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Endoscopic surgery on the thoracolumbar junction of the spine

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Abstract The thoracolumbar junction is the section of the truncal spine most often affected by injuries. Acute instability with structural damage to the anterior load-bearing spinal column and post-traumatic deformity represents the most frequent indications for surgery. In the past few years, endoscopic techniques for these indications have partially superseded the open procedures, which are associated with high access morbidity. The particular position of this section of the spine, which lies in the transition area between the thoracic and abdominal cavities, makes it necessary in most cases to partially detach the diaphragm endoscopically in

order to expose the surgical site, and this also provides access to the retroperitoneal section of the thoracolumbar junction. A now standardised operating technique, instruments and implants specially developed for the endoscopic procedure, from angle stable plate and screw implants to endoscopically implantable vertebral body replacements, have gradually opened up the entire spectrum of anterior spine surgery to endoscopic techniques.

Keywords Thoracolumbar junction · Endoscopic spine surgery · Spinal canal decompression · Spinal lesions · Diaphragm detachment

Introduction

The approach to the anterior column of the thoracolumbar junction of the spine was first described by Hodgson et al. [15] and cited by Louis [28]. It represents an extension of deep lateral thoracotomy into the retroperitoneal space and involves almost complete detachment of the diaphragm and in most cases resection of the 10th or 11th rib [6]. This extended approach led to excellent anterolateral exposure of the thoracolumbar junction, making it possible to perform all spine surgery procedures on this section. Until the mid 1990s we also used this standard approach routinely for all resection and reconstructive interventions on the anterior spine. In view of the access morbidity associated with the open technique, the indications were generally restrictive and reserved for injuries and post-traumatic

conditions or illnesses involving extensive structural damage and necessitating reconstruction of the anterior spine. Overall however, there was a clear increase in the number of these operations, resulting on the one hand from a rise in the number of serious spine injuries involving high energy trauma and on the other from a growing number of corrective operations following the failure of inadequate fracture treatment of spinal injuries.

Simultaneously with this development, endoscopic techniques were making their way into spine surgery as into other disciplines. The first publications on this subject [29, 35, 36] describe operations to treat spinal disorders and to remove intervertebral disc material. The first endoscopic spine surgery atlas, now in its second revised edition, was published in 1995 by John Regan and also contains the first references to the use of

endoscopy in spine trauma. In the Berufsgenossenschaftliche Unfallklinik in Murnau we performed our first endoscopic operation on the spine in May 1996 and subsequently developed the endoscopic approach to the thoracolumbar junction described below [4, 18]. The following overview of the endoscopic approach and surgical spectrum is based on the experience of more than 800 endoscopic operations on the spine performed in our hospital over the past 8 years.

Technical requirement

For this approach we use four reusable flexible threaded trocars with a diameter of 11 mm. Flexible trocars are used in order to reduce the pressure on the intercostal nerve and vascular bundle as much as possible. Light reflections and their interference with the regulation of light intensity can be avoided by using black trocars and instruments with matt surfaces.

A high intensity xenon light source is required to illuminate the thoracic cavity. For image transmission we use a 30° camera, which enables us to position the camera far away from the working portal, thus facilitating undisturbed working as well as variable adjustment of the angle of vision. The intraoperative situs is transmitted onto two flat screens that form part of an endoscopy tower containing a digital image recorder and the generator for the ultrasonic knife (Figs. 1, 2). Air insufflation is not required.

Nowadays, various manufacturers offer a set of instruments for soft tissue and bone preparation. Here it is important to make sure that there is a depth scale on both sides and that the instruments are ergonomically designed for good control and handling.



Fig. 1 Standard set up for endoscopic spine surgery. The patient is placed in a true lateral position; four portals are positioned



Fig. 2 OR—set-up and instruments

The endoscopic approach to the thoracolumbar junction

The operation is performed under one lung respiration using a double lumen tube. The patient is positioned on his or her side and stabilised in this position with a vacuum mattress or suitable support at the symphysis and sacrum and at the level of the shoulder blades. The approach side is decided first and foremost by the location of the major vessels, which can be identified from the preoperative CT scan. In most cases the best approach to the thoracolumbar junction is from the left.

As a first step, we draw the affected section of the spine onto the skin of the lateral abdominal and thoracic wall under image intensifier control. Here we pay very careful attention to correct projection of the vertebrae, whose endplates and anterior and posterior margins should be displayed in the central beam, in sharp focus with no double contour. This marking is used as the sole reference for subsequent placement of the portals.

Placing the portals

Opinions on portal placement in the literature are divided and should be seen as depending on the surgical school and specialist area from which the authors originate. Thus, the neurosurgeon and orthopaedic surgeon in the American school around Dickman [9] and Regan and co-authors [29] usually stands in front of the patient, facing and working in a diagonal dorsal direction towards the spinal canal. By contrast, surgeons orientated towards orthopaedics and traumatology

are accustomed from open spine surgery to stand behind the patient and to look and operate on the spine from the side.

Independent of this, experience shows that the placement of the trocars with reference to the planned operation and the surgical target area is of fundamental importance for the entire course of the operation. The arrangement we normally use for endoscopic access to the thoracolumbar approach is described below.

The working portal is situated directly above the lesion, the portal for the endoscope is placed over the spine two to three intercostal spaces away from the working portal in a cranial direction. The portals for the retractor and the suction/irrigation instrument are situated ventrally from this point (Fig. 3).

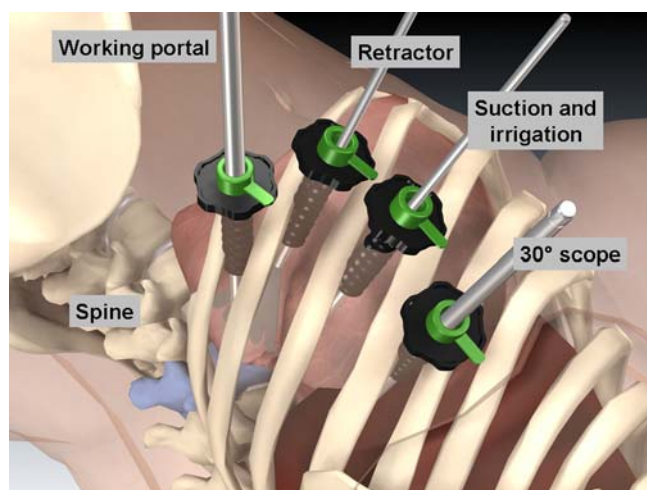
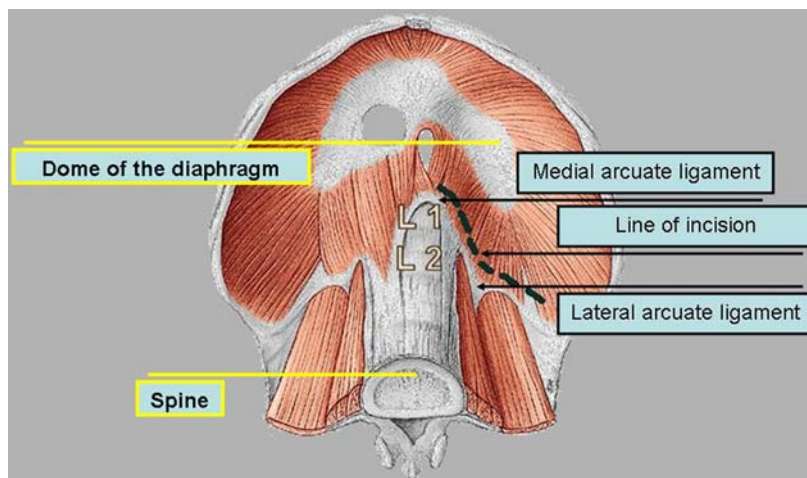


Fig. 3 Placement of the trocars at the thoracolumbar junction

Fig. 4 View at the diaphragm from below, showing the diaphragm and the anatomical conditions at the thoracolumbar junction. The course of the incision (*black interrupted line*) runs parallel to the attachment of the diaphragm



Approach to the retroperitoneal section of the thoracolumbar junction

Anatomy of the diaphragm

The dome-like diaphragm is firmly connected at its margins with the sternum, ribs and spine, and arches up into the thoracic cavity. The attachment site on the spine and on the directly adjacent ribs is different from one side to the other and has a right (dexter) and left (sinister) crus. The former springs from the lateral surfaces of the L1–L3 vertebrae, the left crus springs from the lateral vertebral wall of the 1st and 2nd lumbar vertebrae. In a lateral direction the diaphragm spans the upper portion of the psoas muscle with the medial arcuate ligament, which originates medially from the lateral surface of the 1st lumbar vertebra and attaches at the transverse process of the same vertebra (Fig. 4). The lateral arcuate ligament in turn arises here at the tip of the transverse process, arches across the lumbar quadratus muscle, which stretches in a cranial direction, and attaches to the inferior margin of the twelfth rib. Viewed topographically, the attachments of the diaphragm to the spine lie at the level of the 1st lumbar vertebra, whereas the lowest point of the thoracic cavity projects with the phrenicocostal sinus at the level of the baseplate of the second lumbar vertebra. This makes it possible to place a trocar intrathoracically in the phrenicocostal sinus, which, after incision of the diaphragm attachment to the spine, provides access to the retroperitoneal section of the thoracolumbar junction right down to the base plate of the second lumbar vertebra. This needs a 4–5 cm long incision; access to the L1–L2 vertebrae is achievable with a shorter incision of 2–3 cm [3, 4, 18] (Fig. 5).

Given the anatomical conditions, we consider the nature of the diaphragmatic attachment incision important in order to prevent the occurrence of a

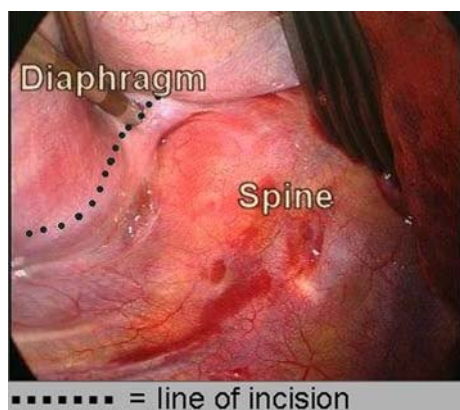


Fig. 5 Endoscopic view at the thoracolumbar junction from above. The course of the incision at the attachment of the diaphragm is marked

postoperative diaphragmatic hernia. Of the two alternatives—radial incision of the diaphragmatic attachment in extension of the spinal axis or semicircular incision running parallel to the diaphragmatic attachment to the spine and the ribs—we prefer the latter for the following reason: because of the dome-like architecture of the diaphragm, an increase in intraabdominal pressure from a semi-circular incision parallel to the attachment causes the resected margins to come together and adhere spontaneously, whereas a radial incision in direct proximity to the orifices of the aorta and the oesophagus weakens the diaphragm fixation and causes the resected margins to gape. In addition, we recommend that every incision in the attachment longer than 2 cm should be sutured endoscopically to be sure of avoiding a hernia.

Potential and technical implementation of endoscopic procedures on the thoracolumbar junction

The past 10 years of endoscopic spine surgery have been characterised by continuous further development of the operating technique accompanied by a considerable expansion of the indication spectrum. Today this covers not only the indications for reconstruction of the anterior spine, including anterior decompression of the spinal canal, vertebral body replacement and ventral instrumentation using angle stable implants, but also the treatment of post-traumatic malpositions and unsuccessful osteosyntheses. It is also possible to treat infections and to remove tumors and metastases endoscopically, although because of the substantial vascularisation in some cases it has to be remembered that the bleeding tendency significantly increases the difficulty of these operations.

Treatment of fractures

Based on our own experience, the results of the multi-centre study of the German Society for Traumatology (DGU) conducted from 1994 to 1996 [20–22] and other publications on the outcomes of surgical treatment of spinal fractures [5, 19, 26, 27], we must expect a post-traumatic loss of correction to a greater or lesser extent depending on the nature of the spinal injury and the type of surgical treatment. Injuries where we have the major loss of correction are injuries with an anterior column damage combined with a disruption of the posterior tension banding system. As long as the posterior tension banding system is intact, usually at least in younger patients, there is no significant progression of the vertebral body damage. The vertebral body damage reaches, immediately after trauma, the definitive amount of compression and remains as such as long as the tension banding system is intact.

Operating technique

The operating technique described below is used in all reconstructive procedures on the anterior spine and is supplemented with further surgical steps according to indication. After placement of the trocars, the situs is first explored with a blunt probe and the course of the spine and aorta identified. For fracture treatments below the twelfth thoracic vertebra we first incise the diaphragmatic attachment above the spine and push the retroperitoneal fatty tissue away from the psoas muscle (Fig. 4). After mobilising this muscle from ventrally to dorsally, we place the first implants or K-wires under image intensifier control, and these already define the entry point for the screw implants. Under endoscopic conditions it has proved valuable to work with landmarks such as these very early in the course of the operation, since they greatly facilitate orientation in the operating site.

The reconstruction of the anterior spine then proceeds in standardised steps

- The segmental vessels are exposed with an elevator, pulled down and mobilised using a 90° angled Overholt, ligated with titanium clips and resected. The lateral vertebral body wall is exposed (Fig. 6).
- The intervertebral disc(s) is (are) incised. The ventral and dorsal extent of the partial corpectomy is marked using an osteotome. In mono-segmental treatment the caudal limit of the resection is defined using the image intensifier in the AP projection, and osteotomy of the residual vertebral body is performed. We remove the fragments and intervertebral disc material with rongeurs. Particular importance is placed on removing the disc material and freshening up the end plates of the adjacent vertebrae.

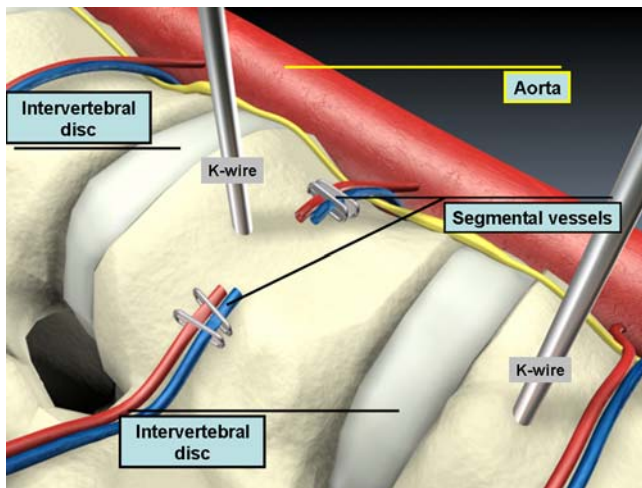


Fig. 6 K-wire insertion, exposure and dissection of the segmental vessels

- After the length of the defect has been measured a vertebral body replacement of the corresponding length is implanted. In monosegmental treatment we prefer to use an autologous tricortical bone graft, and for bisegmental bridging an expandable titanium cage that we surround with spongiosa harvested from the partial corpectomy [7] (Fig. 7).
- Building on the K-wires or screws inserted in the first step of the operation, we routinely perform a ventral instrumentation. For this we use an angle stable plate and screw implant with the intention of achieving higher primary stability and hence a better initial situation for bone ingrowth in the fusion area [8] (Fig. 8). The operation then concludes with manual

endoscopic suturing of the diaphragm incision and the placement of thoracic drainage. Re-inflation of the lung is monitored endoscopically and the four skin incisions are sutured layer by layer after the trocars have been removed.

Decompression of the spinal canal

Depending on the level of stenosis, compression of the spinal canal can lead to a neurological deficit. The spectrum of injuries to the spinal canal, medullary cone and cauda equina ranges from simple contusion to complete tearing of the neural structures. As long as the structures have not been severed, recovery of function and sensory deficits may be possible in principle. This has been demonstrated in both animal investigations [8] and clinical studies [1, 13, 17, 32]. The statements in the literature concerning the effectiveness of spinal canal decompression with regard to influencing progress and final outcome after spinal canal injury are, however, extremely controversial [7, 10, 13, 14, 25].

We consider the indications for anterior decompression as given when significant narrowing and a neurological deficit remain after primary dorsal reduction and stabilisation. If it is clear from a myelogram that adequate indirect decompression was not achieved through reduction in the primary operation, we then perform a hemilaminectomy as an emergency measure to relieve the compression dorsally and then in a second elective step we attempt to remove the anterior compressing bony fragments and disc material endoscopically.

Fig. 7 Insertion of the tricortical bone graft into the partial corpectomy defect. Dissection of the retropulsed fragment under direct visualisation of the dura. Removal of the fragment

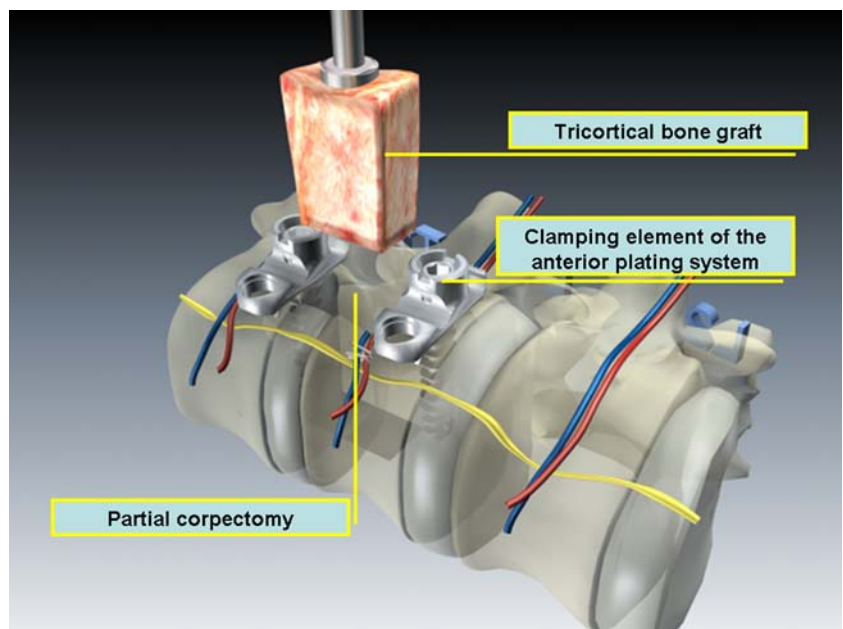
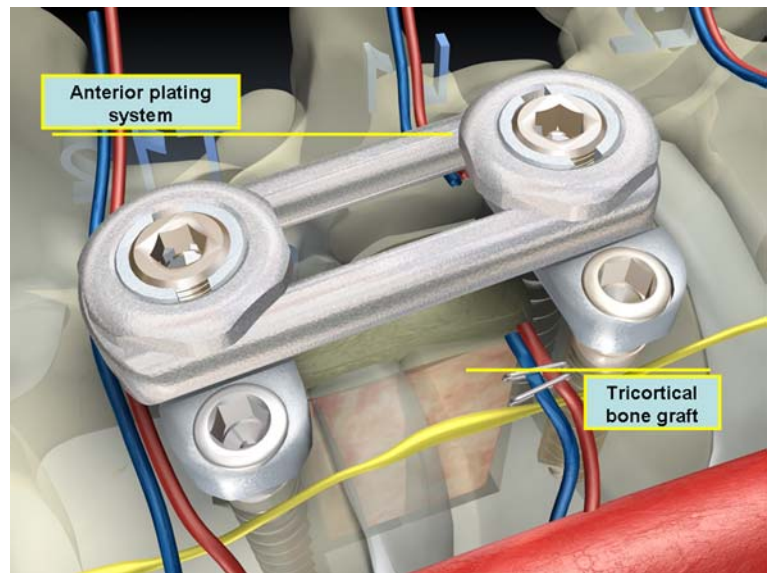


Fig. 8 The anterior reconstruction including bone graft insertion and instrumentation is completed



Operating technique

In our experience it is important to use fixed landmarks such as K-wires or screws to maintain proper alignment and surgical trajectories. Therefore, we recommend placing K-wires or screws under fluoroscopic control into the vertebral bodies above and below the level selected for corpectomy. After this, the adjacent intervertebral discs are incised and removed, and the central part of the vertebral body is resected with osteotomes and rongeurs. Initially, the posterior vertebral body wall is preserved to avoid further canal compromise during the partial corpectomy. In addition, removal of the retropulsed fragment can cause significant bleeding from the epidural venous plexus. Therefore, we recommend completing the partial corpectomy and adjacent diskectomies before the canal decompression. The next step is to identify the pedicle of the fractured vertebral body. In traumatic burst fracture, the pedicles are nearly always preserved and the retropulsed fragment is usually located medial to the pedicle. Thus, the retropulsed fragment is trapped between the two pedicles and is difficult to remove or to reduce. Therefore, we recommend resecting the ipsilateral pedicle with a punch [9] prior to attempting to remove the retropulsed fragment. For this reason the resection of the ipsilateral pedicle has a dual importance: it exposes the spinal canal and at the same time it frees the retropulsed fragment from the pincer grip of the pedicles.

Therefore, after completing the partial corpectomy and resecting the rib heads if necessary, we use a Cobb rasp to expose the ipsilateral pedicle subperiosteally and to push away the nerve root dorsally. The inferior margin of the pedicle is identified with a nerve hook and the pedicle is transected with a punch (Fig. 9).

Removing the dorsocranial section of the vertebral body together with the base of the pedicle exposes the posterior margin fragment and will bring the dura into view (Fig. 10). The compressing fragment can now be lifted off the dura under direct view, mobilised in the direction of the partial corpectomy and resected. A nerve hook is used under image intensifier control to document the completeness of the posterior margin fragment resection in both planes [11].

We use an expandable titanium cage as a vertebral body replacement because of its higher stability and the smaller risk of dislocation. The operation concludes with the ventral instrumentation and suturing of the diaphragm attachment.

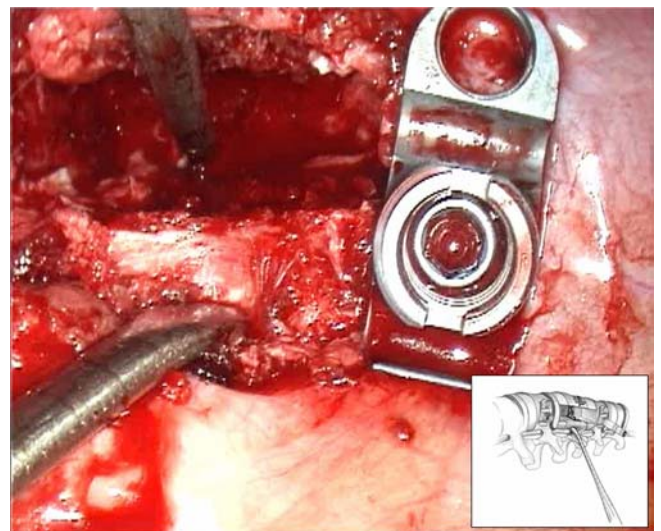


Fig. 9 Resection of the pedicle in order to expose the lateral dural sac

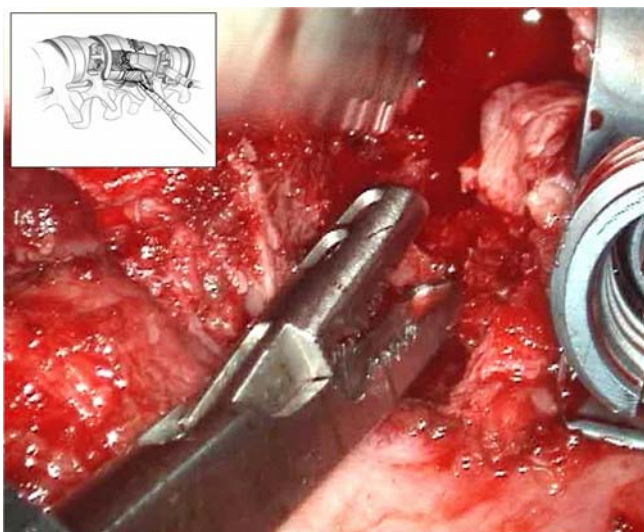


Fig. 10 Resection of parts of the postero-lateral aspect of the vertebral body under endoscopic view at the dura

Correcting post-traumatic deformities

Post-traumatic deformities of the thoracolumbar junction usually take the form of a kyphotic axial deformity. To correct these with a Smith Peterson osteotomy, extensive anterior release is required in addition to dorsal release or osteotomy. This anterior release procedure includes the entire anterior circumference and the posterior longitudinal ligament [40]. Both the ventral act and the reconstruction of the anterior spine can be performed endoscopically. In contrast to scoliosis surgery, the major vessels lie in direct proximity to the spine (Fig. 11). Not infrequently they are deformed by scarring and adhesions from the fracture healing process and are relatively adherent. It is absolutely essential to take these changes into consideration both in preoperative planning and in selecting the approach side.

After placement of the trocars and partial detachment of the diaphragm it is sometimes necessary to ligate and sever the segmental vessels on several levels in order to mobilise the vessels. The anterior release can best be performed at the level of the intervertebral discs. Using a Cobb raspator, we mobilise the vessels directly following the anterior longitudinal ligament and then we place a blunt and slightly curved Cobb raspator, which is inserted via a fifth trocar around the anterior margin of the spine at the height of the intervertebral disc (Fig. 12). Protected by the blunt Cobb raspator, the disc and the anterior longitudinal ligament are then incised. The disc transsection can be completed to the opposite side with a sharp osteotome, the position of which is monitored by the image intensifier in the AP projection. In most cases it is recommended to perform the release in the area of two neighbouring intervertebral

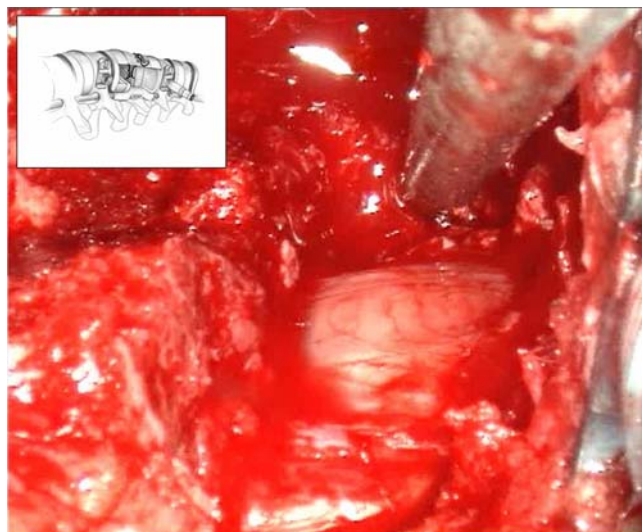


Fig. 11 The decompression of the spinal canal is completed

discs for better mobilisation (Fig. 12). The release is followed by the corpectomy and the reconstruction of the anterior spine in the usual way. Here we again use an expandable titanium cage as the vertebral body replacement because of its higher primary stability and its potential for reduction.

Treatment of infections

Destructive discitis and spondylodiscitis can also be treated endoscopically [31]. Before the operation we carry out a CT-controlled puncture of the seat of

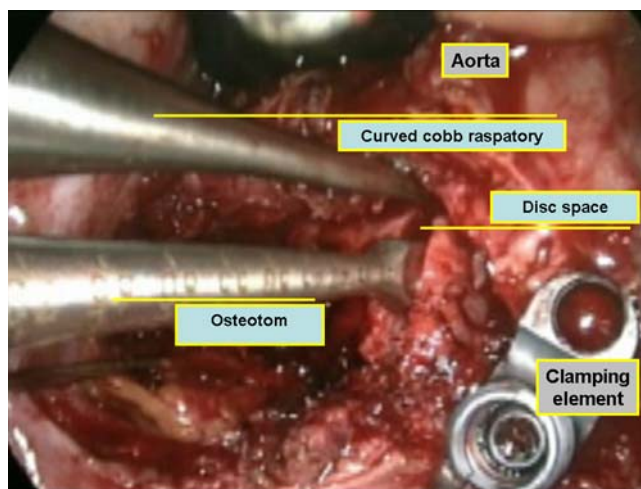


Fig. 12 Endoscopic anterior release using a sharp osteotome at the intervertebral disc T12/L1. A blunt and slightly curved cobb raspator is placed in front of the intervertebral disc to protect the aorta

infection in order to define the agent responsible and thus be able to administer the appropriate antibiotic locally and systemically during surgery. Here too, inflammatory scarring can cause changes in the location and structure of the vessels, the severity of which can extend to arosion, and this must be excluded preoperatively. We attempt simultaneous clearing of the infection and reconstruction, since this represents a less stressful alternative for the frequently weakened patients than multiple revision operations. The stability of the reconstruction is crucial for successful healing of the infection.

The approach and operating procedure are essentially the same as for fracture treatment. The inflammatory formation of a pannus and increased blood flow frequently make orientation more difficult, and for this reason we place short K-wires as landmarks under image intensifier control at the earliest possible point in time, before we begin to clear out the infection. Following radical debridement of the infection an expandable titanium cage is inserted as a vertebral body replacement and filled and surrounded with a mixture of autologous spongiosa and an appropriate antibiotic medium according to the findings of the infection test. Dorso-ventral instrumentation and bridging of the previously infected segment is recommended in order to enhance the primary stability.

Special indications

Special indications include, for example, metal removal due to implant loosening. Figure 13 shows the case of a 42-year-old woman on whom dorsoventral reduction and stabilisation was performed in 1986 because of a total burst fracture of the first lumbar vertebra. The ventral operation was performed in open surgery via a thoracophrenolumbotomy. Partial loosening of the

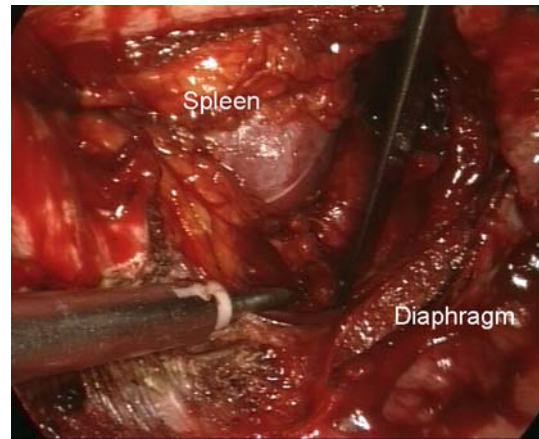
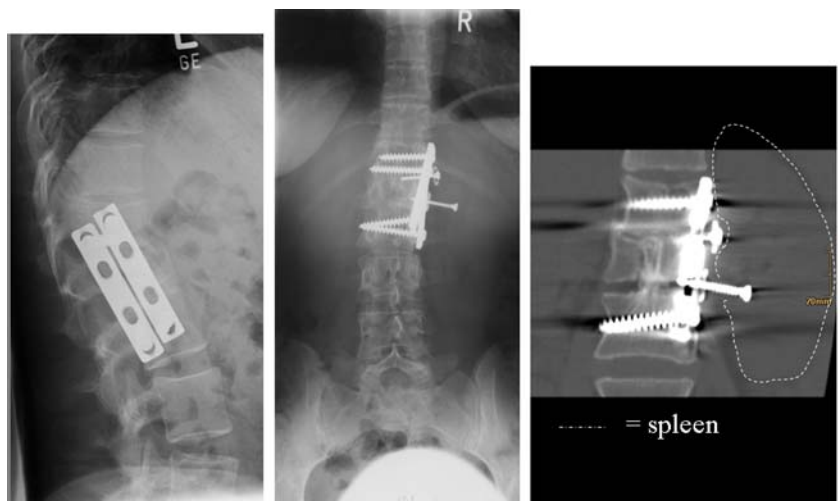


Fig. 14 Endoscopic detachment of the diaphragm and exposure of the spleen and screw

screws had occurred, with the potential to migrate and to cause arosion of adjacent structures like the spleen (see Fig. 13). The indication for endoscopic removal of the screws was made.

Operating technique: after digital checking for possible pleural adhesions after the extensive primary operation, the first trocar for the endoscope was carefully placed using the minithoracotomy technique, and this was followed by placement of the other trocars under endoscopic vision. Adhesions between the lower lobe of the left lung and the pleura were removed using both sharp and blunt instruments. The diaphragmatic attachment was exposed and incised following the semicircular technique. Because of the adhesions and the altered anatomy the spleen is lying directly on top of the plate and the screws, and this was now carefully mobilised (Fig. 14). The screws could then be freed with the working trocar and removed (Fig. 15). Because of the

Fig. 13 Screw loosening after anterior instrumentation. The screw migrates towards the spleen



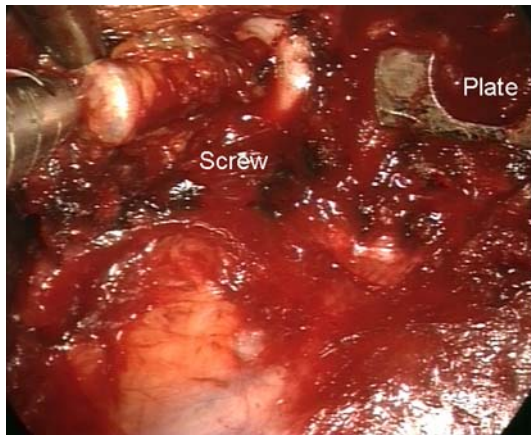


Fig. 15 Removal of the screws

danger of injury to the spleen the plate itself was not removed. Postoperative healing was free from complications. The postoperative X-ray on the third day following surgery clearly shows the different extent of the incisions after open and endoscopic access (Fig. 16).

Results

Fracture treatment

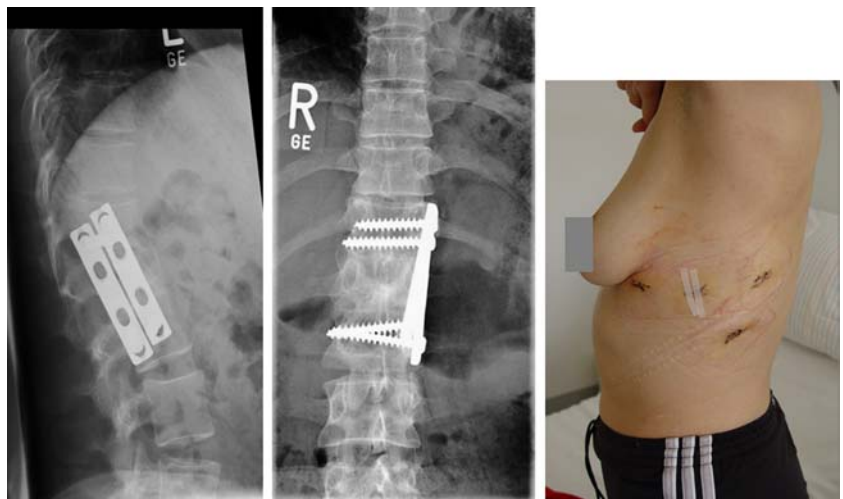
In a collective study by the Berufsgenossenschaftliche Unfallklinik Murnau and Stanford University, California, data on 220 patients with unstable injuries to the thoracolumbar junction in the region of the twelfth thoracic and first lumbar vertebra were recorded between May 1996 and June 2002 [18]. The 186 patients were from the clientele of the BG-Klinik Murnau and 34

from the Stanford University patient base. The average age was 36. The follow-up period was between 4 months and 6 years, with a mean of 2 years. A neurological deficit was present in 43% of the patients, categorised as follows according to the Frankel Scale [12]: 16% D, 6% C, 5% C and 15% A with complete neurological deficit symptoms. A 89 patients were (40.5%) presented with a fracture of the twelfth thoracic vertebra, and 131 patients (59.5%) had a fracture of the first lumbar vertebra.

The injuries were categorised according to the AO classification [30]. All the patients with B and C injuries were primarily dorsally repositioned and stabilised. Thus, of the 220 patients 64.5% (142) were stabilised dorsoventrally and 35.5% of the patients with preoperatively diagnosed Type A compression injuries were exclusively ventrally stabilised. Between 1996 and 1999 we used the Z Plate (Sofamor-Danek) for ventral instrumentation and since November 1999 we have used the angle stable MACS TL System (Aesculap) specially designed for the endoscopic technique. At this point in time we predominantly used a tricortical bone graft from the iliac crest as a vertebral body replacement (84%) (Figs. 17, 18, 19, 20, 21) and much less frequently (16%) an extendable titanium cage (Synex, Synthes). At 1 year follow-up complete fusion could be identified in 85% of the exclusively ventrally treated fractures and in 90% of the dorsoventrally treated fractures. Reconstruction of the spine profile was successful in over 90% of the cases.

The operating time was between 70 min and 9 h, with an average operating time of 3.5 h. The times included in this total for the approach to the retroperitoneal section were between 10 and 20 min including the suture. Passing the learning curve and introducing implants specially developed for the endoscopic technique made it possible to shorten the operating time significantly.

Fig. 16 Postoperative radiological and clinical result demonstrating the different aesthetical aspects after open and endoscopic approach



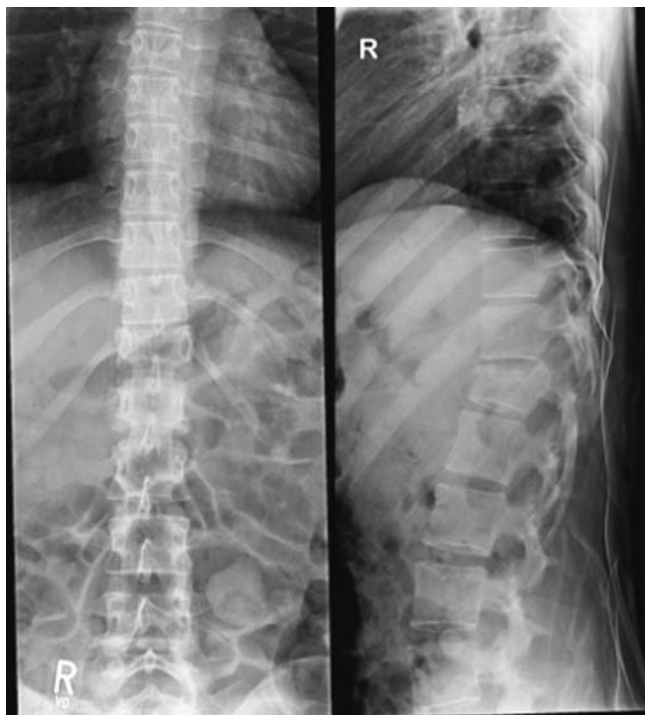


Fig. 17 Case report: 18-year-old female after car accident, compression/rotation fissured fracture type C 1.3.2 (AO classification)

Complications and conversion rates

Three of the 220 patients we converted to the open surgery technique, corresponded to a conversion rate of 1.3%. Of these, two occurred in the first five operations. The respective reasons for these were inadequate control of bleeding from the bone and jamming of a screw. Both cases would have been resolvable endoscopically given the present state of technology. During a revision operation following implant failure of a Z Plate a small tear occurred in the aorta as the plate was being exposed, and this was treated by direct suturing of the aorta in open surgery.

Altogether we recorded five cases of implant loosening, of which four involved the Z Plate with loosening of one of the anterior, non-angle stable screws. In one case the entire MACS implant became loose due to an excessively broad indication setting in a case of severe osteoporosis. Of these five cases, three underwent revision surgery because of the accompanying loss of correction.

Approach-related complications such as pleural effusions, persistent pneumothorax or intercostal neuralgia occurred in 5.4% of the cases. In one case, the L1 root was irritated by the application of monopolar current using the dissection hook during endoscopic detachment of the diaphragm. In the follow-up there was no occurrence of diaphragmatic hernia in any of the cases.

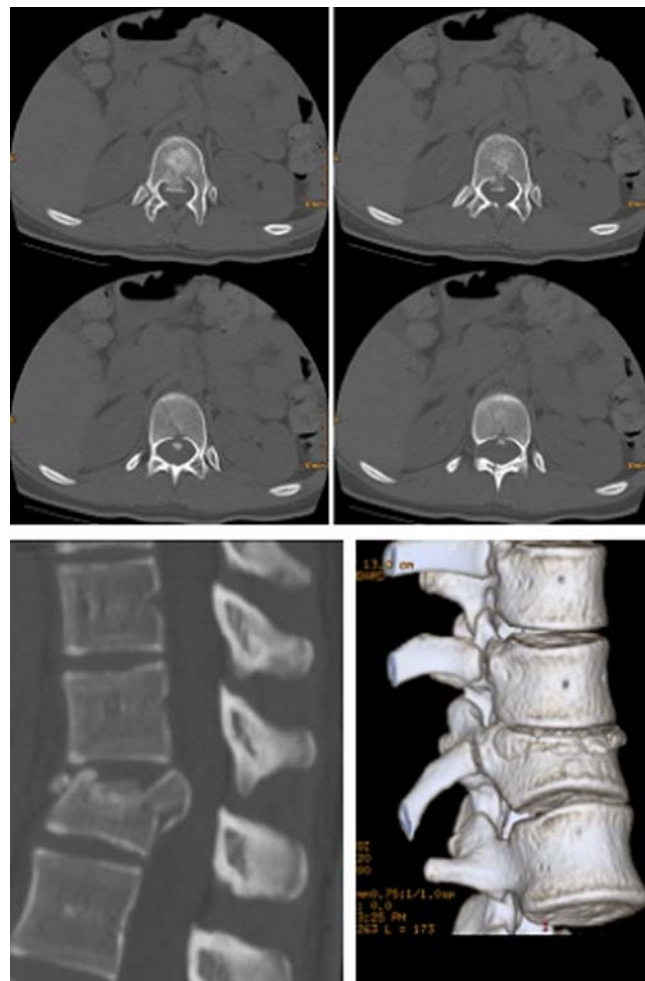


Fig. 18 Transversal CT layer and two-dimensional and three-dimensional reconstruction of the injury

Anterior decompression

The results of a study on a consecutive series of 30 patients of the Berufsgenossenschaftliche Unfallklinik Murnau are reported, on whom endoscopic anterior decompression was performed [2].

The average preoperative narrowing of the spinal canal, defined according to the Bradford and McBride method, was 55%. The average postoperative clearance of the spinal canal was 110% due to the postoperative larger extension of the spinal canal in comparison to the normal diameter, documented by CT and determined planimetrically. In no case was there a deterioration of the pre-existing neurological situation. In one of the four patients with complete paraplegia there was an improvement in neurological status of one grade on the Frankel Scale. Among the patients with incomplete paraplegia we observed a significant improvement in neurostatus in 13 out of 20 patients.

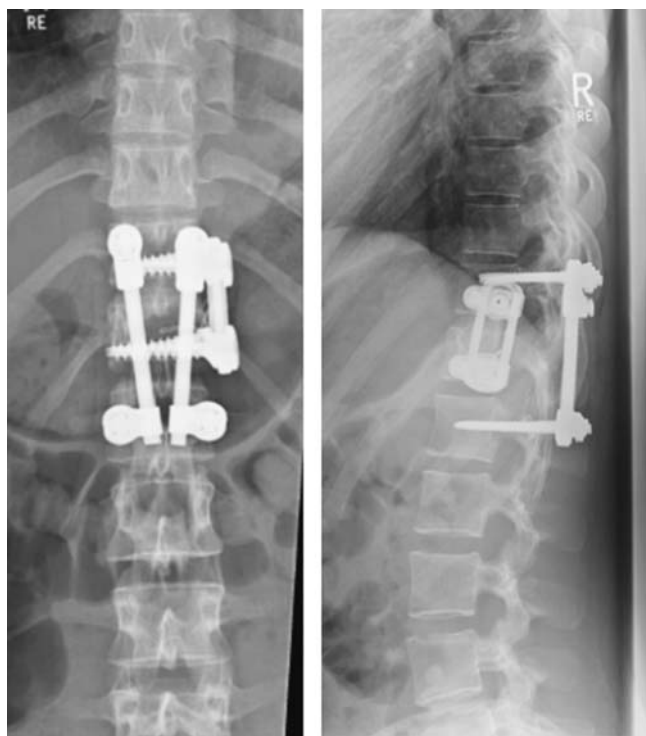


Fig. 19 Postoperative X-ray check after initial dorsal bisegmental stabilisation and subsequent thoracoscopic monosegmental ventral fusion with the MACS TL system Th 11-12

The average duration of surgery, including complex correction operations, was 5 h 42 min. The estimated blood loss with routine use of a Cell Saver system was 870 ml. The average stay in intensive care was 1.4 days.

We recorded a complication in 36.7% (11 of 30) of the patients. Of these, five were associated with the harvest of the bone graft from the iliac crest, and essentially concerned postoperative pain in this region. The remaining six complications involved

- postoperative pulmonary insufficiency requiring prolonged artificial respiration in intensive care,
- two pleural effusions requiring surgical intervention,
- one pulmonary embolism with deep vein thrombosis in the leg and pre-existing total paraplegia,
- one transient irritation of the brachial plexus caused by the patient's position, and
- one case of persistent damage to the sympathetic nerve plexus (Figs. 22, 23, 24, 25).

Correction of post-traumatic deformities

In a prospective study we recorded 31 patients over a 2-year period (2001–2003). Included were all patients endoscopically operated for

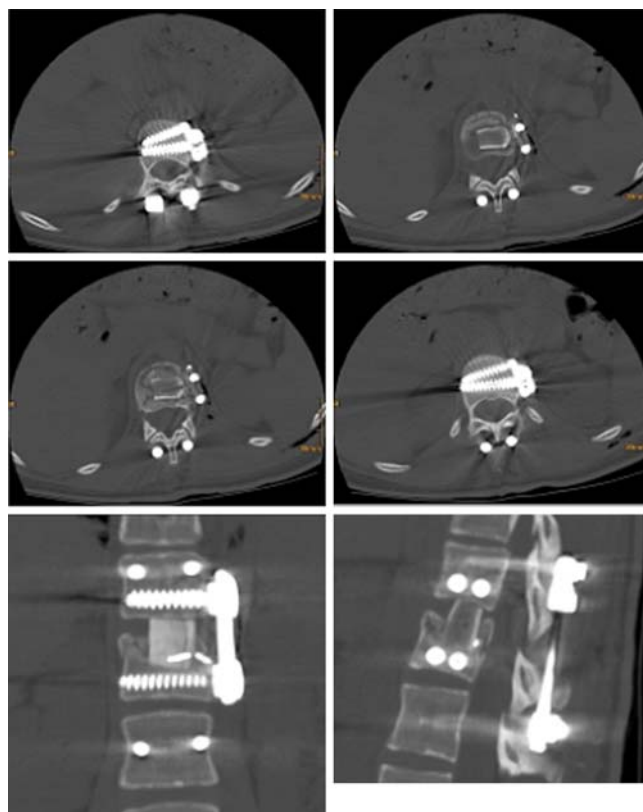


Fig. 20 Transversal CT layers showing the bicortical screw fixation of the caudal section of Th 12, position check of tricortical iliac crest graft and two-dimensional reconstruction to check position after monosegmental stabilisation Th 11-12

- post-traumatic kyphotic deformity following primary conservative treatment,
- persistent ventral instability and deformity after exclusively dorsal instrumentation, and



Fig. 21 Clinical and cosmetic result after suture removal 10 days post-op

Fig. 22 Case example of a burst fracture L1(type A 3.3) with incomplete neurological deficit (ASIA C) and severe canal compromise. Preoperative X-rays and CT scans



Fig. 23 Postoperative CT scans for the assessment of spinal canal clearance after having performed dorsal reduction and fixation



Fig. 24 Postoperative X-rays and CT reconstructions

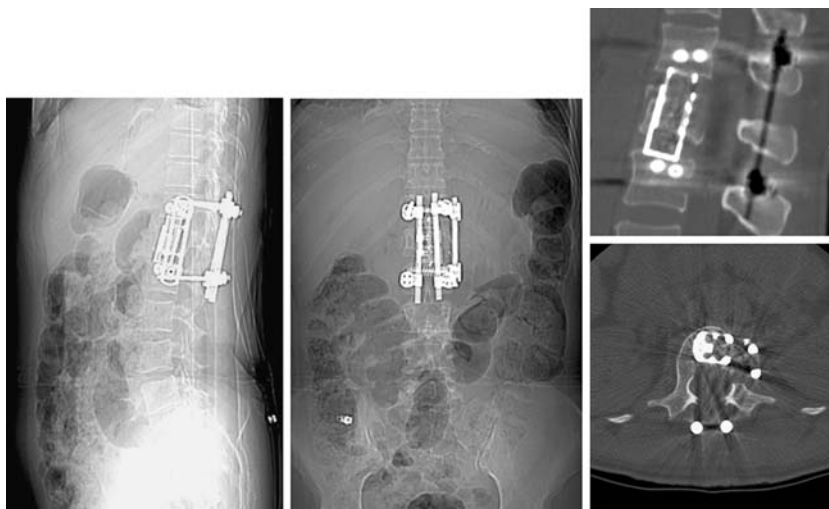


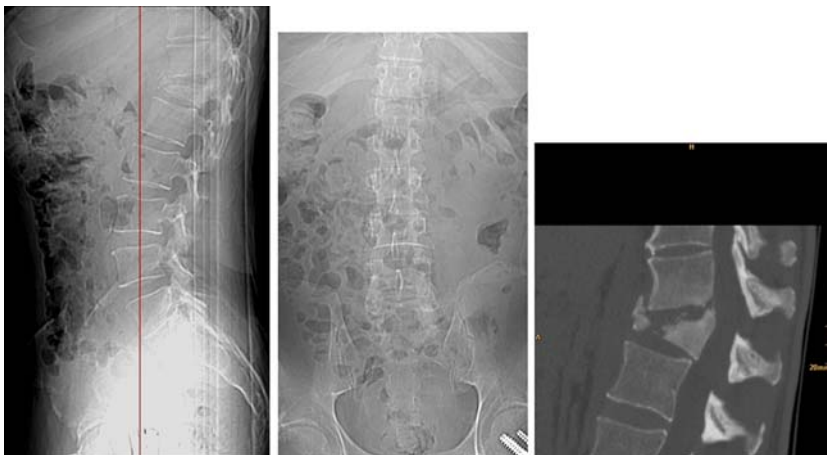


Fig. 25 Lateral X-ray view showing the relation of a bisegmental anterior instrumentation T12–L2 to the diaphragm

- implant failure with increasing deformity of the spinal axis.

In addition to the deformity, nearly all patients suffered from instability with the corresponding symptoms like concussion and load-related pain (Figs. 26, 27) and these were also included in the indication setting as well as the average recorded kyphotic deformity of 16° (Fig. 28). The average correction achieved was 6° . The VAS score showed a clear increase after 1 year from an average 45 points before surgery to 80 points postoperatively (Fig. 29).

Fig. 26 Post-traumatic kyphosis and instability after initial dorsal reduction and stabilisation of a L1-fracture followed by infection and early implant removal



Treatment of infections and special indications

On this topic there are to date two publications on several cases of endoscopic operations and one case report. Huang et al. [16] reported on a series of ten patients with tuberculous spondylitis. Their technique consisted of endoscopic debridement without anterior instrumentation. Complications included bone graft subsidence and progressive kyphosis. One patient required open conversion. Muckley et al. [31] reported a series of three patients treated with thoracoscopic spine surgery and demonstrated the feasibility of a one-stage anterior debridement, interbody reconstruction, and anterolateral instrumentation. Operative time (150–270 min) and estimated blood loss (500–850 ml) were comparable to open techniques. During the follow-up period (22–24 months) no recurrent infections, hardware failures, or loss of correction were noted.

Discussion

In the past 10 years, endoscopic operations on the spine have developed from an alternative technique to the standard spine surgery procedure, usefully combining the familiar proven techniques from the open procedures of bone and disc resection, vertebral body replacement and ventral instrumentation with the video-assisted operating technique of thoracic surgery (VATS). The subsequent development of instruments and implants as well as the standardisation of the operating procedures meant increasingly that even complex operations could be performed endoscopically and that the initially longer operating times required by the endoscopic procedures could be decreased to a level known from conventional open surgery.

However, the approach to the thoracolumbar junction of the spine, that at the same time represents the

Fig. 27 Postoperative result after dorso-ventral osteotomy and dorso-ventral-dorsale instrumentation

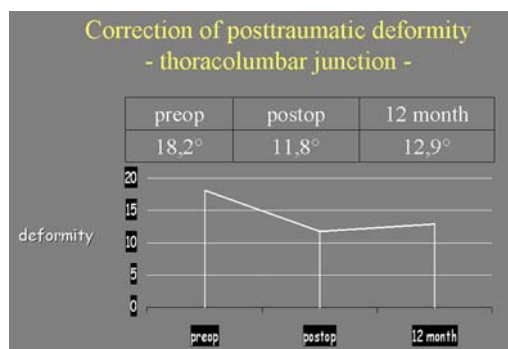
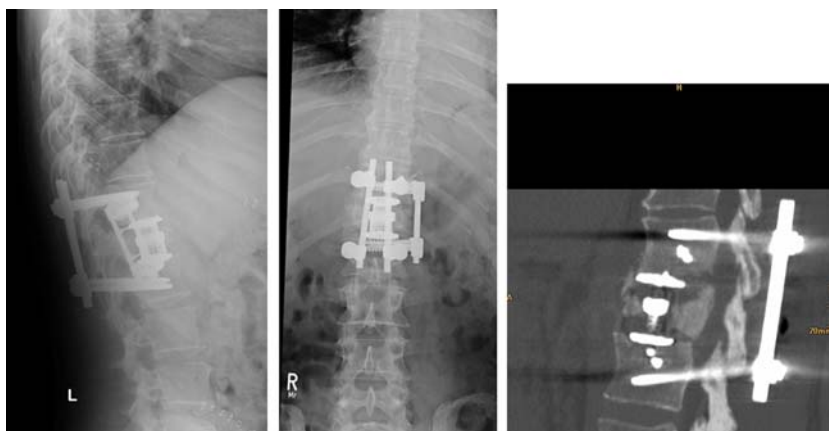


Fig. 28 Correction of post-traumatic kyphosis: preoperative and postoperative result and mean loss of correction in a 1-year period

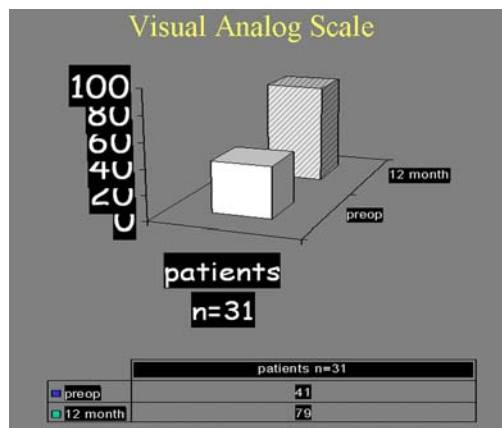


Fig. 29 Preoperative and postoperative status of the patients according to the VAS-scale

border region between the thoracic and abdominal cavity, was for a long time considered difficult to access endoscopically. The lower limit of the thoracoscopically accessible was generally claimed to be the 1st lumbar

vertebra [9]. With partial detachment of the diaphragm running parallel to the diaphragmatic attachment, as described by us and published in 1998 [4], it is also possible to reach the region of the second lumbar vertebra near to the baseplate under thoracoscopic conditions. This ensures that the first lumbar vertebra, the one most frequently affected by injuries, can also be treated endoscopically using the bisegmental technique.

As shown by the collective study on 220 patients by the BG Unfallklinik Murnau and Stanford University, California in 2004 [18], the approach to the thoracolumbar junction described above has a low complication rate. Crucial for successful implementation of this technique is an incision parallel to the attachment of the diaphragm onto the spine and the ribs. For the approach to the first lumbar vertebra, this incision is about 2-cm long. For the approach to the second lumbar vertebra, an opening of about 4–6 cm is made in the diaphragm. The incision should be closed by suturing to avoid a diaphragmatic hernia. The occurrence of a diaphragmatic hernia must be considered as probably the most serious potential complication, and this has not so far occurred in any case in which the technique we recommend has been used [3, 4, 18]. However, two cases of diaphragmatic hernia are known to us personally following endoscopic diaphragm detachment performed elsewhere. In these cases a radial incision was made over the spine and left unsutured. In both cases, the incarceration of abdominal contents in the hernia gap led to serious complications.

Another approach to the thoracolumbar junction is described by Dickman et al. [9] in which the patient is placed in a reverse Trendelenburg position in order to shift the intraabdominal organs in a caudal direction and relax the diaphragm. Separation of the pulmonary ligament and mobilisation of the pleura is recommended to give access to the 12 thoracic and first lumbar vertebrae. For lower lying regions the authors recommend the use of retroperitoneally positioned portals.

Our preferred concept of reconstruction of the load-bearing anterior spine as a fusion procedure in fracture treatment contains

- resection of the injured intervertebral discs and the burst sections of the fractured vertebra in the form of a partial corporectomy,
- implantation of a vertebral body replacement in the form of an autologous bone graft from the iliac crest or an extendable titanium cage filled and surrounded with spongiosa, and
- ventral instrumentation as a purely ventral stabilisation measure or to provide additional stabilisation for a dorsal implant.

The discussion on the sense or necessity of ventral instrumentation in cases where a dorsal stabilisation system has already been implanted is not yet concluded. In biomechanical studies, Knop et al. [23, 24] were able to demonstrate adequate stability using a fixateur interne and an extendable titanium cage (Synex) that is 'braced' against the fixateur. Other current biomechanical studies have shown that ventral instrumentation has a substantial reinforcing influence on the primary stability of the spine section treated with this method [38, 39]. However, the crucial question of how much stability a fusion requires for bone ingrowth remains open.

The indication for anterior decompression is the subject of a similar controversial discussion. From animal experiments it is known that both the magnitude of the initial force exerted on the spinal cord and the duration of the compression of neural structures influence not only the severity of the neurological deficits but also the ability of the spinal cord to recover [8, 32]. Clinical studies were able to demonstrate similar effects in humans [1, 13, 17], although according to Gaebler et al. [13] optimum recovery can be expected when decompression occurs within the first 6 h after the trauma. Therefore, our concept foresees immediate dorsal reduction and stabilisation for indirect reposition of the posterior margin fragment in every case of an unstable injury to the thoracolumbar junction combined with a neurological deficit, and myelographic documentation has proved this to be sufficient to relieve the neural structures in around 80% of the cases. However, if the intraoperative myelogram shows a further contrast medium stop, dorsal decompression is immediately performed. Endoscopic anterior decompression as an elective operation then serves to remove the ventrally compressing fragments with a view to avoiding long-term consequences [33].

The special features of the endoscopic technique come into effect particularly in anterior decompression. Among the advantages is the excellent image of the situs obtained with the 30° scope, which we routinely use, and which, depending on the rotation of the scope and the nearness to the object, can be compared to the image obtained with the surgical microscope. One of the disadvantages is the

two-dimensional nature of the image, which makes it difficult or impossible for the surgeon to correctly assess the working angle and the penetration depths of the instruments and screws from an orthograde view. Starting from these premises and based on the analysis of the typical fracture form associated with traumatic spinal canal narrowing, we have developed a procedure adapted to the endoscopic technique, the effectiveness of which we were able to demonstrate in the study of 30 consecutively recorded patients described above [2]. The key site is the pedicle, the resection of which on the one hand provides an unobstructed view onto the dura and on the other exposes the posterior margin fragment, which in most cases is trapped between the intact pedicles, for reposition and resection. The compressing fragments can thus be gently lifted away from the dura with a dissector under direct vision, moved ventrally into the partial corporectomy defect and removed. The study showed an equivalent effectiveness in spinal canal clearance of approximately 100% compared to the open ventral technique. The average operating times have since been reduced from over 5 h to between 3 and 3.5 h.

Post-traumatic deformities of the thoracolumbar junction generally take the form of a kyphotic deformity, where the sagittal imbalance is frequently associated with instability and corresponding symptoms. Surgical treatment therefore consists on the one hand of correcting the deformity and on the other of removing the instability, which normally requires a dorsoventral procedure [40]. The ventral part of the operation in the form of anterior release [9, 34] and ventral reconstruction with vertebral body replacement and angle stable instrumentation can be performed endoscopically. In 1999, Kloeckner et al. [40] reported on a series of 34 patients who were operated on to correct a malalignment using an open technique [40]. The average correction gain was 13° with a subsequent recorded correction loss during follow-up of 5° on average. In our clientele of 31 patients with a starting diagnosis of on average 18° post-traumatic kyphosis we were able to achieve an average correction gain of 7°, followed by a correction loss of 1° within 1 year. Despite the unsatisfactory result with regard to the degree of correction achieved, which we attribute to over careful and therefore ineffective anterior release in the initial phase, a good result was achieved, measured with the VAS score, in terms of the reduction in symptoms and the satisfaction of the patients with the operation result.

The results published to date of endoscopic operations for infections and tumors represent descriptions of individual cases [31, 37] and demonstrate the feasibility of the technique in principle. The same applies for the case group of special indications. For these cases the endoscopic technique represents an important and gentler alternative to the conventional open procedure, however, a controlled prospective randomised study is

lacking to prove the superiority of the endoscopic over the conventional technique.

The typology of complications introduced by Aebi et al. [1] also applies in principle for endoscopic spine surgery. These are the complications caused by

- Reduction,
- Approach,
- Preparation, placement of screws and implants, and
- The implant, lack of fusion, infection.

The reposition of larger deformities via the ventral spine alone is limited for biomechanical reasons. Complications arise here through the inadequate application of force on implants or endplates during attempts at repositioning, and these can lead to primary or premature implant loosening.

However, of greater importance for the endoscopic procedure on the thoracolumbar junction are the approach-related complications. The proximity of the diaphragm and the organs immediately beneath it demands great care in placing the trocars. We recommend that the portal for the endoscope, the one situated furthest in a cranial direction in the thoracic cavity, should be placed first and the thorax opened via a small thoracotomy 2-cm long, allowing the situs to be palpated with the fingers to exclude the possibility of adhesions of the lung, pleura and diaphragm. The other portals can then be placed under endoscopic control. The operation should begin and end with an inspection all around the thoracic cavity. Before the endoscope is removed, it is absolutely essential to monitor the complete re-inflation of the lung endoscopically in order to prevent atelectases and the formation of effusions. To prevent intercostal neuralgias we recommend the use of flexible trocars that reduce the pressure on the intercostal nerve and vascular bundle to an unavoidable minimum. With the minimally invasive approach and the consistent implementation of these recommendations it was possible to reduce substantially the rate of approach-related complications during surgery. According to an analysis of our first 371 patients this stood at 5.4%. The equivalent rate for open interventions in a multi-centre study by Faciszewski et al. [11] was just over 14%. commentFaciszewski [11] have been changed to Faciszewski et al. [11] to match the reference list. Please confirm or correct the change.

With regard to the direct proximity of vital structures, the complication potential of surgical operations on the spine must be regarded as high. While the risk of neurological complications at the level of the thoracolumbar junction is to be regarded as less in comparison with the thoracic spine because of the tapering of the spinal cord and the greater width of the spinal canal, more attention must be paid to the ventrally situated vessels. Injury to these represents a life-threatening complication, which has to be brought under control by

immediate thoracophenotomy with extensive exposure, mobilization and tying of the vessels. Dangerous malpositioning of screws and implants can be avoided by using the image intensifier when inserting the vertebral body replacement and screwing in the screws. In our patient series of 371 patients from the first 5 years after introduction of the endoscopic technique the rate of vascular complications (leakage from the aorta) was 0.3%. The equivalent value from the multi-centre study on open procedures is 0.08% [11]. In the same time period we had one spleen injury and temporary damage to the L1 root caused by the application of monopolar current, corresponding to a rate of organ complications of 0.3% for each.

From the group of complications caused by implants, infection or lack of bone fusion, similar results have to be reported for endoscopic and open techniques. The fusion rates are given as between 85% and 90%. The advantages of the smaller approaches with regard to possible contamination of the situs and the development of infection are partly offset by the longer operating times for the endoscopic procedure, at least in the initial phase.

Conclusion

In the last 10 years, endoscopic procedures on the spine have become an alternative standardised spine surgery. The standardisation of procedures and the development of instruments and implants for the minimally invasive operating technique have made a substantial contribution to this. Through the trans-diaphragmatic approach it has been possible to open up the thoracolumbar junction, including the retroperitoneal segments of the spine, to the endoscopic technique. With the extension of the technique to the retroperitoneal sections of the thoracolumbar junction it was possible at the same time to increase the indication spectrum of the endoscopic technique substantially, so that it today includes complete fracture treatment with vertebral body replacement and ventral instrumentation as well as anterior decompression of the spinal canal and the correction of post-traumatic deformities in terms of anterior release and the reconstruction of the anterior spine. Special indications include the endoscopic treatment of infections and tumors, the feasibility of which has been demonstrated in principle in individual studies. The complication rate of the endoscopic procedure is of the same scale as that known from the open procedures, with clear advantages in terms of the reduced access morbidity associated with the minimally invasive technique.

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