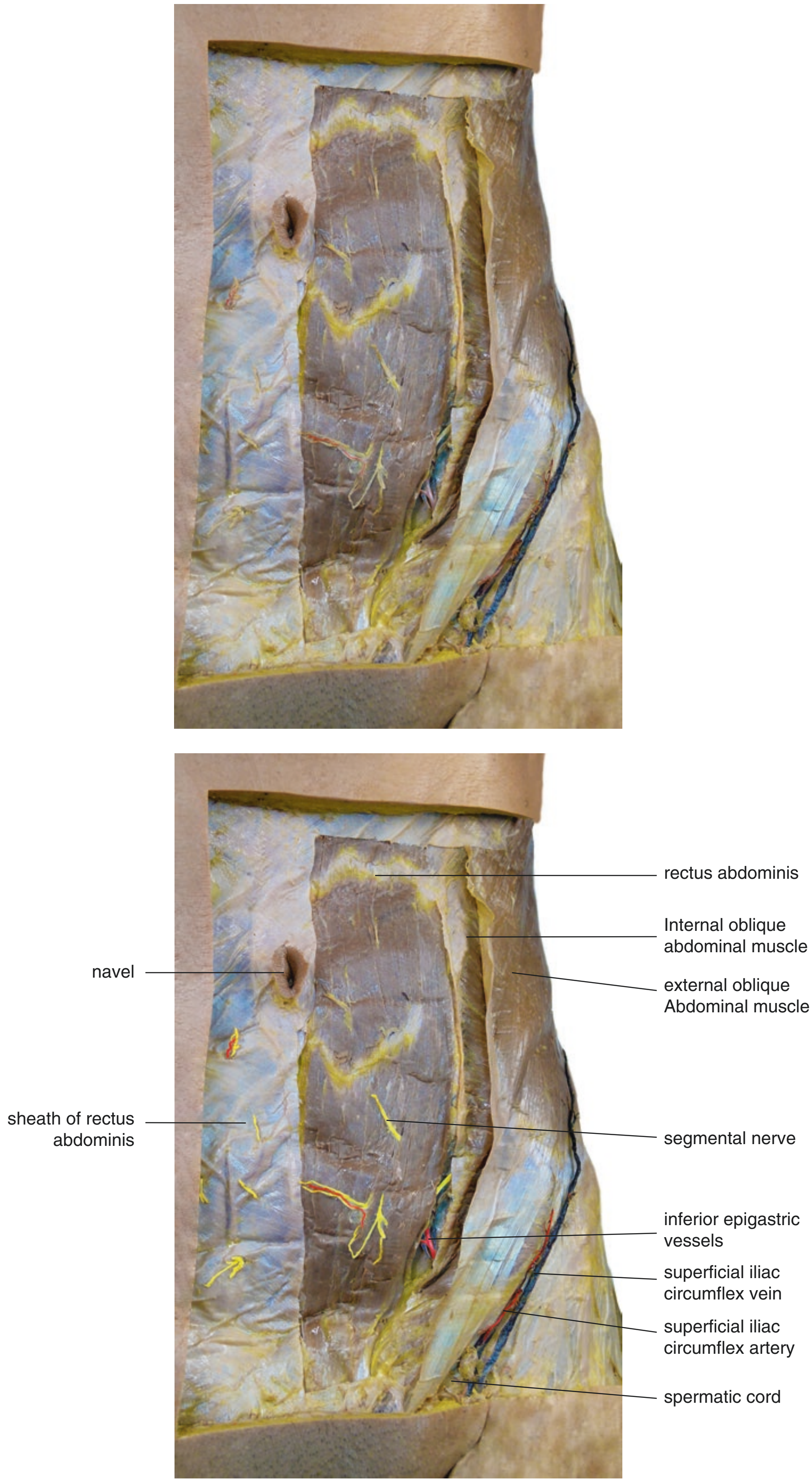


Fig. 4.104 Anatomy of the inferior epigastric artery

5.3 Open Abdominal Cavity

The peritoneum under the linea alba is elevated with a pair of forceps on both sides of the midline.

A scalpel is used to open the peritoneum between the forceps with care to avoid damage to the abdominal contents (Fig. 4.105).

A finger is inserted underneath the peritoneum to separate the peritoneum from the visceral organs. A scissors is then used to extend the incision cranially and caudally.

The small bowel is gently retracted to the right and the sigmoid colon to the left.

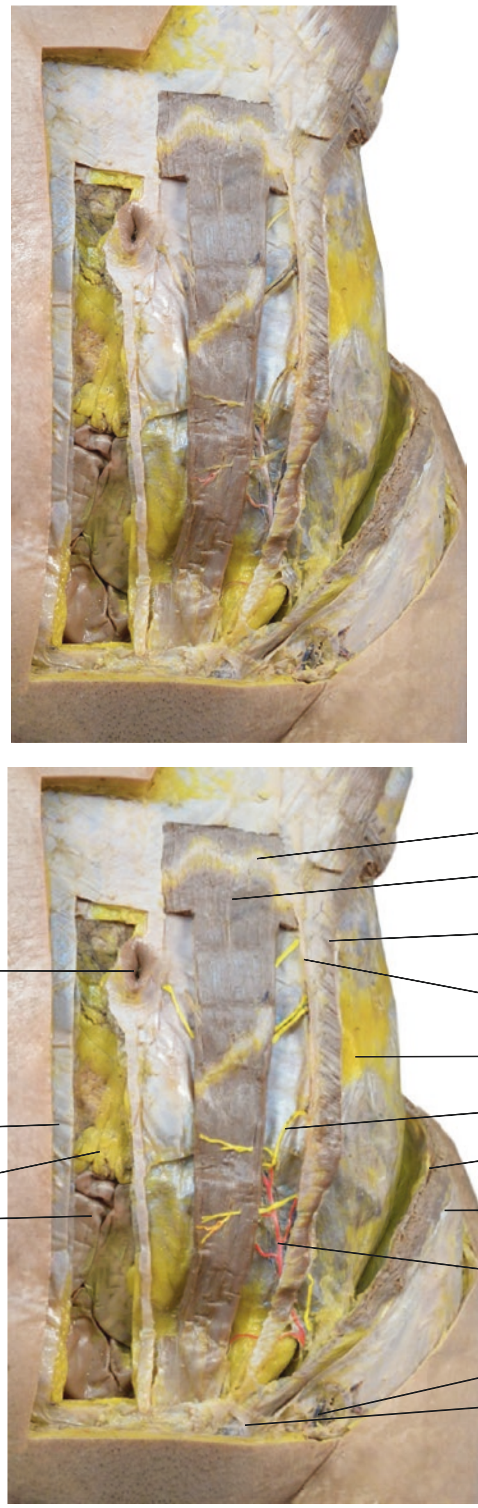


Fig. 4.105 Structures around the sheath of the rectus abdominis muscle

Retroperitoneal space (Fig. 4.106): is the anatomical space in the abdominal cavity behind the peritoneum. Except for the excessively thin individuals, the retroperitoneal space is usually filled with adipose tissue.

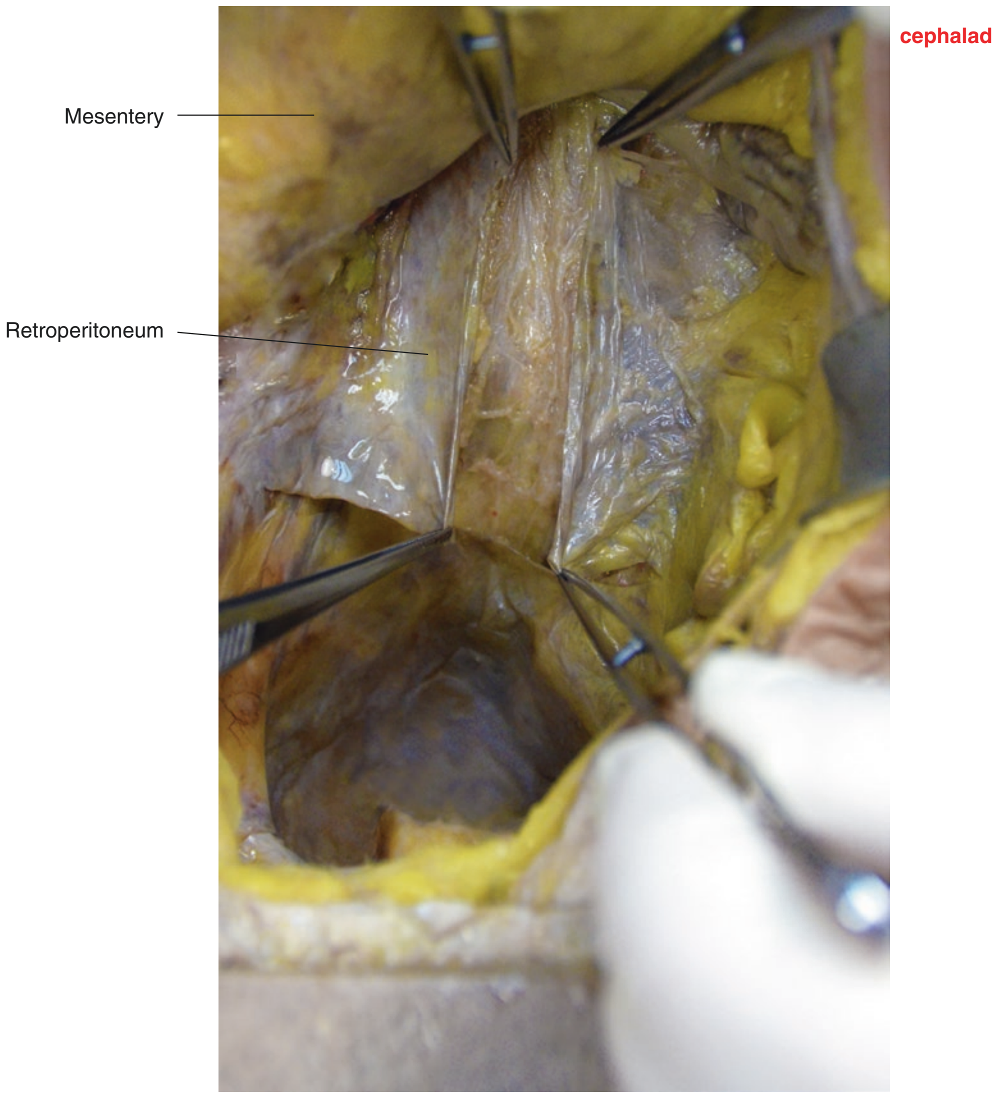


Fig. 4.106 The posterior peritoneum (incised)

5.4 Exposure of Vertebral Bodies

The sacral promontory, aorta, and iliac vessels are palpated.

Infiltrate presacral soft tissue with a little normal saline to identify and separate contents within the retroperitoneal space.

The retroperitoneum is elevated and the incision extended cranially and caudally with care taken to avoid the underlying great vessels and autonomic nerves (Fig. 4.107).

Presacral fascia: the presacral fascia is located between the lumbosacral vertebrae and the posterior peritoneum, with the superior hypogastric plexus running in front of it and the sacral vessel and lumbosacral sympathetic nerve running posterior to it (Fig. 4.108).

Superior hypogastric plexus: it is formed by the abdominal aorta plexus with the lumbar splanchnic nerves branched from L3 to L4 ganglions. It is flat and strip shaped, running along the abdominal aorta branches in the left midline down to the anterior of L5 vertebra, extending down to the nerve plexus, and then dividing into left and the right hypogastric plexus further connecting with the inferior hypogastric plexus.

Make an incision on one side of the superior hypogastric plexus; carefully retract the superior hypogastric plexus along with the presacral fascia to the opposite side. Injection of normal saline in presacral soft tissue can facilitate the identification and protection of the superior hypogastric plexus.

Incise the presacral fascia to one side to expose the L5–S1 intervertebral space, and bluntly peel the remaining tissue from the midline of the other side of the intervertebral space (Figs. 4.109 and 4.110).

During operation in the L4–L5 intervertebral space, more extensive exposure is needed, and the great vessel usually needs to be separated and moved.

The ureter is located in the lateral side of the operative field, which should not be retracted excessively to prevent postoperative ischemic stenosis.

Median sacral artery runs down along the anterior sacrum, and it should be ligatured during surgery.

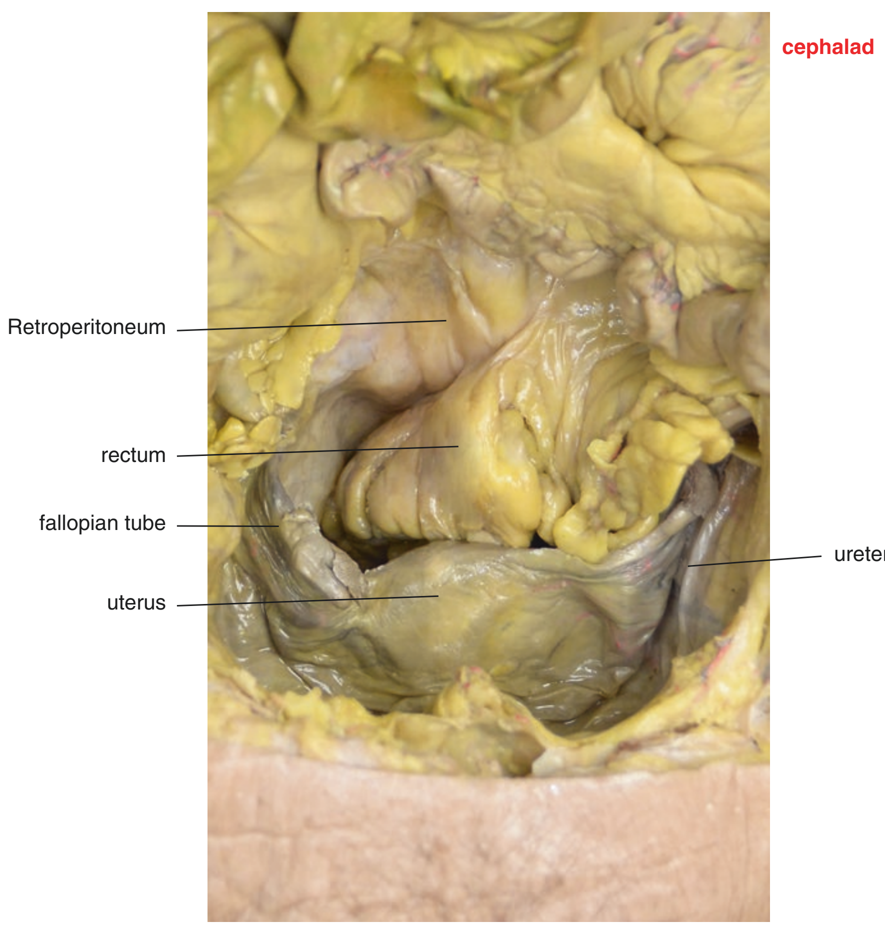


Fig. 4.107 Contents in the pelvic cavity (female)

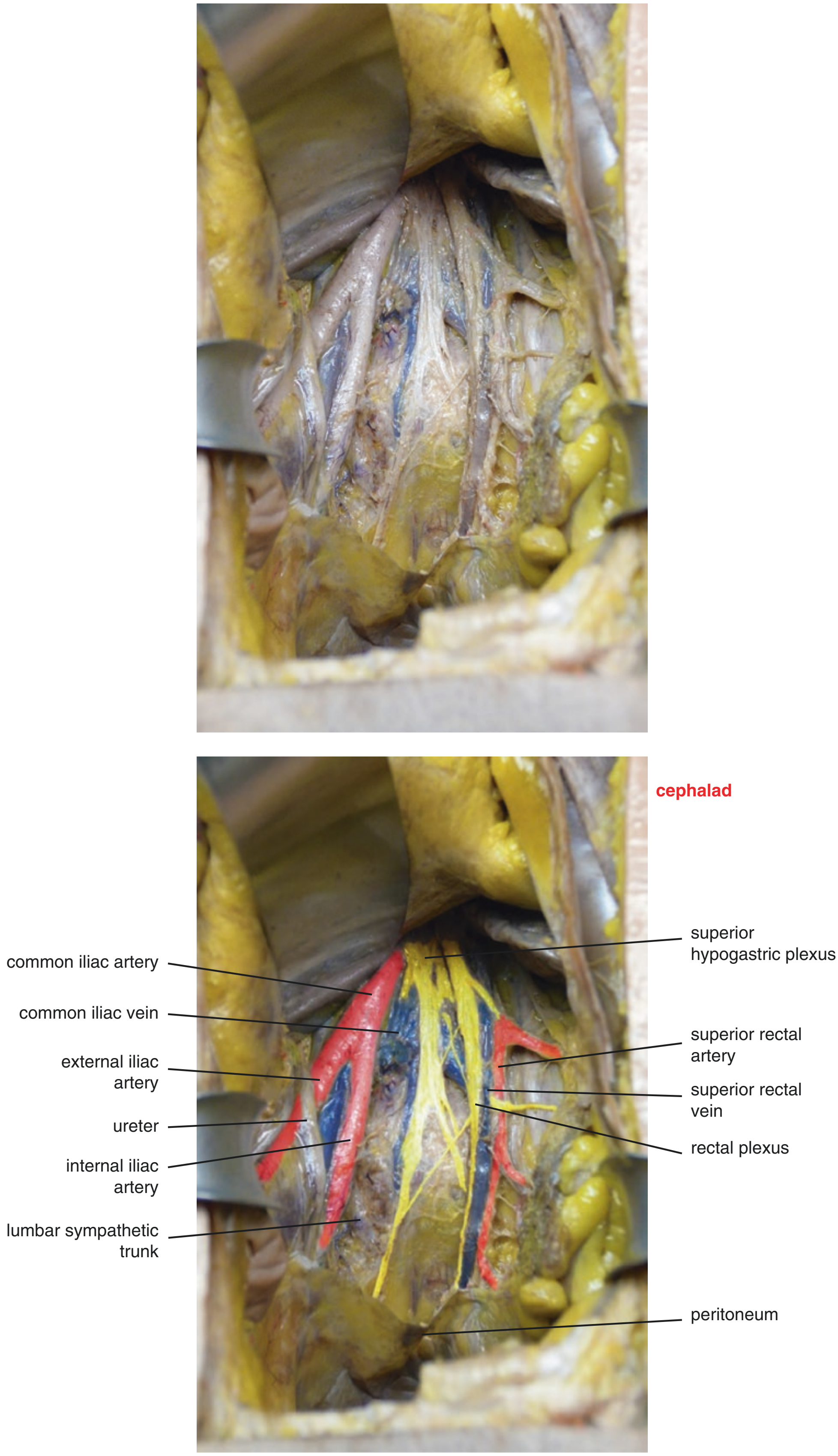


Fig. 4.108 Retroperitoneal nerves and vessels

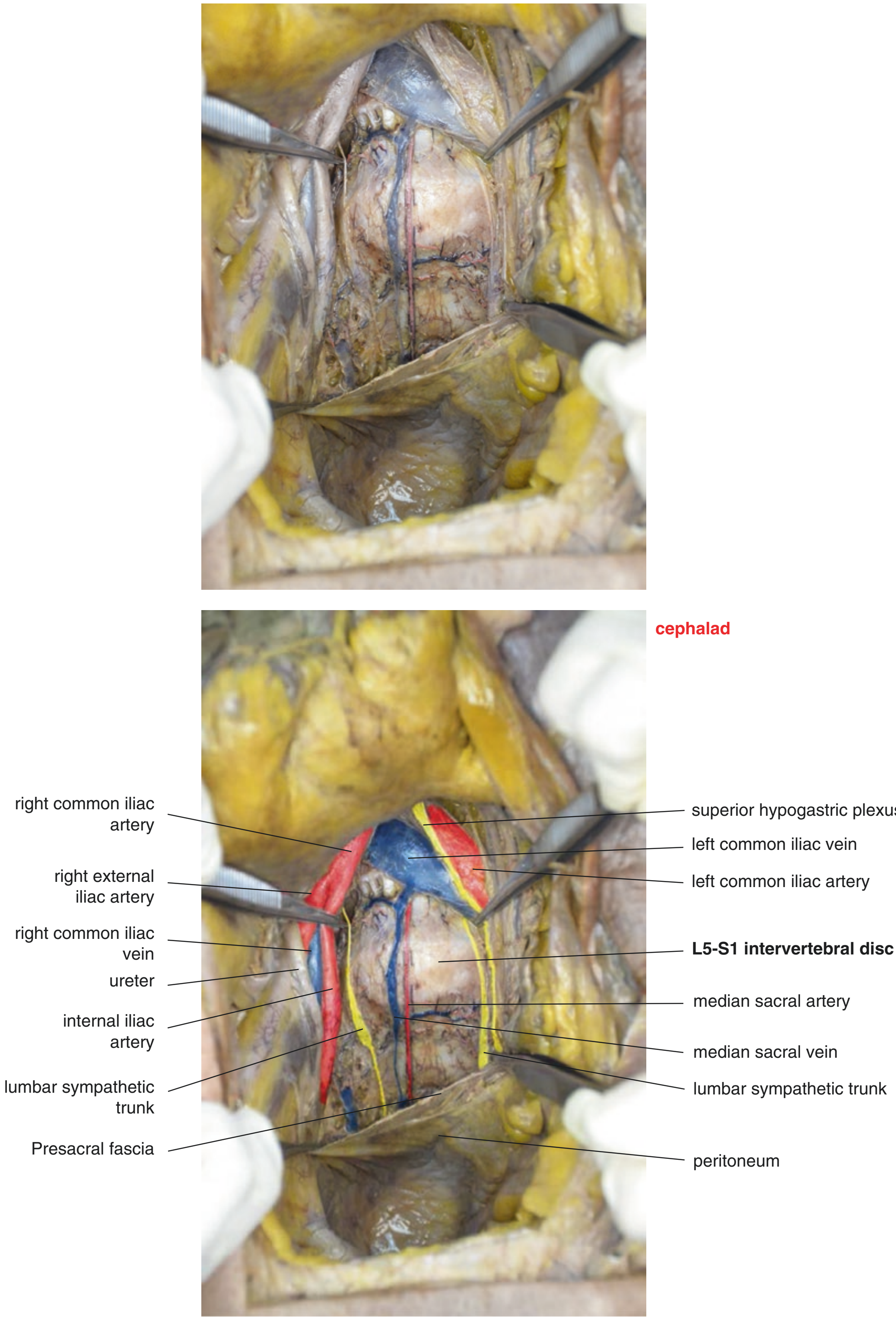
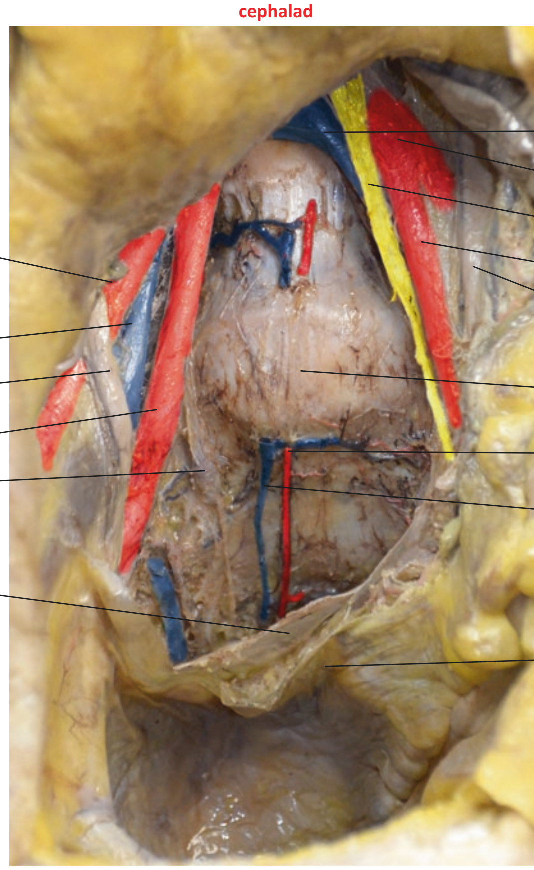


Fig. 4.109 Exposure of the intervertebral space at L5–S1

Fig. 4.110 Anatomy of the anterior sacrum



6 Paramedian Retroperitoneal Approach and Anterior Lumbar Interbody Fusion

6.1 Overview

The paramedian retroperitoneal approach can expose the distal lumbar and anterior sacral spine (L3–S1). The main indications of anterior lumbar interbody fusion (ALIF) include lumbar intervertebral disc protrusion (including recurrent lumbar disc herniation), lumbar instability, lumbar degeneration and lumbar isthmic spondylolisthesis, tumors (primary or metastatic) on the distal lumbar or sacral spine, lumbar or sacral inflammation (tuberculous or purulent), and lumbar spinal trauma. Preoperative CT or MRI examination is necessary to determine the anatomy among the abdominal aorta, vena cava, and iliac vessels in the segments requiring surgery.

6.2 Position

Patients are placed in the supine position after general anesthesia (Fig. 4.111).

The C-arm fluoroscopy is performed to determine the level for surgery.

A transverse skin incision can be made from the midline to the lateral border of the rectus abdominis for exposure of one or two levels.

A slightly curved longitudinal incision centered over the lateral border of the rectus abdominis is used for the exposure of one to two or more levels.

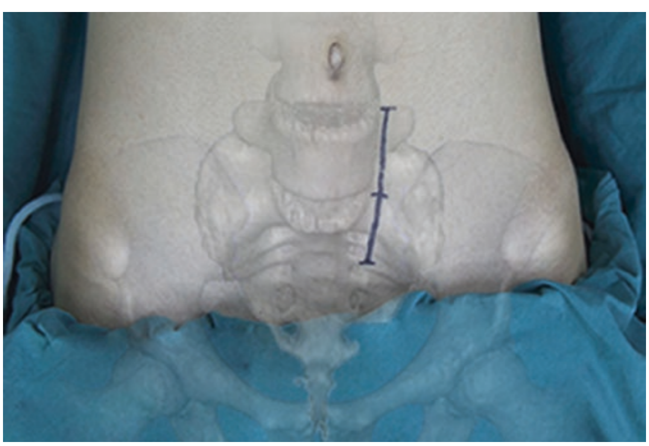


Fig. 4.111 Position and incision for exposure of the lumbar spine via the paramedian retroperitoneal approach

6.3 Exposure

The lateral border of the rectus abdominis is palpated, and the anterior rectus fascia is incised along this border (Figs. 4.112 and 4.113).

The rectus muscles are then retracted medially to expose the posterior rectus fascia and transversalis fascia.

The inferior epigastric vessel encountered can be ligated or protected by a moistened drape and then retracted laterally.

The transversalis fascia is incised to expose the preperitoneal fat and peritoneum (Fig. 4.114).

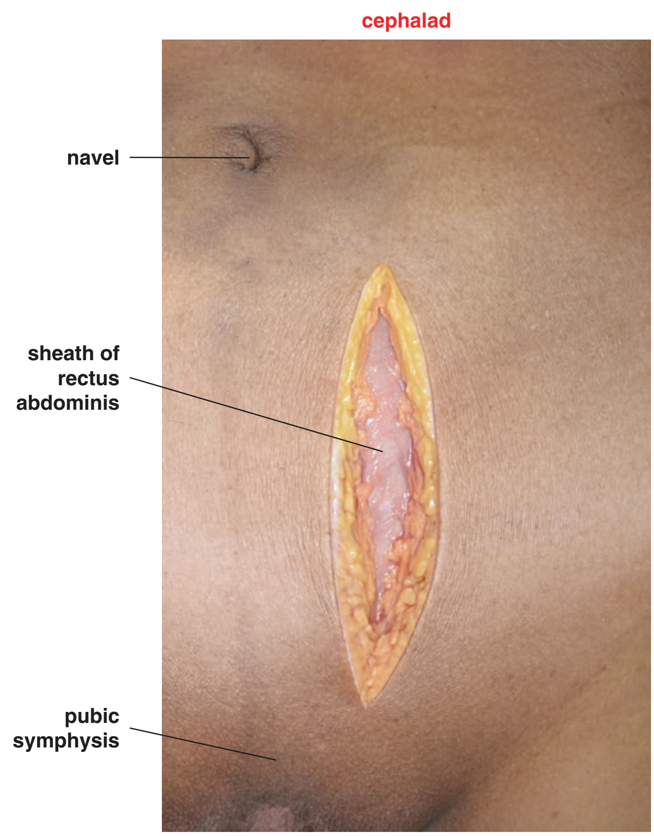


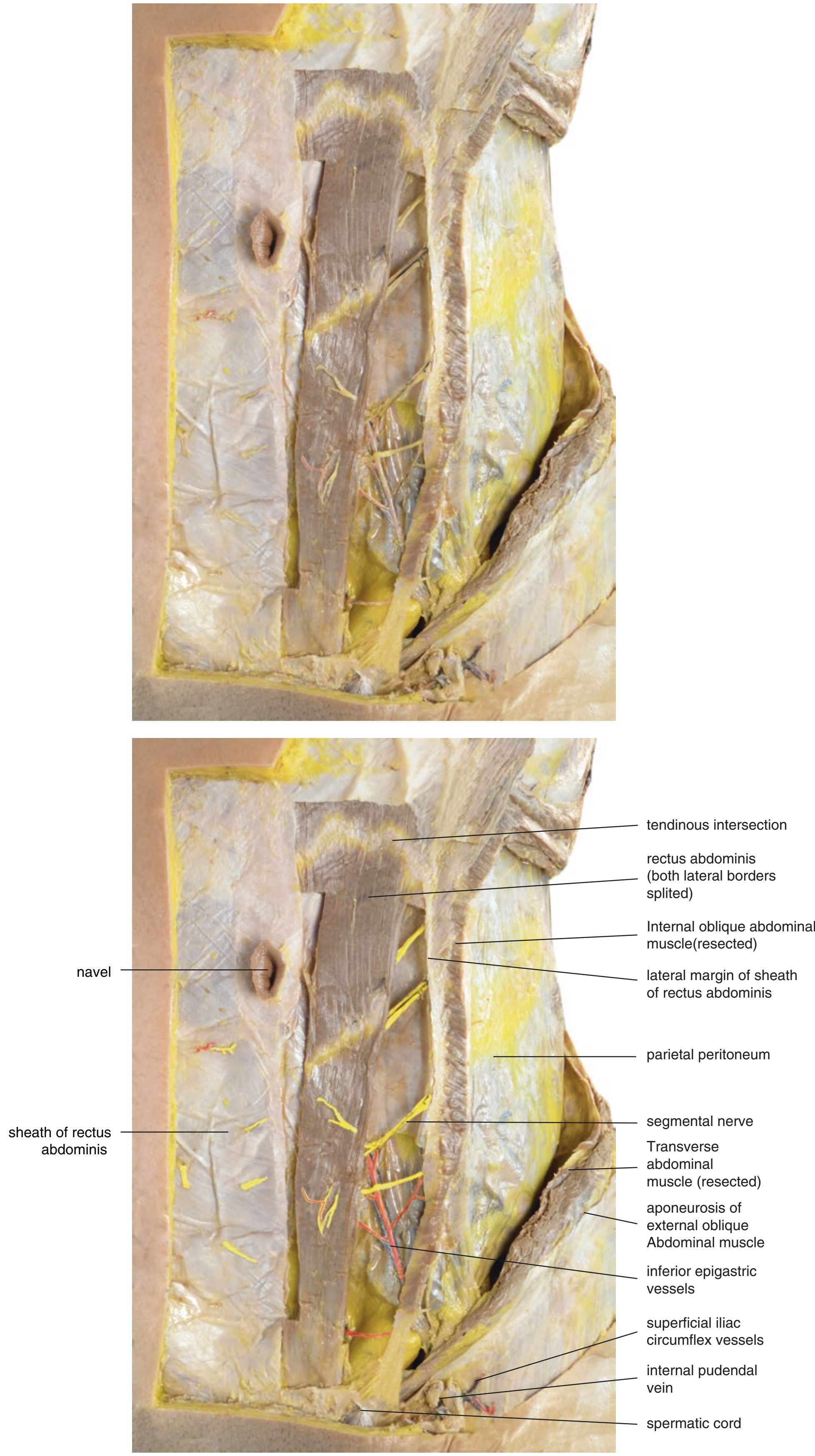
Fig. 4.112 Exposure of the anterior rectus fascia

Fig. 4.113 Exposure of the rectus abdominis muscle

Fig. 4.114 Exposure of the preperitoneal fat

The anterior sheath of the rectus abdominis muscle, the rectus abdominis muscle, the posterior sheath of the rectus abdominis muscle, and the peritoneum (Fig. 4.115). The incision should not be lower than the inferior epigastric vessel. Moreover, protect the innervation and blood supply of the rectus abdominis muscle. The spermatic cord and the testicular vein are located at the distal end of the incision. The proximal end of the arcuate line is the posterior sheath of rectus abdominis, while the distal end is the transverse fascia.

Fig. 4.115 Anatomy of the abdominal wall



Bluntly separate the retroperitoneal space until it reaches the anterior vertebrae, and retract the peritoneum and the abdominal viscera to the medial side.

The segmental vessels should be ligated and cut close to the vena cava and aorta.

If the L4/L5 disc space is to be exposed, all the branches of the left common iliac vein must be ligated and cut to enable the movement of the common iliac vein. If the exposure is to L5/S1, there is no need to mobilize the iliac vessels; however, ligation and transection of the middle sacral artery and vein are needed (Fig. 4.116).

During surgery, don't use an electrotome under the aortic bifurcation to prevent the superior hypogastric plexus from being injured.

The superior hypogastric plexus is bluntly dissected to either side of the vertebral body.

Common iliac arteries: they originate from the abdominal aorta at the level of the L4 vertebral body or L4–L5 intervertebral disc and end in front of the sacroiliac joint, and each bifurcates into the external and internal iliac arteries. The angle between the common iliac arteries is about 60° in male, while the angle in female is about 40°. They run in the deep surface of the parietal peritoneum, and there are ureters and the genital gland vessels run in front of them (Figs. 4.117 and 4.118).

The lumbar sympathetic trunk (Fig. 4.119) is composed of three or four ganglions and interganglionic branches. It is located between the vertebral column and the psoas major muscle and covered by the prevertebral fascia. Its superior portion is connected with the thoracic sympathetic trunk, and its inferior portion is connected to the sacral sympathetic trunk. The left lumbar sympathetic trunk is adjacent to the left margin of the abdominal aorta, and the distance between them is about 0.5–2 cm (mostly about 1 cm). The anterior area of the right lumbar sympathetic trunk is covered by the inferior vena cava and sometimes passed through by one or two lumbar veins. The inferior sympathetic trunk is located behind the right common iliac vein. The left and right sympathetic trunks travel together with the genitofemoral nerve on the lateral lumbar sides.

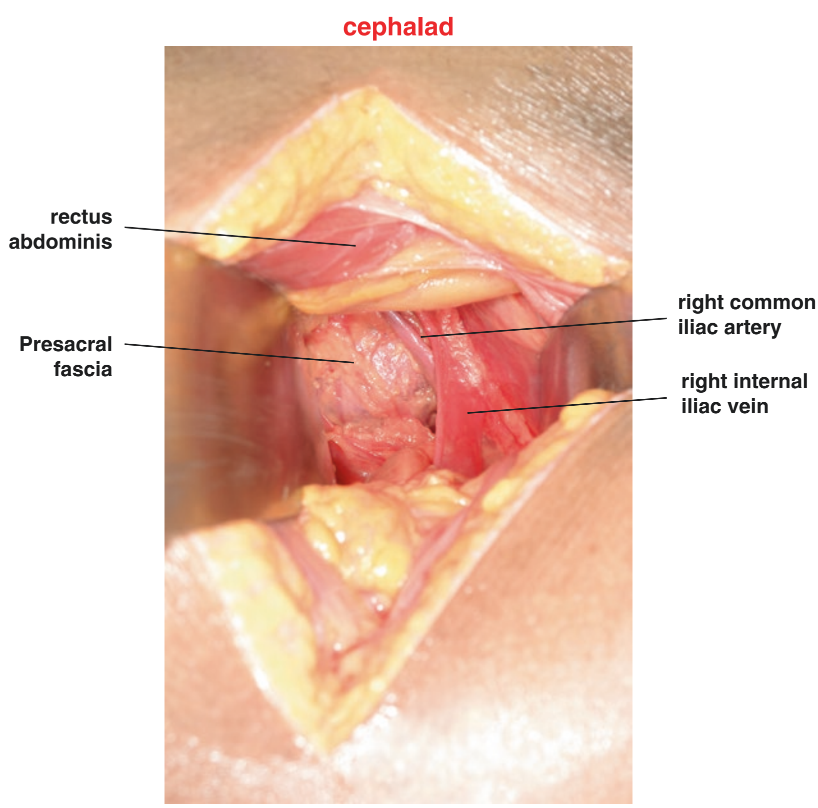
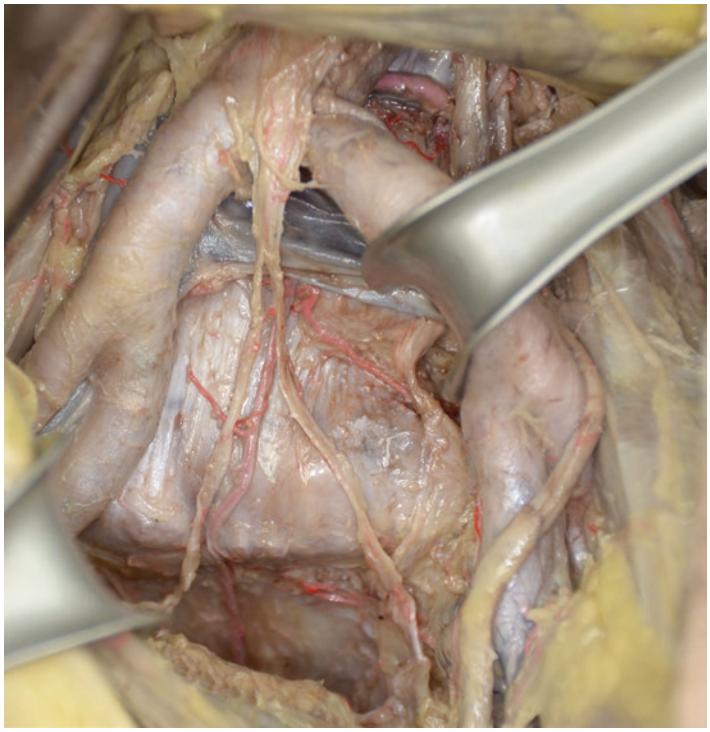


Fig. 4.116 Exposure of the anatomic structure of the anterior vertebral body



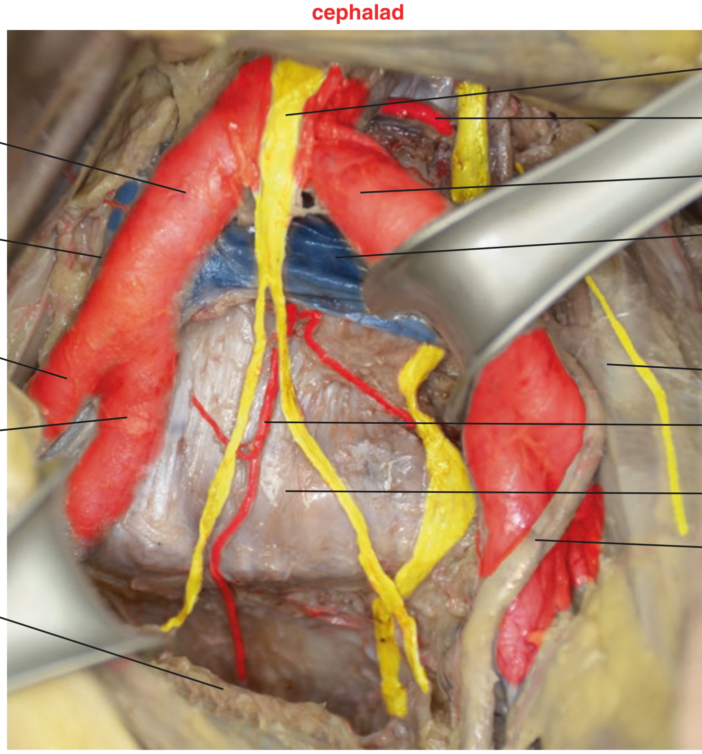


Fig. 4.117 Retroperitoneal space of the lumbosacral level

Fig. 4.118 Neurovascular structures within the pelvic cavity

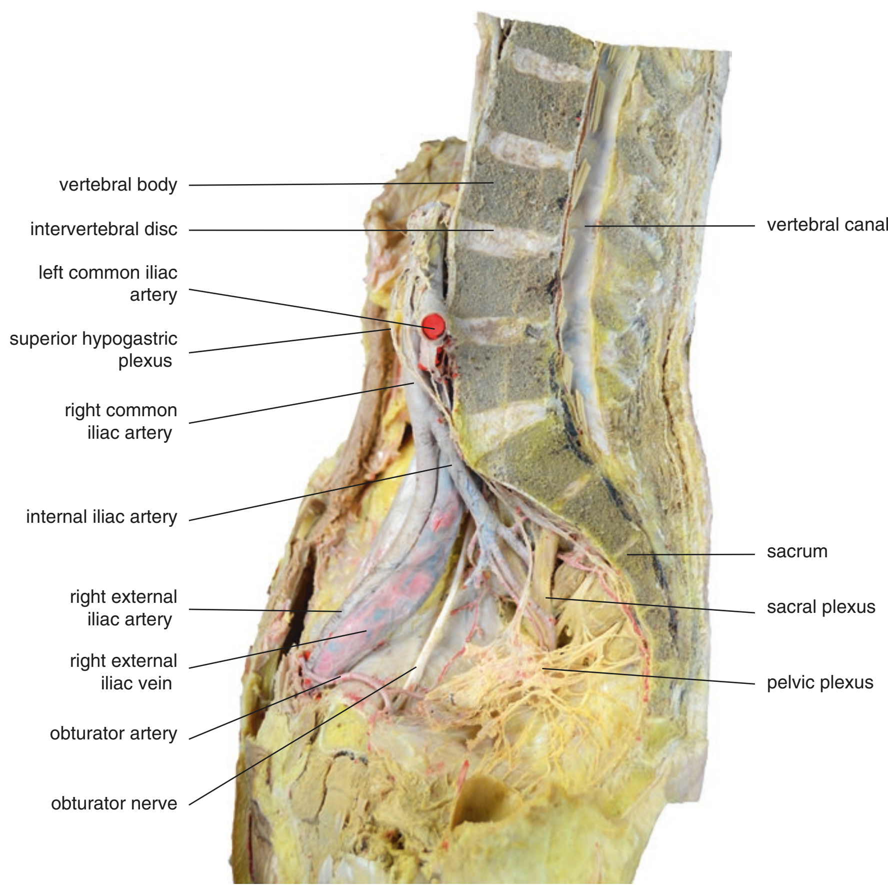
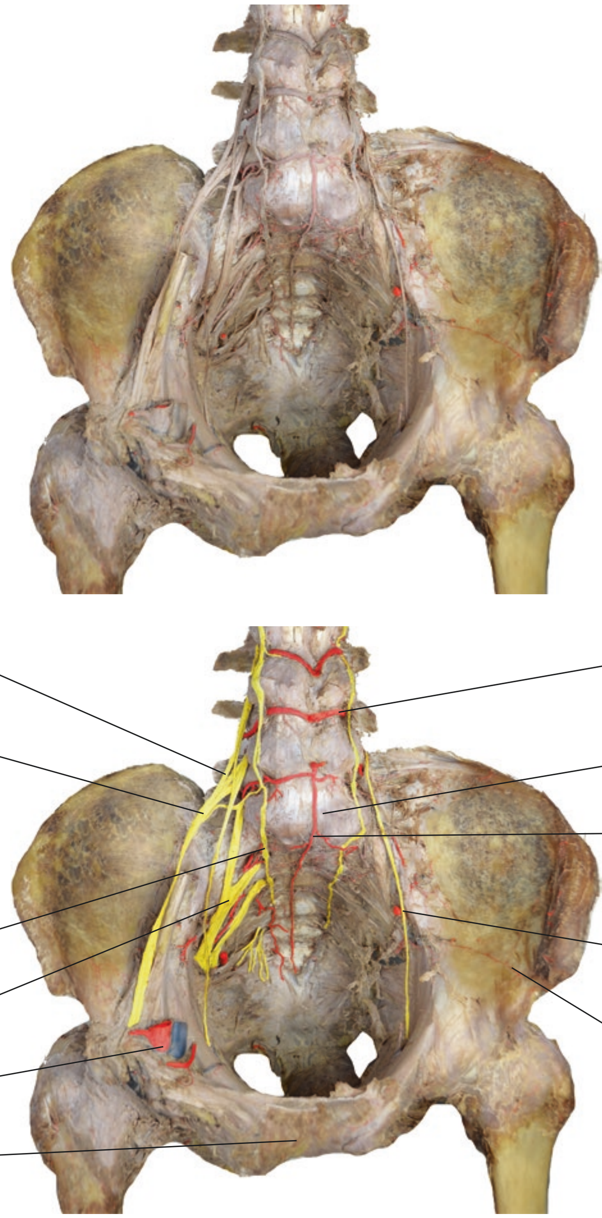


Fig. 4.119 Anatomy of the anterior vertebral body



6.4 Discectomy

A long handle blade is used to incise the anterior annulus fibrosus. Rongeurs and curettes are used to remove the disc contents (Fig. 4.120).

Use a shaver to prepare the end plate to gain a mild bleeding end plate for bone graft and fusion.

The intervertebral fusion cage with a proper size and graft bones is placed into the intervertebral disc.

The anteroposterior fluoroscopy and lateral fluoroscopy show the anterior intervertebral fusion cage is located well (Figs. 4.121 and 4.122).

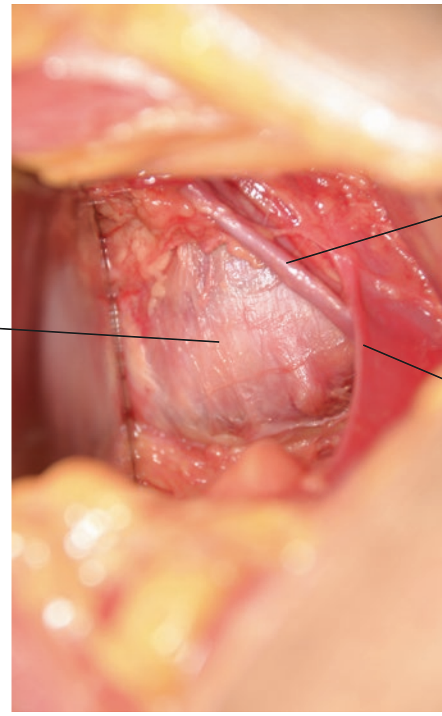


Fig. 4.120 Exposure of the L5–S1 intervertebral disc

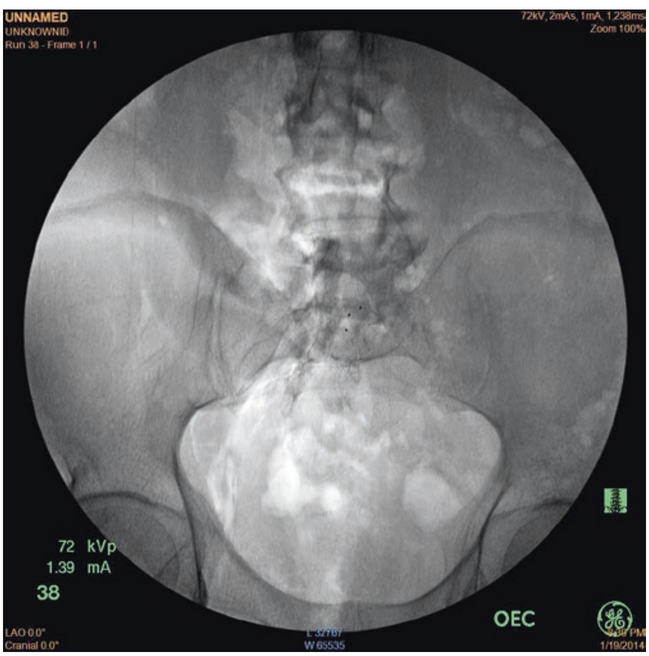


Fig. 4.121 Placement of an intervertebral fusion cage (anteroposterior fluoroscopy)

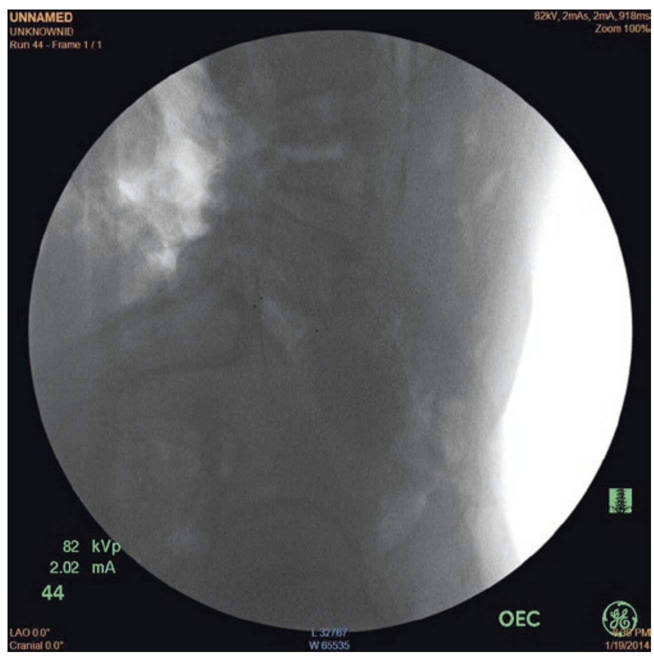


Fig. 4.122 Placement of an intervertebral fusion cage (lateral fluoroscopy)

7 Placement of Lumbar Pedicle Screws

7.1 Overview

After years of clinical use, lumbar pedicle screws have proved to be a safe and effective technique for intervertebral stabilization. Indications of lumbar pedicle screw placement include excision of lumbar nucleus pulposus, laminectomy for decompression, lumbar fusion, tumor resection, lumbar spine spondylolisthesis, fractures, and restoration and internal fixation after dislocation. The entry point, entry angle, and entry depth should be determined based on the individual anatomical characteristics after fully referring to various existing methods.

7.2 Entry Point and Trajectory

The entry points are at the junction of the lateral margin of the superior facet and the horizontal line of the center of the transverse processes (Fig. 4.123).

For L1–3 and L4–5, the angles between the drilling pathbreaker and the sagittal plane are 5–10° and 10–15°, respectively, and the sagittal trajectory should be parallel with the end plates of vertebral bodies.

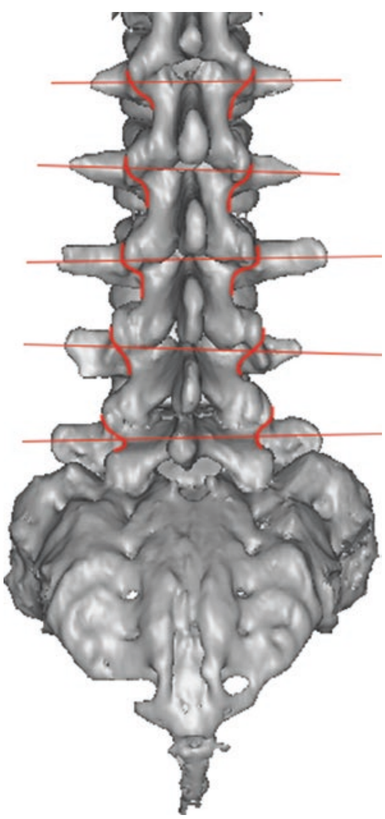


Fig. 4.123 Roy-Camille technique

7.3 Screw Placement

The cortical bone over the entry points is removed by a high-speed burr or rongeur.

Place a hand drill into entry points and slowly drill into the pedicles at an appropriate angle.

Strictly maintain the trajectory for screw placement. Small transverse plane trajectories may cause penetration through the lateral cortical bone of the pedicle and injury of adjacent organs. Too much transverse plane trajectories can result in violation into the spinal canal and injure the spinal nerve roots or cauda equina.

Markers are placed into the screw path to facilitate further intraoperative fluoroscopy to determine whether the screw path needs to be adjusted (Figs. Fig. 4.124, 4.125, and Fig. 4.126).

A pedicle sounder is used to detect the walls of screw path and depths.

In general, the entry depths are 40–50 mm (40–45 mm at L1 and 45–50 mm at L5).

Perform a lateral fluoroscopy to ensure that the entry depths do not exceed 80% of the anteroposterior length of the vertebral bodies.

Pedicle screws are placed after tapping and sounding of the screw path (Fig. 4.127).

Pedicle screws should be parallel to end plates or slightly incline upward to be placed in high-density end plates (Figs. 4.128 and 4.129).

Fig. 4.124 Steel balls are placed into the entry points in each segments to show the entry point on the fluoroscopy

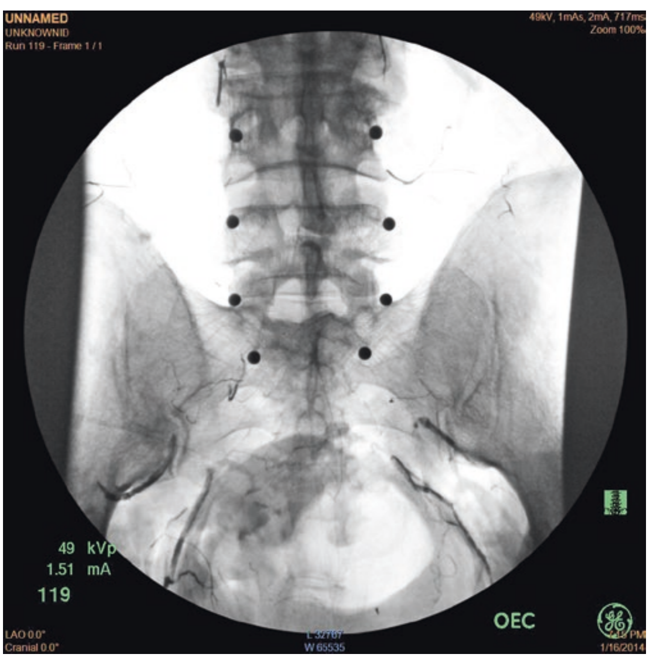


Fig. 4.125 Fluoroscopy shows the relationship between the entry points marked by steel balls and pedicles

Fig. 4.126 Markers are placed into the screw paths

Fig. 4.127 Pedicle screws are placed into the target segments

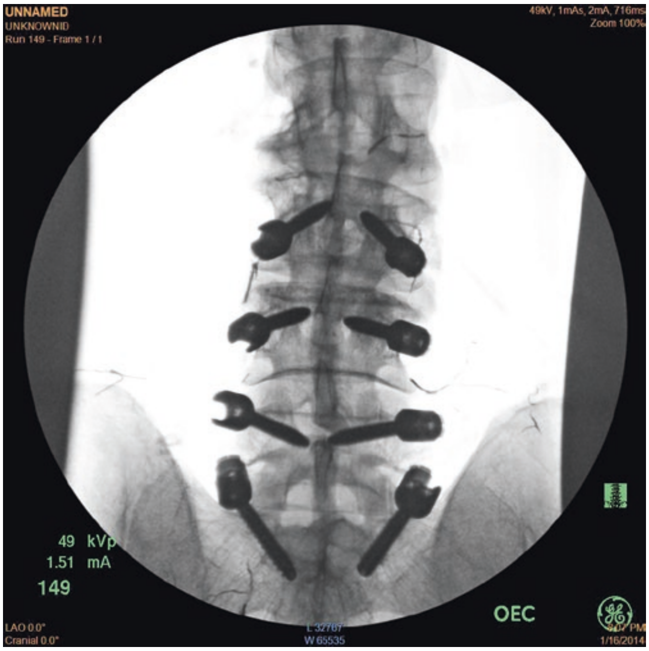


Fig. 4.128 Perform a fluoroscopy after screws are placed into vertebral bodies (anteroposterior view), and it shows pedicle screws are located well

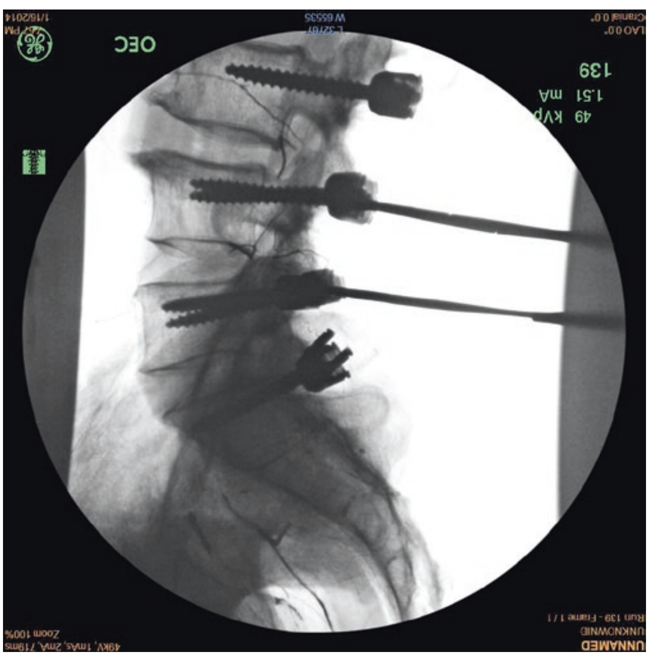


Fig. 4.129 Perform a fluoroscopy after inserting screws into vertebral bodies (lateral view)

References

1. Shepard M, Safain M, Burke SM, et al. Lateral retroperitoneal transpsoas approach to the lumbar spine for the treatment of spondylodiscitis. Minim Invasive Ther Allied Technol. 2014;23(5):ii.
2. Ghobrial GM, Alsaiegh F, Franco D, et al. Lateral lumbar retroperitoneal transpsoas approach in the setting of spondylodiscitis: a technical note. J Clin Neurosci. 2017;39:193–8.
3. Marsicano J, Mirovsky Y, Remer S, et al. Thrombotic occlusion of the left common iliac artery after an anterior retroperitoneal approach to the lumbar spine. Spine. 1994;19(3):357–9.
4. Rajaraman V, Vingan R, Roth P, et al. Visceral and vascular complications resulting from anterior lumbar interbody fusion. J Neurosurg. 1999;91(1 Suppl):60.
5. Mobbs RJ, Phan K, Daly D, et al. Approach-related complications of anterior lumbar Interbody fusion: results of a combined spine and vascular surgical team. Global Spine J. 2016;6(2):147–54.
6. Kettler A, Schmoelz W, Kast E, et al. In vitro stabilizing effect of a transforaminal compared with two posterior lumbar interbody fusion cages. Spine. 2005;30(22):665–70.
7. Rosenberg WS, Mummaneni PV. Transforaminal lumbar interbody fusion: technique, complications, and early results. Neurosurgery. 2001;48(3):569.
8. Harris BM, Hilibrand AS, Savas PE, et al. Transforaminal lumbar interbody fusion: the effect of various instrumentation techniques on the flexibility of the lumbar spine. Spine. 2004;29(4):E65.
9. Osman SG, Nibu K, Panjabi MM, et al. Transforaminal and posterior decompressions of the lumbar spine. A comparative study of stability and intervertebral foramen area. Spine. 1997;22(15):1690.
10. Golub BS, Silverman B. Transforaminal ligaments of the lumbar spine. J Bone Joint Surg (Am Vol). 1969;51(5):947.
11. Park HK, Rudrappa S, Dujovny M, et al. Intervertebral foraminal ligaments of the lumbar spine: anatomy and biomechanics. Childs Nerv Syst. 2001;17(4):275–82.
12. Hasegawa T, An HS, Haughton VM, et al. Lumbar foraminal stenosis: critical heights of the intervertebral discs and foramina. A cryomicrotome study in cadavera. J Bone Joint Surg Am. 1995;77(1):32–8.
13. Inufusa A, An HS, Lim TH, et al. Anatomic changes of the spinal canal and intervertebral foramen associated with flexion-extension movement. Spine. 1996;21(21):2412–20.
14. Bridwell KH, Lewis SJ, Rinella A, et al. Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance. Surgical technique. J Bone Joint Surg Am. 2004;86-A(Suppl 1):3–44.
15. Cho KJ, Bridwell KH, Lenke LG, et al. Comparison of Smith-Petersen versus pedicle subtraction osteotomy for the correction of fixed sagittal imbalance. Spine. 2005;30(18):2030.
16. Bridwell KH, Lewis SJ, Edwards C, et al. Complications and outcomes of pedicle subtraction osteotomies for fixed sagittal imbalance. Spine. 2003;28(18):2093–101.
17. Hyun SJ, Rhim SC. Clinical outcomes and complications after pedicle subtraction osteotomy for fixed sagittal imbalance patients: a long-term follow-up data. J Korean Neurosurg Soc. 2010;47(2):95–101.
18. Debarge R, Demey G, Roussouly P. Sagittal balance analysis after pedicle subtraction osteotomy in ankylosing spondylitis. Eur Spine J. 2011;20(5):619–25.

19. Kepler CK, Bogner EA, Herzog RJ, et al. Anatomy of the psoas muscle and lumbar plexus with respect to the surgical approach for lateral transpsoas interbody fusion. Eur Spine J. 2011;20(4):550.
20. Davis TT, Bae HW, Mok JM, et al. Lumbar plexus anatomy within the psoas muscle: implications for the transpsoas lateral approach to the L4-L5 disc. Jbjs. 2011;93(16):1482.
21. Paulino C, Patel A, Carrer A. Anatomical considerations for the extreme lateral (XLIF) approach. Curr Orthop Pract. 2010;21(21):368–74.
22. Sun JC, Wang JR, Luo T, et al. Surgical incision and approach in thoracolumbar extreme lateral interbody fusion surgery: an anatomic study of the diaphragmatic attachments. Spine. 2016;41(4):E186.
23. Baaj AA, Papadimitriou K, Amin AG, et al. Surgical anatomy of the diaphragm in the anterolateral approach to the spine: a cadaveric study. J Spinal Disord Tech. 2014;27(4):220–3.
24. Sembrano JN, Yson SC, Horazdovsky RD, et al. Radiographic comparison of lateral lumbar interbody fusion versus traditional fusion approaches: analysis of sagittal contour change. Int J Spine Surg. 2015;9:16.
25. Tubbs RS, Salter EG, Rd WJ, et al. Anatomical landmarks for the lumbar plexus on the posterior abdominal wall. J Neurosurg Spine. 2005;2(3):335–8.
26. Sasso RC, Kenneth BJ, Lehuec JC. Retrograde ejaculation after anterior lumbar interbody fusion: transperitoneal versus retroperitoneal exposure. Spine. 2003;28(10):1023.
27. Lieberman IH, Willsher PC, Litwin DE, et al. Transperitoneal laparoscopic exposure for lumbar interbody fusion. Spine. 2000;25(4):509.
28. Wimmer C, Krismer M, Gluch H, et al. Anterior interbody fusion of the lumbar spine. Orthopade. 1997;26(6):563–7.
29. Kim DH. Surgical anatomy & techniques to the spine. Philadelphia: Saunders Elsevier; 2006.
30. Lane JD Jr, Moore ES Jr. Transperitoneal approach to the intervertebral disc in the lumbar area. Ann Surg. 1948;127(3):537–51.
31. Unruh KP, Camp CL, Zietlow SP. Anatomical variations of the iliolumbar vein with application to the anterior retroperitoneal approach to the lumbar spine: a cadaver study. Clin Anat. 2008;21(7):666–73.
32. Lazennec JY, Pouzet B, Ramare S, et al. Anatomic basis of minimal anterior extraperitoneal approach to the lumbar spine. Surg Radiol Anat. 1999;21(1):7–15.
33. Taheri SA, Gawronski S, Smith D. Paramedian retroperitoneal approach to the abdominal aorta. J Cardiovasc Surg. 1983;24(5):529–31.
34. Crofts KM, Wong DA, Murr PC. Anterior paramedian retroperitoneal surgical approach to the lumbar spine. Orthopedics. 1994;17(8):699.
35. Gumbs AA, Shah RV, Yue JJ, et al. The open anterior paramedian retroperitoneal approach for spine procedures. Arch Surg. 2005;140(4):339–43.
36. Shetty AS, Avadhani R, Mahesha B, et al. Anatomy of the thoracic pedicle in relation to the pedicle screw fixation -a cadaveric study. Biomedicine. 2013;33(1):468–72.
37. Yang H, Xing WP, Shang XW. A clinical analysis of manual placement of 277 lumbar pedicle screws. Chongqing Med. 2010.
38. Smith HE, Welsch MD, Sasso RC, et al. Comparison of radiation exposure in lumbar pedicle screw placement with fluoroscopy vs computer-assisted image guidance with intraoperative three-dimensional imaging. J Spinal Cord Med. 2008;31(5):532–7.
39. Gertzbein SD, Robbins SE. Accuracy of pedicular screw placement in vivo. Spine. 1990;15(1):11–4.
40. Gelalis ID, Paschos NK, Pakos EE, et al. Accuracy of pedicle screw placement: a systematic review of prospective in vivo studies comparing free hand, fluoroscopy guidance and navigation techniques. Eur Spine J. 2012;21(2):247–55.
41. Beresford ZM, Kendall RW, Willick SE. Lumbar facet syndromes. Curr Sports Med Rep. 2010;9(1):50.