Complications in Endoscopic Anterior Thoracolumbar Spinal Reconstructive Surgery

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Abstract

The use of endoscopic, minimally invasive surgical techniques in the reconstruction of the anterior column of the spine results in a significant decrease of approach-related complications. Depending on the level of injury, every stage of the surgical procedure is associated with a specific risk of complications requiring a detailed preparation of the operation. Preoperative preparations aim at recognition and improvement of preexisting cardiopulmonary diseases (e.g. chronic obstructive pulmonary diseases) as well as planning of anesthesia (twin tube airway, monitoring) and surgical technique, including optimal position of the patient, approach, reduction and stabilization of the fracture. Intraoperatively, a specific management is necessary to avoid complications, e.g. vascular, dura, or spinal cord injuries or lesions of the lung and the abdominal organs. In the postoperative course, general complications (infection, wound healing problems, bleeding, atelectasis), implant-associated complications (aseptic loosening, cage sinking), or fusion-associated complications (loss of reduction, pseudarthrosis, corresponding problems) have to be differentiated.

Key Words

Spine · Endoscopic surgery · Vertebral body · Anterior reconstruction · Complications

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Introduction

The video-assisted endoscopic thoracolumbar vertebral body reconstruction represents a milestone in the surgical treatment of spine injuries. The majority of vertebral fractures are located at the level of T12 and L1 [1]. Unstable injuries and lesions result in a reduced load-bearing capacity of the anterior spinal column requiring stabilization. Previously, the anterior reconstruction at this level was performed by an extensive surgical approach with opening of the thoracic and the abdominal cavity (thoracolumbophrenotomy) which was associated with a high morbidity. For example, using the open technique, a chronic pain syndrome was seen in up to 50% of the patients postoperatively, even when a stable reconstruction was achieved [2]. To avoid approach-related complications, surgery was often performed only by posterior or posterolateral stabilization without any anterior spinal reconstruction, resulting in poor outcome, especially high rates of nonunions, ranging from 13 to 82% [3–6].

Although thoracoscopy was first described by Jacobaeus [7] using a rigid cystoscope, it took a long time until Mack et al. [8] successfully performed a thoracoscopic spinal fusion in 1993. Within the last few years the endoscopic approach proceed to the standard technique in anterior thoracolumbar spine reconstructive surgery reducing approach-associated morbidity. Although the incidence of complications in minimally invasive surgery decreased with increasing experience, there are still a number of similar complications reported in the literature. According to the study of Beisse et al. [9], analyzing 371 patients, conversion to the open technique was only required in four patients (1.2%). The complication rate was low including infections (1.8%), aseptic loosening (2.1%), and an injury of the spleen. One patient suffered from a neurological aggravation (Frankel D to B); another one from a lesion of the nerve root L1 due to surgical diathermy. Approach-related complications, e.g. pleural effusion, pneumothorax, or intercostal neuralgia were seen in 5.4%. In a following study by the same group [10], including 30 patients with endoscopic spinal decompression, the total complication rate was 16.7%, predominantly approach related (four patients). According to Borm et al. [11], intercostal neuralgia is the most frequent complication seen postoperatively (12.9%) confirmed by the study of McAffee et al. [12] with 6 out of 100 patients.

In a study, including 55 patients requiring endoscopic anterior spine surgery due to thoracolumbar vertebral fractures, which was performed by the authors [13] to investigate whether a stable mono- or bisegmental spinal fusion can be achieved by bone grafts from the iliac crest, complications were seen in 11 patients. These were located at different sites: the chest (one chylothorax, three intercostal neuralgia of the chest wall), the iliac crest (one infection, one fracture of the iliac bone, three neuralgia of the genitofemoral nerve/cutaneous lateral femoral nerve), and others (one deep vein thrombosis, one myocardial infarction).

Complications generally associated with anterior reconstruction of the spine are seen intraoperatively (e.g. vascular, dura, or spinal cord injuries as well as lesions of the lung or abdominal organs), postoperatively (e.g. pulmonary problems including pneumothorax, pleural effusion, respiratory insufficiency; secondary bleeding, wound healing problems, liquorcele/liquorrhea), or in the late course (loss of reduction, displacement or loosing of the implant, pseudarthrosis, reduced recreational activities).

The risk management, recommended to avoid or reduce the incidence of complications, requires a permanent analysis and checkup before and at every stage of video-assisted minimally invasive spine surgery.

Endoscopic anterior thoracolumbar spinal reconstructive surgery: surgical procedure and related risks/complications:

Preoperative Preparation

Present and Past Medical History

To ensure a sufficient overview during endoscopic surgery general endotracheal anesthesia with twin tube airway is required. After lung deflation the pleura is retracted using an endoscopic hook or an abdominal pad under visual control. This technique represents an enormous physical exertion, especially for the cardiopulmonary system; the individual consequences depend on the general condition and concomitant injuries of the patient. The most frequent postoperative complications, described in different studies, are pulmonary problems ranging from pleural effusion, atelectasis to respiratory insufficiency [11, 14]. The preoperative recognition, diagnosis and, if possible, improvement of specific pulmonary problems, e.g. obstructive ventilation disorders due to emphysema, smoking, postoperative adhesions or trauma, is essential to achieve an optimal oxygen exchange during surgery. In case of suspicion of obstructive disease, preoperative pulmonary function tests, e.g. vital capacity and forced expiratory volume, are indicated as well as therapeutic strategies including inhalation and mucolysis. Furthermore, basic preparations for surgery, e.g. laboratory tests, electrocardiogram, or chest X-ray, should be carried out to ensure the best possible result for the patient; in addition to cell saver option, three units of packed red cells are necessary.

Anesthesia/Ventilation

General endotracheal anesthesia with twin tube airway is the standard procedure in thoracic surgery (Figure 1a). It is recommended to insert the tube left-sided due to technical and anatomical reasons. Because of the anatomy with a short distance between the bifurcation of the trachea and of the right superior pulmonary lobe a right-sided twin tube, even when located correctly in the right main bronchus (Figure 1b), would bear the risk of a dislocation of the cuff in a more caudal position. The consecutive occlusion of the right superior pulmonary lobe, in addition to the deflated left lung, would result in an increased postoperative morbidity and mortality. The tube is inserted under fiber-optic control to ensure correct positioning. Every change in the position of patient could result in a displacement or dislocation of the airway tube; therefore correct position and blocking of the tube has to be checked by the anesthesiologists.

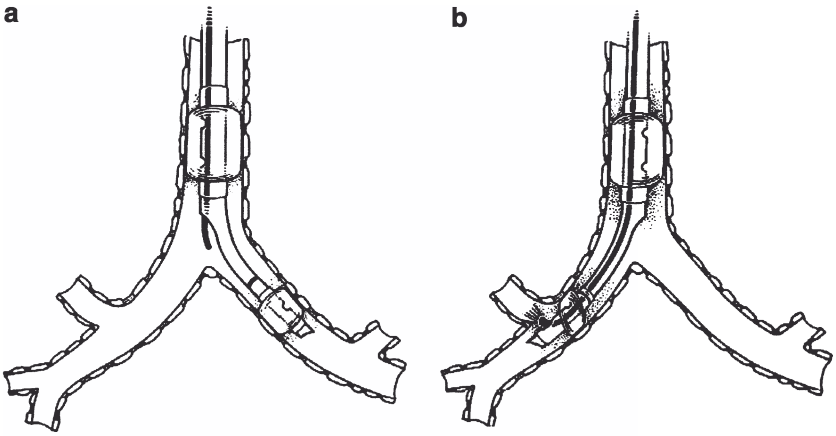


Figure 1a and 1b. a) Left-sided twin tube airway: standard position in thoracic surgery. b) Right-sided twin tube.

Figure 2. Correct 90° lateral side position of the patient in a vacuum splint mattress (4-point stabilization). The level of the injury (region of interest) is marked under radiological control.

Figure 3. Position of the portals in left-sided thoracic approach.

Intraoperative Monitoring

Sudden bleeding can cause cardiac shock and eventually circulatory arrest. Therefore, the intraoperative management includes permanent monitoring of the arterial blood pressure and the central venous pressure, measured by a central venous line, which in turn allows volume resuscitation. Renal function and volume level should be balanced by insertion of a urinary catheter. The early recognition and prevention of pulmonary problems due to a displaced or dislocated airways tube requires the continuous measurement of the end-tidal carbon dioxide (ET CO2). A drop of the oxygen saturation (SaO2) requires a temporary stop of the single-lung ventilation. By use of positive end-expiratory pressure (PEEP) on the ventilated lung and continuous positive airway pressure (CPAP) on the unventilated lung decreases the rate of postoperative atelectasis.

Planning of Surgical Procedure

The preoperative analysis of the level of the spine injury and its relation to the adjacent anatomical structures is essential to choose the optimal approach. The X-rays including computerized tomography with three-dimensional reconstructions should be analyzed according to the following questions:

1. What is the correct or optimal stabilization technique of the injured anterior spine column (mono- or bisegmental; autogenous bone graft/cage with or without additional stabilization; optimal device)?
2. What is the optimal approach to the injured spine (left lateral/right lateral approach)?
3. Are there any relevant malpositions of the main and important anatomical structures (CT imaging). What is the position of the aorta to the injured vertebral body?
4. What are the width and the depth of the vertebral body [determination of the length and direction of the screws, the size, the distraction and the end plates of the cage (angulation)]?

The right lateral approach, preferred for the endoscopic reconstruction of spine injuries at the levels T3–T7, bears the risk of damaging anatomical structures and organs located in the right posterior mediastinum/ right retropleural cavity. The structures at risk include

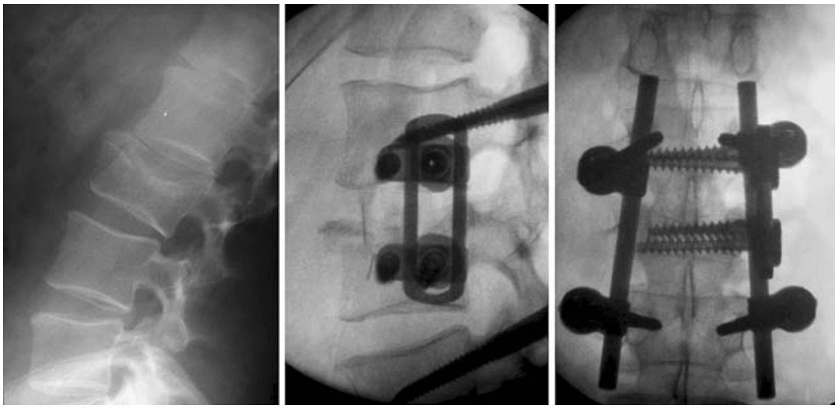


Figure 4. Stabilization of a L1 fracture (X-ray, lateral view) by endoscopic monosegmental spinal fusion L1 with an autogenous graft (iliac crest) and an additional instrumentation. The reduction was performed by an external fixator, which in combined posteroanterior surgery is removed at the end of the operation.

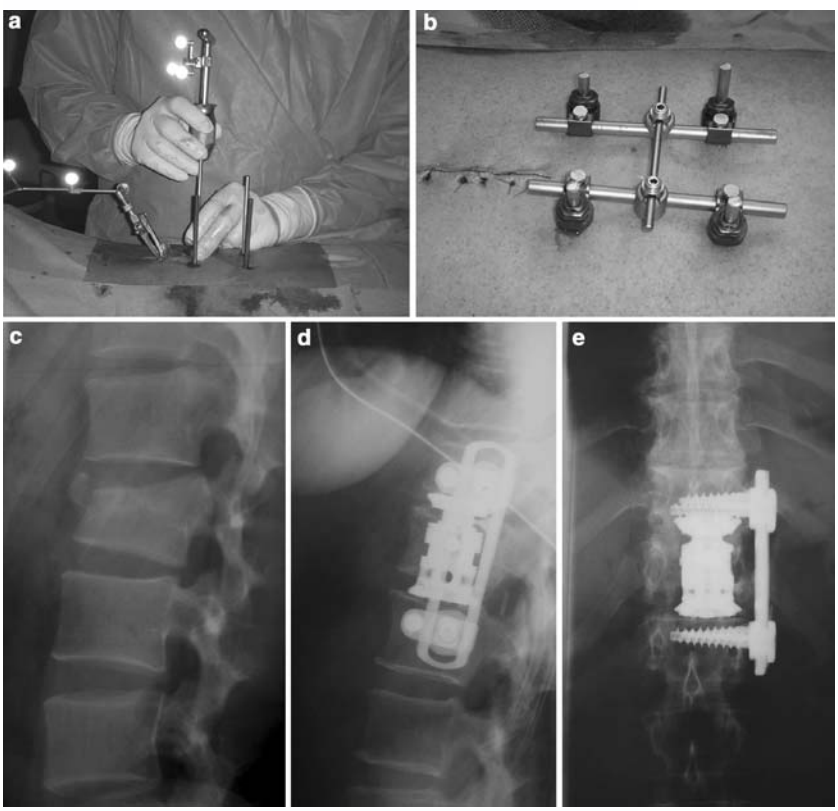


Figure 5a to 5e. Combined, single-stage dorso-ventro-dorsal stabilization of a type A fracture T12 (A3.2) (X-ray, lateral view; c). Reduction by an external fixator (a, b), followed by endoscopic corporectomy of T12, interposition of a cage and additional stabilization by a plate. The external fixator is removed at the end of the operation [X-ray, lateral (d) and anterior posterior (e) view].

the right lung, the esophagus, the azygos vein, the sympathetic trunk, as well as the thoracic duct.

The left lateral approach, preferred for the endoscopic reconstruction of spine injuries at the levels T8–L2, bears the risk of damaging anatomical structures and organs located in the left posterior mediastinum/left retropleural cavity: left lung, thoracic aorta, accessory hemiazygos vein, intercostal vessels, sympathetic trunk, as well as the thoracic duct.

Injuries of the thoracic duct are of special interest because of its variant position in relation to the main thoracic vessels: it can be located left- (36%) or right-sided (6%), median (20%), or oblique (17%) [15]. In the postoperative course, an injury of the thoracic duct is diagnosed by persistent pleural effusions (chylothorax) with the corresponding clinical features, chest X-rays, and laboratory values. In the majority of patients, this complication is treated successfully with a diet program aiming on a reduction in fat intake with an increase in the polyunsaturated/saturated ratio. If the chylothorax persists despite the diet, a parenteral nutrition is indicated. Failure of the conservative treatment required re-surgery with location and ligature of the leak.

Preparations Immediately Prior to Surgery

Position

Correct positioning of the patient on the operating table is essential for the successful surgical procedure. An insufficient position can cause injuries of anatomical structures adjacent to the vertebral body (e.g. thoracic aorta, vena cava, spinal cord), especially by the surgical instruments, e.g. chisel, marking wires, or screws. These complications can result in poor outcome and eventually death. The surgical procedure has to be performed under continuous visual control to avoid complications and to achieve an adequate overview requiring a permanent orientation about the position of the spine and the instruments, respectively, at every stage of the operation. This aim

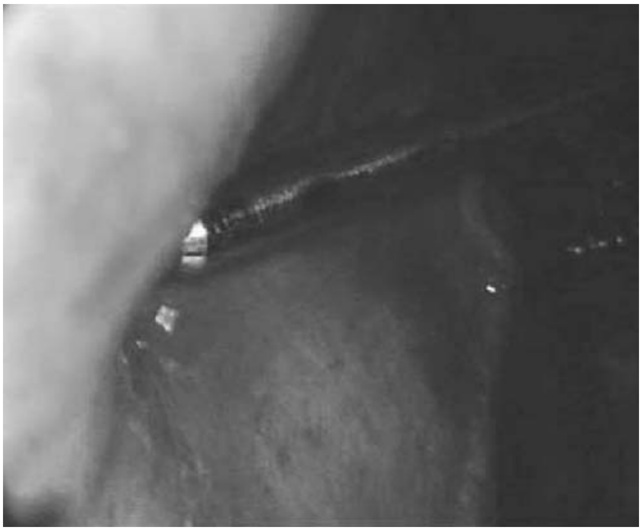


Figure 6. Loss of visual control especially of the marking-wires bears the risk of an unrecognized lesion of the spleen by perforation of the diaphragm.

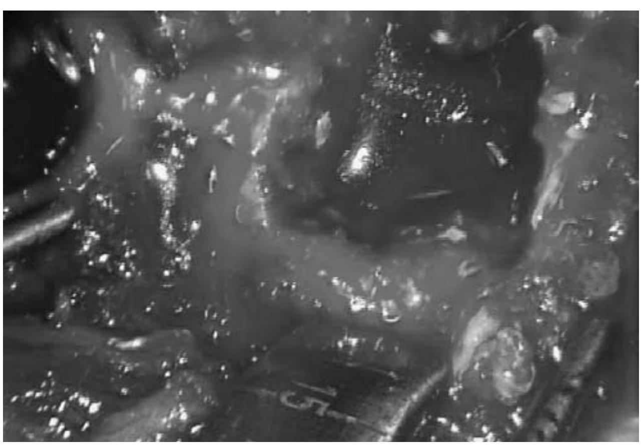


Figure 7. Diskectomy/corporectomy: instruments marked with a scale (here chisel) are used to avoid uncontrolled resection. The posterior wall of the vertebral body is marked by two Kirschner's wires.

can be achieved by a correct 90° lateral side position of the patient that allows preparation and surgical procedure in a strict vertical direction to the spine. The correct position has to be controlled radiologically prior to surgery; in parallel the corresponding part of the spine (region of interest) should be marked (Figure 2). The positioning of the patient is facilitated by the use of a vacuum splint mattress (Figure 2) (four-point stabilization) making additional stabilization dispensable. The use of an operating table made of carbon is the prerequisite for the intraoperative control by Iso-C3D imaging (Figure 2).

Table 1. Frequent mistakes and source of risks.

- Insufficient preparation for the insertion of the bone graft
- The cage is not placed dorsal to the midline of the spine axis
- No flat contact between the end-plates of the cage and the adjacent vertebral bodies due to incorrect choice or an impacted position of the end-plates
- Insertion of the cage: too posterior (risk of an injury of the spinal cord) or too ventral (cage outside the main load-bearing axis)
- Insertion of cancellous bone without contact to the adjacent vertebral bodies (therefore no definitive spinal fusion can be achieved)

To avoid a lesion of the brachial plexus the upper arm should be positioned raised up and right-angled in an elbow-rest, supported by a thoracic pad; this allows sufficient moving of the optics and the instruments (Figure 2).

Approach to Thoracolumbar Spine

The use of endoscopes permits surgical maneuvers to be performed through small incisions that are characteristic of minimal invasive surgery. The optimal approach is essential for the success of the operation and for the prevention of complications. It is closely associated with the position of the patient, because a correct 90° lateral side position is required to get a strict vertical adjustment to the spine, a prerequisite to mark the level of the spine injury as well as the appropriate access.

For spine injuries located at the level of T4–T7 a lateral position on the left side with a right-sided thoracic approach is recommended due to the prominent aortic arch. In parallel, a lateral position on the right side with a left-sided thoracic approach is recommended for injuries at the level of T8–L2.

The access to work is located median and vertical to the injured vertebral body. Following the incision of the skin (2 cm) in the intercostal line, two Langenbeck's retractors are placed and then the muscles are split in the line of their fibers with scissors. After incision of the parietal pleura and lung deflation the portal for the optics (10 mm) is inserted under digital or visual control, two intercostal spaces cranial to the access to work. A smaller distance would impair the movement of the instruments by the optics. The portals for the retractor (10 mm) and the irrigator–aspirator (5 mm) are placed in the anterior axillary line, handbreadth anterior to the access to work (Figure 3). If a cage or a large bone graft has to be inserted, a partial resection of a rib (4 cm) adjacent to the access to work is recommended.

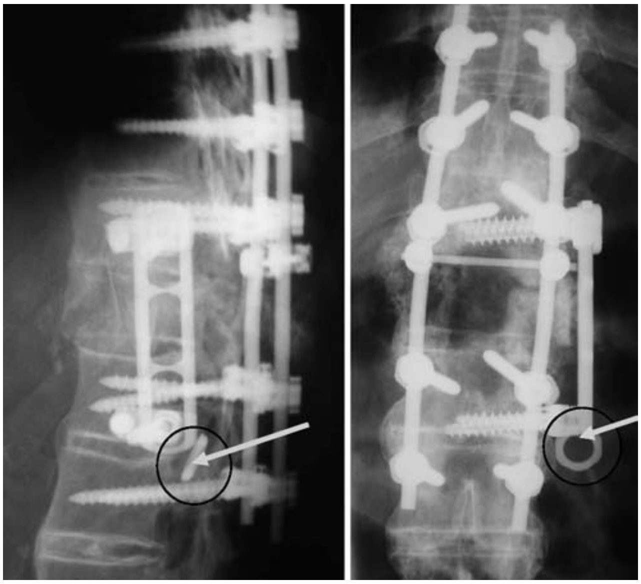


Figure 8. Aseptic loosening of an angular stable ventral instrumentarium (MACS TL, Aesculap, Tuttlingen, Germany) due to a persistent instability (marked by circles).

Reduction

Depending on the fracture type, single injuries of the anterior column, e.g. compression-type fractures (type A according to Magerl [10]) are stabilized only by an anterior reconstruction. The restoration of the physiologic spinal alignment is essential and the basic principle in the treatment of spine fractures. So far the posterior transpedicular stabilization is the most simple and effective technique of reduction. A corresponding and appropriate instrumentation to achieve a sufficient reduction and spinal fusion by a ventral endoscopic one-stage procedure is still not available. Although the majority of type A fractures are successfully treated by a closed reduction, a secondary loss of reduction is seen in many cases, even if the closed reduction is supplemented by an endoscopic anterior reconstruction of the spine. The lateral position bears the risk of an unintentional bending of the spine in the coronal plane, e.g. during the insertion of the tricortical bone graft. Furthermore, the resection of the vertebral body results in an increasing temporary instability with the risk of an injury of spinal cord. Therefore, the surgeon has to perform the reduction and stabilization prior to the endoscopic anterior reconstruction of the spine, usually by the posterior instrumentation. An alternative technique in type A fractures is the temporary use of an external fixator (Figures 4, 5), possibly linked to a navigation system. By this procedure the advantages of the minimally invasive approaches are combined, e.g. the maintenance of the proprioceptive sensibility by preservation of the back muscles as well as the fast mobilization and recovery of the patient.

Table 2. Aspects to avoid malposition of the implant.

- Correct position allows surgical procedure vertical to the spine
- Continuous sufficient visual control of the situs intraoperatively
- Orientation and marking of the dorsal wall of the injured and the adjacent vertebral bodies (marking wires)
- Insertion of the ventral implant under permanent visual control
- Intraoperative control of the correct position of the implant by X-ray fluoroscopy

Intraoperative Management

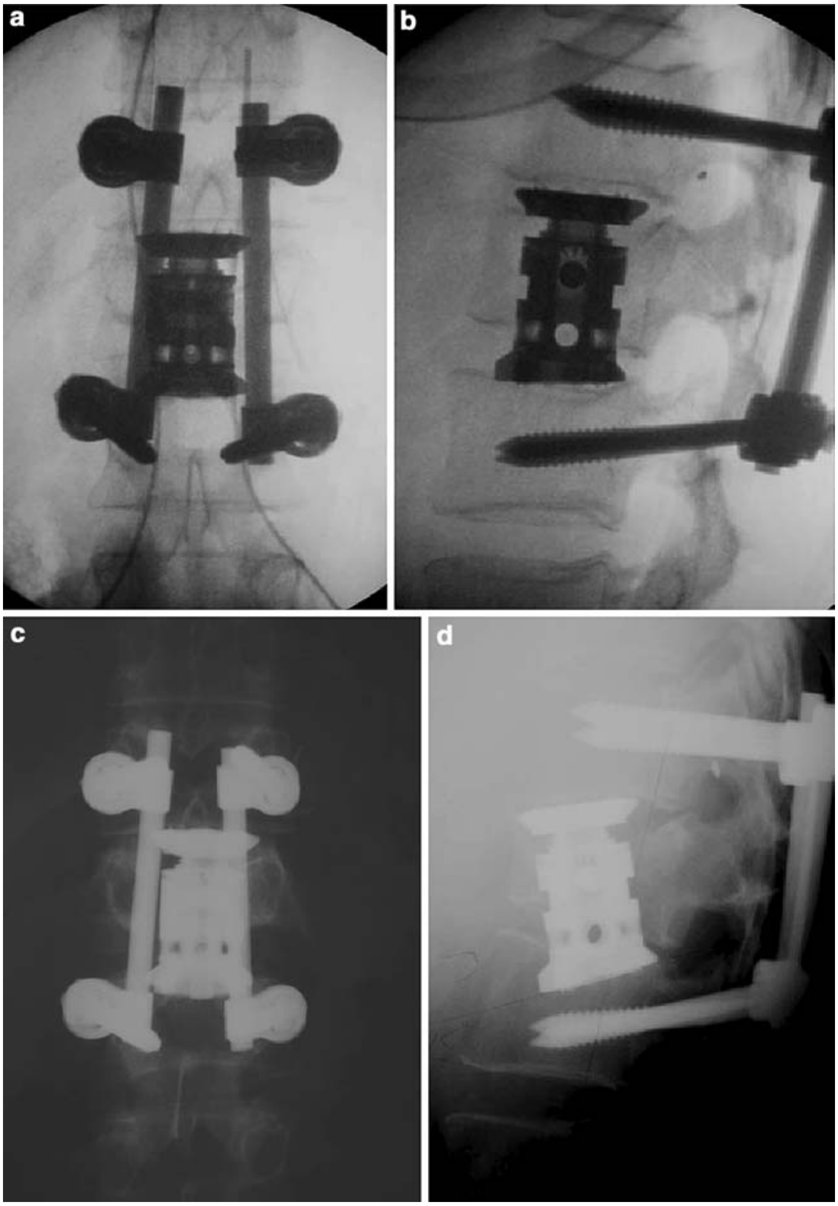
Preparation of the Situs

The images of the camera and the X-ray fluoroscopy, respectively, should be adjusted to the surgeon to allow a better orientation during the surgical procedure. Therefore, the back is projected to the lower part of the image field, the head to the right, and the feet to the left part; the aorta and the spine are projected parallel in line to the lower horizontal part of the image field.

After the insertion of the 30° angled optics, an overview is performed to get information on the situs. The spine is palpated using a staff, especially the anterior interface to the thoracic aorta has to be determined. The diaphragm is retained by a retractor and then the injured vertebral body is identified radiologically. The cranial and caudal resection lines of the vertebral body are marked with Kirschner's wires or wires of the MACS system set (AesculapR). To avoid an injury of the spleen by perforation of the diaphragm a permanent visual control of the marking wires (Figure 6) is required; alternatively the immediate replacement of the wires by screws is recommended.

Segmental Vessels

Segmental vessels are located in the waist of the vertebral body and should be separated and cut after clipping or diathermy. A preparation of the segmental vessels too far in the anterior region can cause bleeding of the azygos/hemiazygos vein by injury. Furthermore, attempts to stop the bleeding by a "blind clipping" without visual control can increase the bleeding. In the majority, a conversion to open thoracotomy is not necessary.



Figures 9a to 9d. Postoperative X-ray-control [anterior posterior (a) and lateral (b) view] following corporectomy L1 and interposition of a titanium cage (ObeliscR, Ulrich medical, Ulm, Germany): correct position of the cage. In the follow-up a sinking of the cage was seen in the X-ray-control 6 weeks later (c, d).

Splitting of the Diaphragm

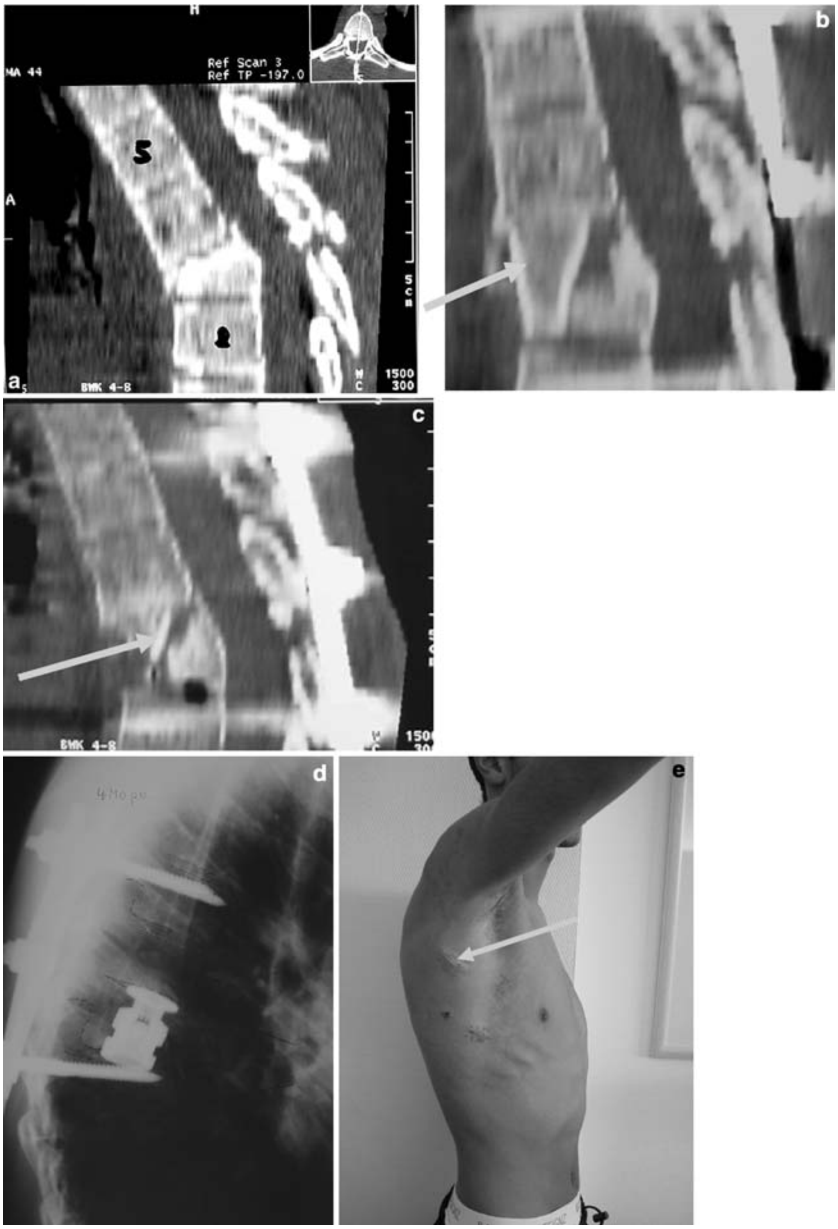
The thoracolumbar part of the spine can be visualized thoracoscopically by splitting of the diaphragm; therefore this approach can be used for the stabilization of L2. The diaphragm is retained by the retractor, then the injured vertebral body is identified, followed by the insertion of a marking wire in the adjacent cranial vertebral body. After the incision of the parietal pleura using monopolar cautery; a stripe of 1-cm width should be preserved. Following incision, the muscular system of the diaphragm is dissected by a swap or by scissors up to the fascia of the psoas muscle. The preperitoneal fatty tissue is dissected from the psoas muscle to the ventral site; the muscle fibers of the psoas muscle are prepared or cut electrosurgically to the posterior site. An injury of the nerve root by monopolar cautery has to be avoided as well as a lesion of the spleen.

Corporectomy/diskectomy

The intervertebral disk is cut with a special dissecting knife at the endplate of the injured vertebral body. To avoid an injury of the main vessels by an unintentional slipping with the knife to the ventral site, the incision should be performed in direction to the surgeon. When a total or partial extirpation of the injured vertebral body is performed, the depth of the body has to be determined preoperatively by using the CT images. Instruments marked with a scale should decrease the risk of an uncontrolled resection, e.g. too near to the opposite side or too plain; the latter resulting in a position too lateral of the bone graft or the cage (Figure 7).

Decompression of Vertebral Canal

After diskectomy of the adjacent intervertebral disk and total or partial corporectomy of the injured vertebral body using an osteotom and straight or angled rongeur, a decompression of the spinal cord is performed by resection of the posterior wall of the vertebral body. First the lower margin of the vertebral arch radicle is prepared and identified; then the radicle is resected directly at the transitional zone to the posterior wall of the vertebral body; an injury of the nerve root has to be avoided. Then the fragments of the posterior wall dislocated from the body into the spinal canal can be resected under permanent control and care of the visualized dura of the spinal cord. To decrease the risk of an additional injury of the



Figures 10a to 10e. A 21-year-old patient was injured and suffered a type B2 fracture T7 without neurological symptoms. a) Sagittal two-dimensional CT reconstructions, b) postoperative X-rays after replacement of the vertebral body by a bisegmental bone graft: correct position of the graft (marked by an arrow). c) Follow-up after 4 months: X-rays revealed a resorption of the bone graft (marked by arrow). d) Postoperative X-rays (lateral view) after a corrective spinal fusion using a titanium cage. e) Position of the portals (work access marked by an arrow).

neural structures the anterior decompression should be performed in the opposite direction to the spinal cord.

Replacement of Vertebral Body

The anterior column is reconstructed by an interbody fusion with an autogenous bone graft from the iliac crest or by intervertebral insertion of a distractible titanium cage. Prior to insertion the cage has to be tested for function, correct height, and choice of end-plates (e.g. 10° or 20° lordosis in the lumbar part of the spine); it is placed posterior to the midline of the spine axis. The end-plates of the cage should be in a flat contact to the proximal and distal plates of the adjacent vertebral bodies to ensure a pressure-stable support. Before distraction of the cage, the correct position must be controlled by X-rays in two projections. Interposition of a cage requires an additional stabilization by a ventral plate or by a posterior instrumentation (Figure 5).

Frequent mistakes and risks are summarized in Table 1.

Implant-associated Complications

Loosening/displacement of the Implant

Aseptic loosening of the implant is caused by a persistent instability. In Figure 8, an example for an aseptic loosening of an angular stable ventral instrumentarium (MACS TL, Aesculap, Tuttlingen, Germany) due to a persistent instability is shown: a patient with Bechterev's disease (ankylosing spondylitis) was injured and suffered from a distraction-compression-type injury (type B3) (T12) with an incomplete paraplegia. A posterior stabilization and decompression of the spinal canal by laminectomy was performed as an emergency operation. In the further course an additional endoscopic bisegmental spinal fusion with autogenous bone graft (from the left iliac crest) was performed, supplemented by an angular stable ventral plate system (MACS TL), secondarily. The retrospective evaluation revealed that an aseptic loosening of the dorsal devices was already seen at the time of revision surgery despite a sufficient reconstruction of the anterior column a loosening of the ventral instrumentation was seen in the following course. Revision surgery using a posterior approach and restoration of the tension band principle resulted in a definitive anterior fusion without any further surgical procedure.

Because 80% of the strength and load is transmitted to the anterior column, the ventral column has to be reconstructed (pressure-stable) with regard to the load sharing system. Additionally, a stabilization of the posterior column by a tension band wiring (tension band principle) is required to re-establish a distribution of the load and strength according to the "crane principle".

Type A (compression-type) fractures are treated by a single endoscopic reconstruction of the anterior column without any additional posterior stabilization. In monosegmental spinal fusion, compression stability is achieved by the insertion of a tricortical bone graft, predominantly supplemented by a ventral instrumentation with a plate. To guarantee pressure-stable support, adjustable distractible titanium cages are preferred for bisegmental spinal fusion.

Malposition of the implants should be avoided by consideration of the aspects summarized in Table 2.

Sinking of the Cage

Sinking of the cage is a problem and possible complication observed in adjustable distractible titanium cages (Figure 9).

Intact end-plates of the vertebral bodies are prerequisites to avoid a sinking of the cage; therefore an injury of the end-plates should be avoided during diskectomy, especially when using sharp instruments (e.g. sharp curette). Because the end-plates of the vertebral bodies are characterized by a more or less prominent concavity a flat contact to the end-plates of the cage cannot be achieved in all cases underlying the importance of the support by the stable end-plates of the body. Another possible explanation for sinking of the cage is the cage itself – the way and the extent of the adjustment and distraction of the cage is still an unsolved problem lacking standard values and requiring a high experience of the surgeon.

Instability Caused by Nonunions of the Bone Graft

Interbody fusion with an autogenous bone graft recovered from the iliac crest is the favorable type of biological healing and should be preferred, assumed that the fracture type is appropriate to this procedure. In some patients a nonunion of the bone graft due to resorption is seen (Figure 10). The incidence of a pseudarthrosis can be decreased by a standardized surgical technique. The following principles have to be considered in the anterior reconstruction of the spine:

- All tissues of the vertebral disk and the cartilage have to be removed from the caudal end-plate of the vertebral body.
- Regular healing of the bone graft required a cancellous bone contact area – this can be achieved by the use of a sharp curette (in contrast to the preparation of the end-plate for the implantation of a cage).
- The size of the bone graft has to be adapted exactly to the size of the defect caused by the diskectomy and corporectomy, ensuring insertion.
- Of the bone graft in pressfit-technique.

The insertion of an over- or undersized bone graft, respectively, results in an angulation of the graft with malalignment and reduction of the contact area leading to a delayed or nonunion of the autogenous bone graft.

In a clinical study performed by the authors [13], 43 patients (average age 40.9 years, level of injury T7–L1) who underwent video-assisted endoscopic vertebral body reconstruction by autogenous bone graft, recovered from the equilateral iliac crest, were followed up for 36 months. Two patients suffered from a nonunion of the bone graft requiring revision surgery with corrective spinal fusion. In two patients only an incomplete fusion was evaluated radiologically because of the absence of pain, discomforts, or clinical features, revision surgery was not indicated. In 39 patients (91%), a

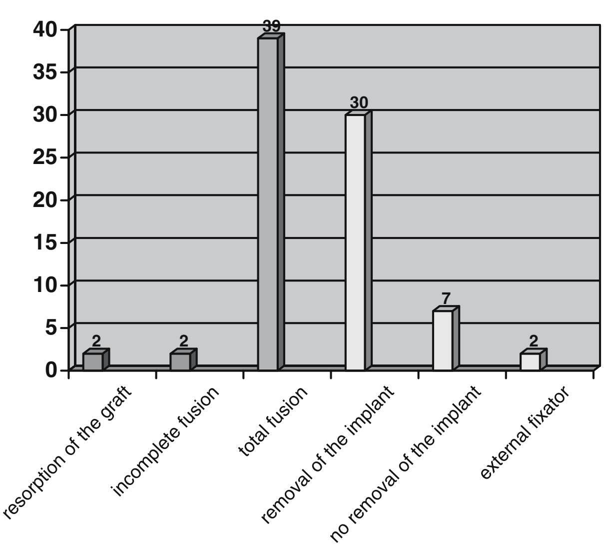
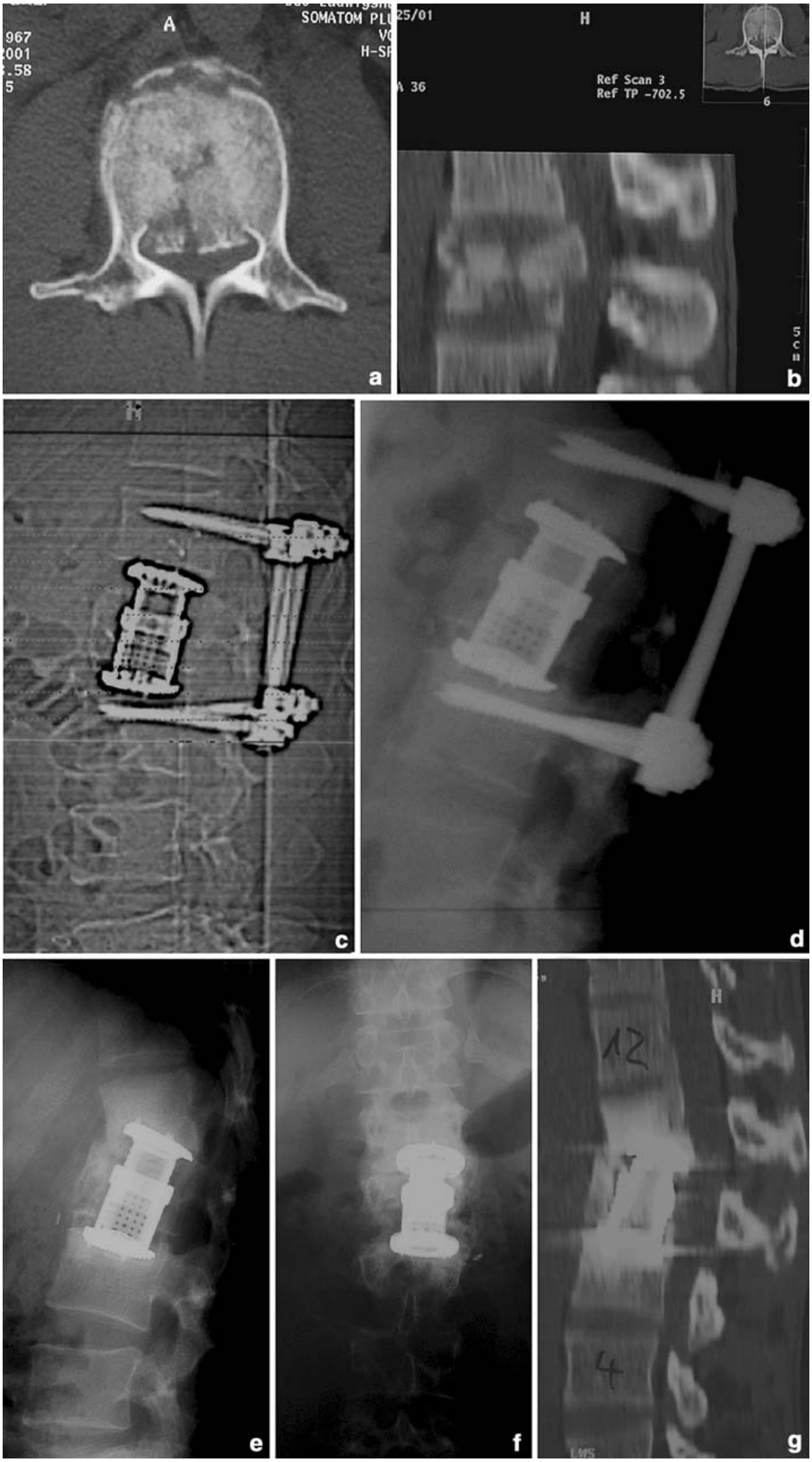
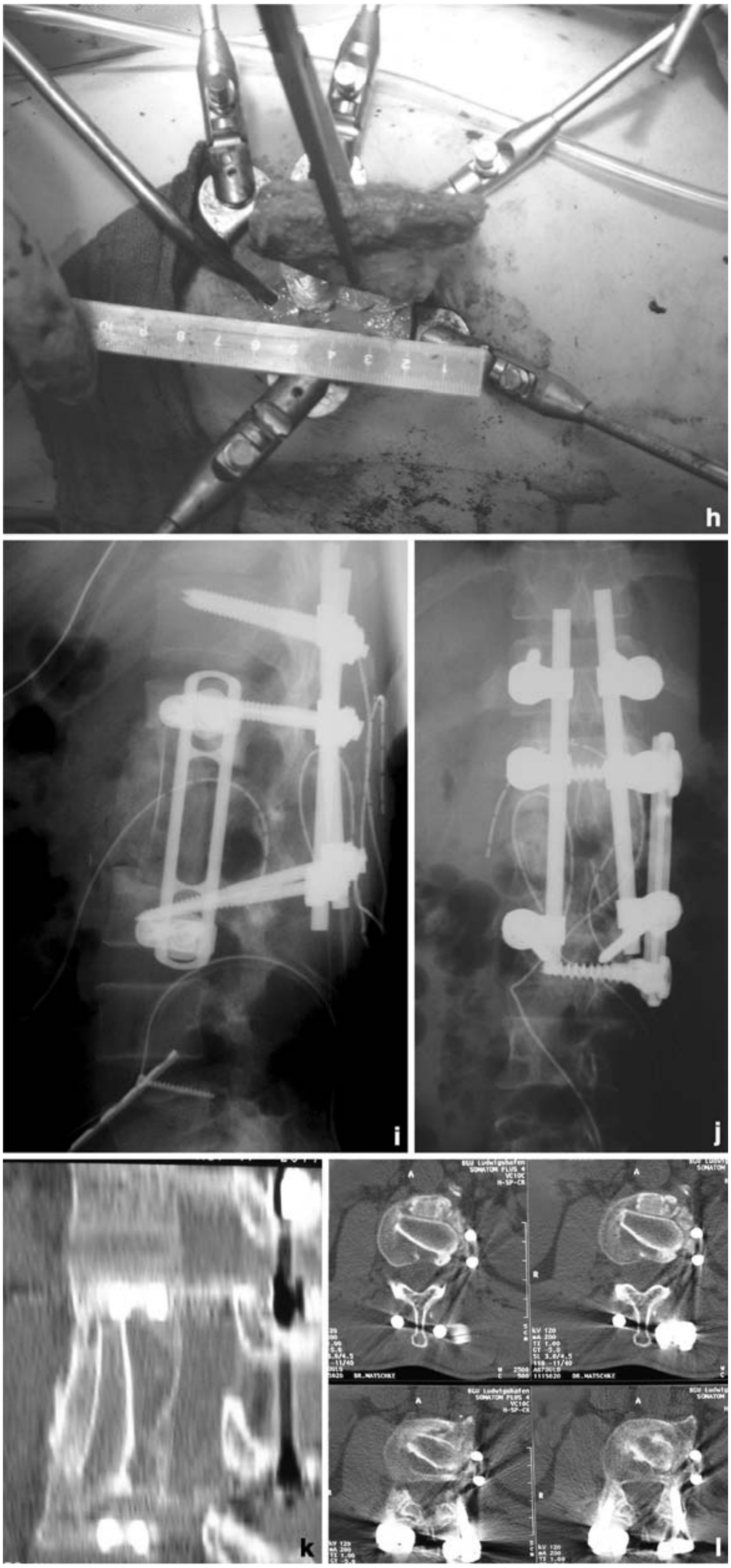


Figure 11. Follow-up of 43 patients after endoscopic ventral spinal fusion by interposition of a bone graft.



Figures 12a to 12l. A 34-year-old patient suffered a type 3.3 fracture L2 with an incomplete conus-cauda-syndrome (Frankel D) after falling from balcony. CT scans revealed a stenosis of the spinal canal (50%) (a, b). He was treated by a bisegmental spinal fusion with posterior stabilization, laminectomy and a ventral fusion using a cage (Synex) and cancellous bone (from left iliac crest). The postoperative X-rays are shown in (c) and (d). In the postoperative course a complete recovery of the neurological symptoms were seen (Frankel E). A removal of the dorsal devices (intraoperative bacteriology: S. aureus) was followed by a secondary loss of reduction with increasing posttraumatic kyphotic deformity (e–g) and persistent pain. The dorso-ventral-dorsal corrective spinal fusion was performed as a combined single-step procedure. In the first step a trisegmental posterior stabilization T12/L1 to L3 was performed followed by a ventral release with removal of the cage. In the second step a tricortical bone graft (7 cm) (h) and homologous cancellous bone (from iliac crest) were inserted endoscopically by a ventral approach. Finally, the stabilization was completed by a dorsal tension band wiring. The postoperative X-ray control is shown in (i) (lateral view) and (j) (anterior–posterior view), the follow-up 12 months after corrective spinal fusion in (k) and (l).



Figures 12a to 12l. (Continued).

reliable complete interbody fusion with the bone graft was seen: 30 patients underwent a removal of the dorsal implant, whereas in seven patients the implant remained. Two patients were treated initially with an external fixator that was removed at the end of the operation (Figure 11).

Infections

The endoscopic anterior reconstruction of the spine is a minimally invasive surgical procedure with preservation of the soft tissue; therefore the incidence of infections is extremely rare, which is confirmed by several studies [9, 10, 12–14]. An example is illustrated as a case report in Figure 12.

Nevertheless, harvesting the bone graft from the iliac crest can be complicated by approach-related complications [5] including local infection. Revision surgery of the spine due to infection can also be performed by endoscopic techniques.

Summary

The anterior endoscopic reconstruction of the injured spine bears the risk of different complications, including injuries of anatomical structures adjacent to the spine. Principles to prevent or to recognize these complications in minimally invasive spine surgery include a continuous visual control during the surgical procedure, e.g. during the opening or closing of the retractor. Prior to informed consent the patients have to be informed about the possibility to convert to an open approach, e.g. due to a sudden bleeding. Therefore, all instruments required for conversion to open thoracotomy must be available in theatre. In addition to these general guidelines a qualified risk management requires a permanent analysis and control at every stage of the surgical procedure.

A short checkup list for the different stages of the operation and associated complications and considerations is summarized in Table 3.

In summary, endoscopic anterior thoracolumbar spinal reconstructive surgery is a reliable and safe surgical procedure and a technique with a low complication rate and

Table 3. Checkup list for different stages of the operation and associated complications.

Stage of surgical procedure	Checkup
Preoperative management	Analysis of the fracture type, planning of strategy, computerized tomography (position of aorta, length of screws, dimension of bone graft or cage), reduction (one- or two-stage technique, external fixator), medical history, chest X-ray, lung function tests
Intraoperative management	Twin tube airway, position, marking
Approach	Portals, partial resection of a rib, splitting of the diaphragm (thoracic injuries)
Preparation of the situs	Dissection of segmental vessels, management in case of bleeding/ marking wires – risk of spleen lesions, position of aorta, pulmonary vessels, thoracic duct, esophagus, spinal cord
Diskectomy, corporectomy, decompression	Lesions of dura mater, spinal cord
Replacement of the vertebral body	Bone graft from iliac crest: size, preparation, insertion under control position
	Cage: size, end-plates, distraction; instrumentation
	Screws: length and direction

high benefit for the patient, provided that the above-mentioned recommendations and principles are considered at every stage of the operation.

References

1. Magerl F, Aebi M, Gertzbein SB, et al. A comprehensive classification of thoracic and lumbar injuries. Eur Spine 1994;3:184–201.
2. Passlick B, Born C, Mandelkow H, et al. Langzeitbeschwerden nach minimal-invasiven thoraxchirurgischen Operationen und nach Thorakotomien. Chirurg 2001;72:934–8.
3. Allardyce T, Ramsey M, Sokoloff B, et al. Early outcome of short–segment pedicle screw fixation and lumbar burst fractures. Presented on the AAOS Annual Meeting, San Francisco, 26 February 1996.
4. Knop C, Blauth M, Bühren V, et al. Operative Behandlung von Verletzungen des thorakolumbalen Übergangs. Teil 2: Operation und röntgenologische Befunde. Unfallchirurg 2000;103:1032–47.
5. Steffee AD. The variable srew placement spinal fixation system: report of a prospective study of 250 patients. Enrolled in Food and Drug Administration Clinical trials. Spine 1993;18:1160–72.
6. Wilkinson HA. The failed back syndrome. Ethiology and therapy, 2nd edn. Berlin Heidelberg New York: Springer, 1992.
7. Jacobaeus HC. Possibility of the use of the cystoscope for investigation of serious cavities. Munch Med Wochenschr 1910;57:2090–2.
8. Mack MJ, Regan JJ, Bobechko WP, et al. Application of thoracoscopy for diseases of the spine. Ann Thorac Surg 1993;56:716–38.
9. Beisse R, Potulski M, Bühren V. Endoscopic techniques for the management of spinal trauma. Eur J Trauma 2001;6:275–90.
10. Beisse R, Potulski M, Bühren V. Surgical technique and results of endoscopic anterior spinal canal decompression. J Neurosurg Spine 2005;2:128–36.
11. Borm W, Huber F, Haffke T, et al. Approach releated complications of transthoracic spinal reconstruction procedures. Zentrbl Neurochir 2004;65:1–6.
12. McAfee PC, Regan JJ, Zdeblick T, et al. The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery: a prospective multicenter study comprising the first 100 cases. Spine 1995;20:1624–32.
13. Davids D, Matschke S, Wentzensen A. Ist eine sichere mono oder bisegmentale Fusion bei operativer Versorgung thorakolumbaler Wirbelfrakturen mit autologen Beckenkammspänen zu erreichen? Presented at the 1st Joint Meeting of the German Societies of Orthopedics and Traumatology, Berlin, 21 October 2005.
14. Huang TJ, Hsu RW, Liu HP, et al. Technique of video-assisted thoracoscopic surgery for the spine: new approach. World J Surg 1997;21:358–62.
15. Kubik ST. Lagevarianten, Lage- und Formveränderungen der Pars thoracalis des Ductus thoracicus. Fortschr Röntgenstr 1975;122:1–5.

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