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REVIEW

C. Knop
L. Bastian
U. Lange
M. Oeser
M. Zdichavsky
M. Blauth

Complications in surgical treatment of thoracolumbar injuries

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C. Knop (✉) · M. Blauth
Department of Trauma Surgery,
Leopold-Franzens-University,
Anichstrasse 35, 6020 Innsbruck, Austria
e-mail: christian.knop@uibk.ac.at,
Tel.: +43-512-5042821,
Fax: +43-512-5042824

L. Bastian · M. Oeser · M. Zdichavsky
Department of Trauma Surgery,
Hannover Medical School, Germany

U. Lange
Department of Trauma Surgery,
Homburg University Hospital, Germany

Abstract The range of surgical methods for operative treatment of thoracolumbar injuries, with their different ways of approach, grafts and techniques, remains wide. The authors present sources of error and specific complications based on their own experience and on the results of a multicenter study of the Spine Study Group of the German Trauma Association (DGU). A systematic overview of possible mistakes and complications is first presented in anatomical order. A detailed analysis is then presented of the complications reported in a multicenter study, carried out prospectively between 1994 and 1996, on 682 patients operated for acute traumatic injuries of the thoracolumbar spine. In 101 cases (15%) at least one complication occurred intra- or postoperatively. In 41 patients (6%) a revision was performed, and in 60 patients (9%) complications without operative revision were observed. These complications were analysed according to the chosen method of initial treatment.

Keywords Spinal injuries · Spinal fixation · Surgical technique · Complications

Introduction

Operative treatment of thoracolumbar injuries has become increasingly important in recent years. The range of surgical methods, with their different ways of approach, grafts and techniques, however, remains wide [7, 8, 9, 32]. Since spinal injuries are usually rather rare lesions, the literature presents evaluations only on small and incongruous groups of patients. Data about complications typical for these operations are hence mainly based on individual cases.

In the present study, the authors present sources of error and specific complications based on their own experience and on the results of multicenter research conducted by the Spine Study Group of the German Trauma Association (DGU). The research was designed as a prospective study, carried out between 1994 and 1996, and included 682 patients operated on only for acute traumatic injuries of the thoracolumbar spine [32, 33, 34]. The results concerning the operative technique for the most frequently used procedure, posterior instrumentation with a transpedicularly fixed implant, are presented.

Typical sources of error and possible complications during operations addressing the thoracolumbar spine can be divided according to the individual steps of the operation:

- Mistakes at positioning and closed reduction of fractures
- Approach-related complications
- Mistakes regarding the decompression of the spinal canal
- Complications related to instrumentation and stabilisation
- Complications related to intervertebral fusion

In addition, there are general surgical complications, which are not specific to spinal operations.

Mistakes at positioning and closed reduction of fractures

After preoperative analysis of injury, assessment of instability, and planning of necessary closed reduction, rough reduction is exercised immediately before the operation in a prone position on the operating table. Here it is very important to correct kyphotic, scoliotic, translational, and rotational malalignment. In particular, the latter two can only be insufficiently controlled during the operation and must therefore be corrected before the operation and checked with an image intensifier in two planes. Exact setting can then take place during the operation using a fixateur interne. Possibilities for reduction during anterior surgery only, are limited. Here it is only possible to control the height of each segment and, to a certain extent, kyphosis and scoliosis during the surgery.

Approach-related complications

The posterior approach to the spine is seen as simple and not prone to complications. The greatest risk is that soft tissue such as muscles and joint capsules are permanently damaged due to unnecessarily extended exposure of the posterior parts of the vertebral segments.

The anterior approach is more dangerous. Each thoracotomy is accompanied by a – mostly temporary – respiratory functional restriction because of postoperative pain and the restriction of the chest wall muscles [30]. These restrictions of lung function can amplify problems arising from existing conditions, such as diseases or accompanying lung contusion, to a critical degree. For each anterior procedure, a preoperative evaluation of respiratory function and a careful postoperative supervision is necessary to quickly address possible complications such as dys- or atelectasis. For patients with accompanying lung contusion or multiple trauma, a thoracotomy during the first 2 weeks after the accident is not advisable [10].

As an alternative to thoracotomy, thoracoscopy has proved successful [5, 6, 11, 44, 47, 56]. With the necessary equipment and after training in the technique, thoracoscopy offers a significant reduction in the perioperative strain for the patient [41, 42]. Patients recorded significantly less postoperative pain and restrictions of lung function. Paraplegics, in particular, benefit from a reduced approach-related morbidity. The trunk muscles – so important for these patients – are less damaged and functionally restricted as a consequence of the endoscopic technique. At the same time, endoscopy achieves a better visualisation. In our view, this presents a great advantage regarding preparation of the vertebral end-plate and, in particular, decompression of the spinal canal.

Further complications of the anterior approach are discussed briefly.

Injury of the thoracic duct

The thoracic duct presents variations in its course, but usually follows the artery on the right side [40]. Complications appear mainly with left-sided thoracotomy and can result in a chylothorax. This complication is conservatively treated with a chest tube, but in individual cases with increasing loss of lymph during a fat-free diet, a surgical therapy with a ligature of the thoracic duct can become necessary [57, 61].

Injury of the azygos vein or hemiazygos vein

These veins usually run in a longitudinal direction, anteriorly above the vertebrae, and can suffer injury if the intercostal vessels are severed too far medially, or if the preparation is not performed close to the anterior longitudinal ligament or subperiostially. In case of injury, the vessel needs to be sutured or ligated.

Injury of greater vessels

Injury of the greater vessels is a very serious complication, which is of particular importance near the lumbosacral crossing. The patient rapidly loses large amounts of blood, and the operated area immediately becomes flooded. In this situation, pre-prepared vessel loops can be very helpful. Otherwise the bleeding must be stopped manually. For surgical treatment it may be necessary to mobilize the vessel further in order for it to be clamped. Since veins are usually lacerated on their bottom side, making access difficult, the vessel must be sufficiently turned and prepared for sewing without restrictions to be possible.

Injury of the ureter

The urinary duct is easy to recognize due to its cylindrical form, the delicate net of vessels under the surface and the peristaltic movement during palpation, and can be clearly distinguished from arteries. In case of partial or complete separation, the two parts are prepared sufficiently in length and are excised in parallel direction. After immobilisation of the urinary duct with a blind catheter in the bladder, anastomosis is done in a one-row “all-layer” single-step suture with absorbable sewing material.

Perforation of the peritoneum

The danger of perforating peritoneum is particularly evident subphrenically. The peritoneum should only be pushed aside as far as absolutely necessary. Usually these perforations can be closed with a continuous suture.

Disturbances of abdominal wall innervation

The front trunk muscles are motorically and sensorically innervated through the anterior branch of the thoracic nerves and the lumbar nerves. Cutting techniques adjusted to the nerves, applied only as much as necessary, help to avoid abdominal wall herniation.

Injury of superior hypogastric plexus

In particular when preparing big vessels, the nerve plexus can suffer damage, which can result in a retrograde ejaculation.

Presentation of wrong segment height

Due to anatomical variations, one can often err regarding assessment of the segment height. Checking this with an image intensifier is therefore absolutely necessary.

Mistakes during decompression of the spinal canal

The worst and most dreaded complication is a deterioration of the neurological status. The risk of neurological damage is greater at the level of the spinal cord and the medullary cone than in the area of cauda equina. The reasons are mostly technical mistakes. In rare cases dramatic deteriorations can sometimes occur without a clear reason. In these cases, after exclusion of all other causes, only vascular reasons remain. In general, new postoperative deficits have to be examined with the use of all available equipment. The overall risk of a neurological deterioration in total is to be seen as fairly small (cf. below).

The following measures can reduce the risk in anterior and posterior surgery:

- Careful, gradual dissection of the rear wall of the vertebral body with milling cutter and curet
- Access to the spinal canal at a less restricted or narrow area
- Working “away from the spinal canal” and avoiding any pressure on neural structures

Insufficient or incomplete decompression of the spinal canal is another typical complication. The relation between the extent of decompression and the recovery of neurological deficiencies is not statistically proven. However, whenever a neurological deficit is encountered, complete release should be achieved and the postoperative result should be checked using computed tomography (CT). In case of doubt, the decompression of the spinal canal can be checked intraoperatively, by myelography or ultrasound [1, 17]. In case of a postoperative stenosis, a decision should be made on an individual basis about whether or not a revision should take place.

Lacerations of the dura can result from poor preparation of the spinal canal and can usually be easily and continuously sutured. In case of very extended lacerations, one has to decide whether bone is going to be “sacrificed” through laminectomy, in order to reach the end of the laceration. If the closure is not complete, muscle tissue should be sutured to the area and fibrinous glue should be applied. A continuing liquor leakage, in particular in the thoracic area, demands a drainage through a lumbar catheter for several days [9].

Complications related to instrumentation and stabilisation

The technique of transpedicular screw fixation, introduced by Roy-Camille, offers the best possibility for correcting malalignments and stabilizing the injured segment of the spine. The procedure is technically difficult; risks and complications have already been well researched.

Cranial screw malalignment leads to reduced stability and possibly to injury of adjacent discs. The tip will very likely not have penetrated the endplate of the vertebra when it presents a distance of at least 3 mm on an exactly adjusted lateral or antero-posterior image [51]. In case of caudal perforation of the cortex of the pedicle, the nerve root may be injured. Medially, a sufficient safety distance can be expected due to the liquor surrounding the spinal cord. Bleeding from epidural veins can result in secondary neurological damage. Roy-Camille et al. [59] recommended a leeway of 2 mm for the lumbar spine. Gertzbein and Robbins [27] observed in their series two patients with slight neurological deterioration during restrictions of 4–8 mm; these deficiencies disappeared without specific measures being taken. Louis [46] also observed a “fairly small” rate of neurological complications in cases of pedicle perforation. West et al. [69] found a 7% neurological deficit after transpedicular fixation in a series of 61 patients. Castro et al. [13] controlled the screw position in four specimens of cadaveric spines and in 30 patients. Only about 60% of the screws, which had been attached under control of an image intensifier in two planes, were in the correct position. There was a good agreement between CT- and in vitro control. Five patients showed a neurological deterioration postoperatively; with all others, screws positioned 6 mm or further medially were found to be acceptable. All patients with a screw malalignment of 4 mm or less did not produce neurological deteriorations.

Lateral perforation of the cortex of the pedicle can also lead to poor stability, and results in insufficient convergence of the screws. In the thoracic area, the lungs, segmental vessels, sympathetic trunk and the artery are at risk. Anterior vessels can be lacerated. The round or heart-shaped form of the vertebrae must be taken into account with regard to the length of screws, in particular in the area of the pelvic spine. When working at the right thoracic pedicle, the esophagus, azygos vein and thoracic duct can be injured; through the left pedicle the artery can also be affected.

In order to accurately determine the distance between the tip of the screw and the front cortex of the vertebra, Krag et al. [39] recommended a projection at a 30°angle from the side view (“near approach view”). In cases of perforation of the cortical bone, George et al. [25] found 11% less stability in screw pull-out strength tests.

Misenhimer et al. [52] described, during implantation of a pedicle with too thick a screw, first a plastic deformation and then a fracture of the pedicle. Whenever the screw is bigger than the inner pedicle diameter, or bigger than 80% of the outer diameter, perforation of the pedicle wall was observed. According to research by Kothe et al. [38], who examined thin-layer bone cuts of 18 thoracic vertebrae, between 62 and 79% of the pedicle is accounted for by cancellous bone, with the cortical wall varying in thickness. They found the medial wall of the pedicle to be two to three times thicker than the lateral wall ($P<0.001$). If there is an incorrect relation between pedicle and screw diameter, it has to be expected that the outer wall will yield and subsequently deform.

For intraoperative control of the screw position, the screw canal should be inspected, e.g. with a length-measuring instrument. Less experienced surgeons are strongly advised to use X-ray control on two planes. Even this does not give absolute certainty: Weinstein et al. [68] analyzed on specimens the value of X-ray control for screw position. All screws were screwed in under anteroposterior and image converter control from the side. The authors found a poor agreement between judgements of the screw position made from radiographic images and the measurements made when the preparation was cut open: 26 out of 124 screws were in a wrong position, 92% of which were in the spinal canal! False-positive results occurred in 7%, and false-negative results in about 13% of cases. There was a clear learning curve: with the first four specimens the error rate was 26.4%, for the next four it was only 6.4%.

The tips of the screws must not touch each other (“kissing screws”) or overlap (“crossing screws”), because then they can run at least partially through the spinal canal. The same is valid when the tip of a screw crosses the midline – distinguishable at the spine of vertebra. A complex but very safe method is the computer-assisted pedicle operation [28].

Sjöström et al. [62] found 16 medial or lateral defects in 82 pedicles. Five screws penetrated the canal by up to a maximum of 3.5 mm. For 48 pedicles, pedicle width before instrumentation and after implant removal was compared: 31 pedicles were broader at the final control than preoperatively, and 14 presented deformations which indicated a fracture of the lateral pedicle wall. When the screw diameter exceeded 65% of the outer pedicle diameter, 85% of the pedicles became broader and extended. One-quarter of the screws had perforated the front wall.

Table 1 Scoring system for evaluation of pedicle screw placement in traumatic thoracic spine fractures, by Zdichavsky et al. [71]

Grade	Criteria for scoring pedicle screws
I a	≥ Half of pedicle screw diameter within the pedicle ≥ Half of pedicle screw diameter within the vertebral body
I b	> Half of pedicle screw diameter lateral to the pedicle > Half of pedicle screw diameter within the vertebral body
II a	≥ Half of pedicle screw diameter within the pedicle > Half of pedicle screw diameter lateral to the vertebral body
II b	≥ Half of pedicle screw diameter within the pedicle Tip of pedicle screw crossing the midline of the vertebral body
III a	> Half of pedicle screw diameter lateral to the pedicle > Half of pedicle screw diameter lateral to the vertebral body
III b	> Half of pedicle screw diameter medial to the pedicle Tip of pedicle screw crossing the midline of the vertebral body

If a medial or lateral perforation is observed during control of the drill canal, this can in most cases be corrected with a lot of fine-tuning. The turning-in of the screw needs to be exercised very carefully so as not to go in the wrong direction. If sufficient stability cannot be achieved, an adjacent segment must be “sacrificed”, and the vertebra immediately above or below must be instrumented.

In order to experience minimal complications and intraoperative “surprises”, the value of an exact preoperative analysis of axial CT cuts, to identify the frequent anatomical variations in particular in pedicles of the thoracic spine, goes without saying.

Zdichavsky et al. [71] developed a clinically relevant and reliable scoring system for evaluation of pedicle screw placement in traumatic thoracic spine fractures (Table 1). The scoring system is based on the relation of pedicle screws to the pedicle and vertebral body. Any such scoring system must be applicable independent of CT quality and metal artifacts, and the authors have proven the system to be easily and reliably utilized for evaluation of pedicle screw placement.

Further complications during instrumentation and stabilisation are briefly summarized in the following overview.

Liquor leakage after preparation of screw hole

In most cases of liquor leakage after preparation of the screw hole, the dural leak does not need to be exposed; however, a replacement of the screw is necessary, sometimes even by changing to the vertebra below or above. In case of continuing leakage, the spinal canal needs to be opened and the leakage needs to be closed.

Insufficient setting of malalignment

In particular with injuries extensive in length or where there is insufficient knowledge of reduction techniques with the available instruments, it can happen that the result of the reduction is misjudged on the intraoperative image of the image intensifier. In cases of serious deviation, revision surgery is the only option.

Overestimating bone quality

Overestimation of bone quality can result in loosening of implants and early loss of correction. It is well known that screw stability depends significantly on bone mineral density. Systematic research with patients, however, is not available yet. In case of doubtful stability of anchorage and advanced age, instrumentation should be applied over an extended length – although no limit can be given for this.

Faulty implant anchorage

Technically and anatomically faulty anchorage of implants presents another reason for treatment failure. Extrapedicular screw fixation, a lack of convergence and/or length of screws and insufficient tightening of mechanical links between screws and longitudinal support are examples of possible mistakes.

Screw fractures

Screw fractures are in the first instance dependent on the diameter and design of screws. Further factors are type and quality of anterior support and the presence of a nonunion as well as the time of implant removal.

Complications related to intervertebral fusion

For spinal fusion of injured segments, posterior and anterior techniques are available. Major complications include neurological deterioration as a result of these measures, biomechanical failure of the chosen technique of fusion with loss of correction and the absence of bone healing processes.

With the transpedicular bone grafting technique [14, 15], using the wrong length or incorrect position of the funnel can lead to parts of the graft getting into the spinal canal and causing neurological deficiencies. Even during positioning of an anterior strut graft, this dreaded complication can happen if a broad iliac crest graft is inserted like a bolt with the “tongue-and-groove” technique [37], leading to fragments of the rear edge being pushed in the direction of the spinal canal.

The question of the need for an anterior procedure and the stabilising role of anterior support in injuries involving the destruction of the anterior column of the spine cannot be answered sufficiently at the moment. Insufficient results after posterior treatment alone indicate that further restoration of the weight-bearing capacity is necessary, which can hardly be achieved using the transpedicular method. In this context, a biomechanically insufficient support with resulting loss of correction and insufficient healing and integration of the transplant has been shown [34, 35, 36, 45, 54, 65, 67, 70]. In other research, a solely posterior interlaminar spinal fusion did not have any influence on loss of correction [34, 36]. So far, results from the final stages proving the value of an anterior vertebral replacement utilizing titanium implants or strut grafts are lacking.

Possible reasons for strut graft pseudoarthrosis include a poorly prepared “graftbed” without careful preparation of the end-plates, and the suspension (“stress-shielding”) of posterior instrumentation, which avoids continuous intervertebral compression. It is recommended to compress the anterior column through the posterior implant [29, 64]. Alternatively, a removal of the implant can be taken into account, e.g., when the graft has a narrow lysis zone on one side, and on the other side has already begun to heal. Due to lack of protection, the graft usually heals quickly after implant removal, and a small loss of correction must be accepted. With graft fractures revision is only necessary in case of significant loss of correction.

Analysis of complications in a multicenter study of operative treatment of thoracolumbar injuries

Eighteen trauma centers in Germany and Austria participated in this prospective multicenter study of the Spine Study Group “Wirbelsäule” of the DGU. An important part of the research included analyzing complications arising during different operating methods, which are described in the following overview. An extensive description can be found in Knop et al. [32, 33, 34].

Patients and operative procedures

From September 1994 until December 1996, 682 patients (64% male) with an average age of 39 1/2 (7–83) years were included. The study includes patients operated exclusively for fresh thoracolumbar injury (T10–L2). Of the total number, 606 patients (89%) had suffered a mono- or bisegmental spine injury, with L1 the most often affected vertebra; 440 patients (65%) had suffered a compression (type A), 136 (20%) a distraction (type B), and 104 (15%) a rotational (type C) injury. The percentage of patients with additional neurological deficit increased in relation to the severity of spinal trauma, according to the Magerl

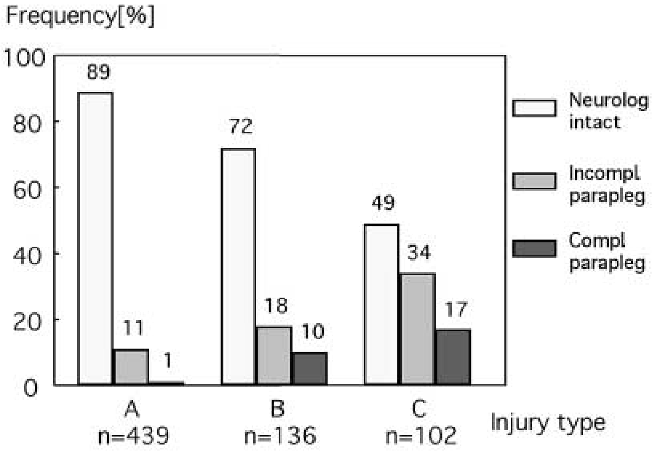

Fig. 1 Relative frequency of paraplegia according to a modified Frankel scheme (*Neurolog. intact* Frankel/ASIA E, *Incompl. parapleg.* Frankel/ASIA B–D, *Compl. parapleg.* Frankel/ASIA A [2, 24]) for the three main types of injury classified according to Magerl [48] (439 type A injuries; 136 type B; 102 type C; 5 patients without any data of classification or neurology)

classification [48] (Fig. 1). Isolated spinal trauma was found in 395 patients (58%), while 245 patients (36%) had suffered one or several additional injuries and 42 (6%) had suffered multiple trauma.

Of the 682 patients included, 448 (66%) were only operated on posteriorly. A combined approach was chosen for 197 (29%), and an anterior approach was used in 37 cases (5%). The groups did not differ significantly with regard to age or frequency of neurological and other injuries (Table 2). Data on operative details in the patient population can be found in Table 3.

Implants and number of stabilised segments

For posterior and combined operations (n=645), a stable-angle internal fixator system was used for reduction and stabilisation, mostly the Universal Spine System (USS), with Schanz screws (n=292; 45%) or with pedicle screws (n=134; 21%), and the AO-fixateur according to Dick (n=137; 21%).

Most surgeons stabilised two segments. Monosegmental instrumentation was chosen in 43 cases (7%) and trisegmental in 40 (6%). Only in exceptional cases were more segments stabilised.

In 29 of 197 combined operations (15%) a stabilising implant was used posteriorly and anteriorly. With isolated anterior operations (n=37), a stable-angle plate system (n=18) was mostly used (LDI- or Z-plate). Stable-angle plates (one or two) were used in 12 and stable-angle rod systems (Ventrofix or USS) in 4 cases. With three patients no implant was used. Twenty-seven bisegmental stabilisations and seven monosegmental ones were used.

Posterior approach

Of 448 patients with only posterior stabilization, 322 (72%) were treated with transpedicular bone grafting. In 241 cases it was monosegmental and in 7 cases a biseg-

Table 2 Frequency of three different operating techniques and data about the patient groups: values are presented as number (frequency in %) or mean value (min. – max); because of missing data, a sum of <100% can result

	Posterior	Combined	Anterior
Frequency of treatment	448 (65.7%)	197 (28.9%)	37 (5.4%)
Mean age [years]	40.1 (7–83)	38.7 (16–82)	40.5 (18–81)
Injury type A	295 (65.8%)	112 (56.9%)	32 (86.5%)
Injury type B	93 (20.8%)	40 (20.3%)	3 (8.1%)
Injury type C	58 (12.9%)	44 (22.3%)	2 (5.4%)
Without neurol. deficit	366 (81.7%)	145 (73.6%)	27 (73.0%)
Incomplete paraplegia	53 (11.8%)	43 (21.8%)	10 (27.0%)
Complete paraplegia	26 (5.8%)	8 (4.1%)	0 (0%)
Without concomitant injury	250 (55.8%)	117 (59.4%)	26 (70.3%)
With concomitant injury	169 (37.7%)	68 (34.5%)	8 (21.6%)
Polytrauma	29 (6.5%)	10 (5.1%)	3 (8.1%)

Table 3 Operative details and frequency of complications in the three treatment groups: values presented as number (frequency in %) or mean value (min. – max)

	Posterior	Combined	Anterior
Frequency	448 (65.7%)	197 (28.9%)	37 (5.4%)
Operative time [minutes]	134 (30–390)	254 (80–562)	218 (108–520)
Scanning time [seconds]	248 (6–1458)	222 (6–1320)	96 (3–330)
Blood loss [milliliter]	828 (0–8000)	1387 (200–8800)	876 (200–5500)
Without complication	385 (85.9%)	170 (86.3%)	26 (70.3%)
Revised complication	21 (4.7%)	16 (8.1%)	4 (10.8%)
Complication without revision	42 (9.4%)	11 (5.6%)	7 (18.9%)

mental *inter*corporal spinal fusion. With 74 patients the bone graft was only inserted *intra*corporally. Operating and X-ray durations were significantly prolonged because of additional transpedicular measures ($P<0.001$; *t*-test). The operation took on average 20 min longer (2 h 20 min vs 2 h) and intraoperative scanning time was prolonged on average by 1 h 16 min (4 h 29 min vs 3 h 13 min).

Additional interlaminar cancellous bone graft attachment and spinal fusion of vertebral joints was performed in about one-quarter of patients (n=114). Eighty-five of these belonged to the group of patients with transpedicular grafting; in another 29, the anterior column was not treated. Of 126 patients with only posterior reduction and stabilisation, 97 (77%) did not get any form of bone fusion.

Anterior approach

During anterior and combined operations (n=234), a thoracotomy was performed 131 times (56%), in order to treat fractures of T10 (n=3), T11 (n=11), T12 (n=47), L1 (n=69) and L2 (n=1). Thoracophrenolumbotomy was performed in 62 patients (27%), to treat injury of T12 (n=10), L1 (n=34) and L2 (n=18), while 36 patients (15%) with fractures of L1 (n=4) and L2 (n=32) were operated on through a lumbotomy. There are no data for five patients (2%) with regard to the anterior approach.

Decompression

Among measures for decompression, we distinguished between “direct” measures, i.e. opening of the spinal canal, and “indirect”, i.e. lordotic and distracting maneuvers within a preoperative closed setting and/or with the help of implants.

Of 144 patients (21%) with neurological deficiencies (Frankel/ASIA A–D; in four cases neurological status unknown), 127 (88%) – nearly all – were treated with measures to widen the spinal canal. In 98 patients (68%), the spinal canal was directly decompressed: 48 posterior, 33 anterior and 17 posterior *and* anterior. In 29 cases (20%), only “indirect” widening of the spinal canal was performed. The width of the spinal canal was intraoperatively checked in 40 (28%) of the 144 patients, using myelography.

In 538 patients (79%), no neurological symptoms were recorded on admission (Frankel/ASIA E). In spite of this, the spinal canal was decompressed in 386 (72%) of these patients: this was carried out “directly” (n=209; 39%) and “indirectly” (n=177; 33%) in nearly equal parts. “Direct” operative decompression was carried out 89 times posteriorly, 106 times anteriorly and 14 times posteriorly and anteriorly. The spinal canal was checked intraoperatively in 117 of 538 patients (22%): using myelography in 109 cases (20%) and sonography in 11 (2%) (3 were checked using both methods).

Complications

In 581 (85%) of the 682 patients, a complication-free course was recorded. In 101 cases (15%) intra- or postoperatively at least one complication occurred. The cases divide themselves into 60 patients (9%) without operative revision and 41 (6%) with a revised complication.

In the three treatment groups, different complication rates were observed (Table 3). The percentage of patients with at least one complication, revised or not, was the same in the posterior and combined treatment group, at 14%. In comparison, in the anterior access only group, the complication rate was significantly higher, at 30% ($P<0.05$; chi-square test). However, the significantly smaller size of the group of patients operated on from anterior alone must be taken into account (n=37).

The frequency of *revised* complications was at its lowest in the group with a posterior approach, at 4.7%; however, the difference between this and the rate for the combined treatment group, at 8%, was not significant (chi-square test). Revised complications occurred most frequently in the anterior approach group, with 11%; however, the differences with the rates of other procedures were not significant due to the small number of cases.

General complications

Among the general complications, seven deaths (1%) have to be reported first (Table 4). Three patients died because of a fulminant pulmonary embolism. The age of these patients was 22, 60 and 68 years respectively. There were no additional injuries of the pelvis or lower extremities; the first two patients had suffered paraplegia (Frankel/ASIA A and B). Two patients with multiple trauma died from their injuries after 3 and 4 weeks, respectively, in intensive care (aged 36 and 55). A 53-year-old patient died from pre-existing hepatic cirrhosis and terminal renal disease, and a 23-year-old patient without documented addi-

Table 4 General complications (n=27), frequency in relation to the total number of patients (n=682). Because of multiple listing, the result is a sum >100%

Complication	*n*	%
Death	7	1.0
Thrombosis followed by pulmonary embolism	6	0.9
Delirium tremens	5	0.7
Pulmonary complication	5	0.7
Abdominal complication	4	0.6

tional injury died on the 4th postoperative day because of lung failure.

Apart from the three patients who died from the complication, there were an additional six cases (1%) of thrombosis and subsequent pulmonary embolism: three of these patients had suffered no significant additional injuries, two had presented with an incomplete paraplegic lesion (Frankel/ASIA D) and injury of the pelvis or the lower extremities, and one had presented with incomplete paraplegia (Frankel/ASIA B).

Five patients suffered from other pulmonary complications: there were two cases of pneumonia, and reintubation became necessary due to respiratory deficiency in two patients; in one case a pleural effusion had to be drained.

The four recorded abdominal complications were: one ileus, one bleeding ulcer, and one posttraumatic pancreatitis after blunt abdominal trauma. Delirium tremens, observed in five cases, was a direct consequence of alcohol or drug addiction.

Operatively treated complications

The types of complications specific to this procedure that were treated operatively can be seen in Table 5. Of the infections that needed revision (*n*=15; 2%), two involved the bone harvesting site at the iliac crest; the same is true for 3 of the 12 wound healing problems. Nine patients had to undergo revision because of implant-related complications: in five patients a malalignment or instability was diagnosed postoperatively, while in four patients misplaced pedicle screws made a revision necessary.

There were two cases of liquor fistula: one resulted from iatrogenic intraoperative injury of the dura, the other was posttraumatic; both had to be revised. A sewn-in drain had to be operatively removed in one patient; another one had to have a revision of the femoral artery due to an embolus.

Table 5 Complications specific to the procedure that were operatively revised (*n*=40), frequency in relation to the total number of patients (*n*=682). Because of multiple listing, the result is a sum >100%

Complication	*n*	%
Deep infection	15	2.2
Hematoma/wound healing disorder	12	1.8
Instability or segmental malalignment	5	0.7
Misplacement of screw/implant	4	0.6
Persisting liquor fistula[a]	2	0.3
Sewn-in drain	1	0.1
Arterial embolism of femoral artery	1	0.1

[a]One of these was a liquor fistula with documented intraoperative injury of dura

Non-revised complications

The most frequently reported complication specific to the procedure that was not revised was heavy intraoperative bleeding (Table 6). Source and amount of bleeding were not further specified. In five cases (1%) an iatrogenic fracture of the pedicle resulted from the implant. In three of these patients, the pedicle screw was repositioned, in one patient the screw was fixed in the same position with bone cement, and in one, the screw was left in its original position without change. Two iatrogenic lesions were reported: one approach-related rib fracture and one injury of the peritoneum during lumbotomy.

Restriction of the spinal canal by about 30% due to transpedicularly inserted cancellous bone graft, observed in one case, did not result in neurological restriction. In three patients implant malalignment, in two an instability or increasing malalignment and in one patient a persisting liquor fistula were not revised. In one case a fracture occurred at the iliac crest, which was treated functionally, and two wound healing complications at the iliac crest were also not revised.

Table 6 Complications specific to the procedure that were not revised (*n*=29), frequency in relation to the total number of patients (*n*=682). Because of multiple listing the result is a sum >100%

Complication	*n*	%
Intraoperative bleeding	10	1.5
Iatrogenic pedicle fracture	5	0.7
Misplacement of screw/implant	3	0.4
Instability or consecutive malalignment	2	0.3
Infection/healing disorder iliac crest	2	0.3
Not specified	2	0.3
Iatrogenic rip fracture, approach related	1	0.1
Iatrogenic lesion of pleura/peritoneum	1	0.1
Narrowing of spinal canal with bone graft	1	0.1
Fracture of iliac crest after graft harvesting	1	0.1
Persisting liquor fistula	1	0.1

Table 7 Neurologic revised and non-revised complications (*n*=13), frequency in relation to the total number of patients (*n*=682). Because of multiple listing the result is a sum >100%

Complication	*n*	%
Peripheral lesion of nerve/root[a]	5	0.7
Remittent neurologic deficit	4	0.6
Neurologic deterioration (Frankel/ASIA E→D)	2	0.3
Neurologic deterioration (Frankel/ASIA D→A)[b]	1	0.1
Paresthesia without neurologic deficit	1	0.1

[a]Three of these lesions were after documented intraoperative root or nerve injury
[b]Operatively revised

Neurological complications

Neurological complications occurred in 13 patients (2%) (Table 7). One patient suffered complete paraplegia (from Frankel/ASIA D to A) which, despite immediate revision, did not improve. The 29-year-old patient presented a burst-type injury (A 3.2.1) of T12, suffered no additional injuries, and was posteriorly stabilised on the day of the injury (AO fixator, transpedicular intercorporal fusion, no decompression). With incipient paraplegia, the patient un-

Table 8 Overview of the literature about complications during operations of the pelvic and thoracic spine (*n* number of all patients, *k* number of patients with complications, *rev*. revised)

Authors	*n*	*k*	Operative treatment and patients	Complications and comments
Been & Bouma 1999 [4]	19	5 (26%)	Posterior, AO-fixator, only trauma	4× implant failure (without consequence), 1× rev. infection
Been & Bouma 1999 [4]	27	4 (15%)	Combined anterior-posterior, Slot-Zielke, CD, only trauma	2× misplaced screw (without consequence), 1× implant failure (without consequence), 1× rev. infection
Carl et al. 1992 [12]	38	11 (28.9%)	Posterior, Cotrel-Debousset system, only trauma	10× implant failure, 1× deep wound infection
Daniaux 1986 [14]	44	4 (9.1%)	Posterior, different implants, mixed patient group	1× wound infection iliac crest, 1× deep venous thrombosis, 2× implant breakage
Defino and Rodriguez-Fuentes 1998 [16]	43	11 (26%)	Combined posterior-anterior (USIS), iliac crest strut graft, only trauma	4× death (3× pulm. embolism, 1× sepsis), 4× infection, 1× neurologic deterioration, 1× meningitis, 1× Stevens Johnson Syndrome
Dick 1987 [18]	183	15 (8.2%)	Posterior, internal fixator, mixed patient group	1× fatal pulm. embolism, 8× wound infection, 2× transient radicular symptoms, 2× permanent radicular symptoms, 1× implant breakage, 1× misplaced implant
Dickson et al. 1978 [19]	59	26 (44.1%)	Posterior, Harrington rod system, only trauma	Many implant-related complications
Eysel et al. 1991 [20]	125	23 (18.7%)	Posterior, different implants, only trauma	2× death, 1× pulm. embolism, 4× neurol. deterioration, 5× wound infection
Faciszewski et al. 1995 [21]	1223	495 (40,5%)	162 anterior, 674 one-stage combined, 387 two-stage combined, mixed patient group	Retrospective 1969–1992: 4× death (2× pulm. embolism), 10× pulm. embolism altogether, 19× wound infection, 2× paraplegia due to loss of correction, 6× transient peripheral neurologic deficit, 1× nerve root lesion
Feil & Wörsdörfer 1992 [22]	58	9 (15.5%)	53 one-stage combined, 5 two-stage combined, only trauma	Late complications included
Gertzbein 1992 [26]	820	204 (24.9%)	113 anterior, 607 posterior, 84 combined, 16 posterolateral, mixed patient group	6× neurologic deterioration, 12× wound infection, 20× wound healing disorder, 102 implant-related complications
Kaneda et al. 1997 [31]	150	?	Anterior, Kaneda system, only trauma	9× implant failure, 1× lesion of vena cava, 4× infection, 3× urinary tract infection, 10× atelectasis, 5× transient peripheral neurologic deficit, 15× transient sympathectomy-effect (after exposure of L4/L5)
Knop et al. 2001 [36]	29	2 (6.9%)	Posterior, internal fixator, only trauma	1× thrombosis with cons. pulm. embolism, 1× wound healing disorder
Knop et al. 2001 [35]	56	2 (3.6%)	Posterior, internal fixator, only trauma	1× infection, 1× pedicle fracture (screw intraoperatively repositioned)
Mayer et al. 1992 [49]	40	5 (12.5%)	Posterior, different implants, only trauma	4× infection, 1× neurologic deterioration
Place et al. 1994 [55]	65	18 (28%)	Only thoracic spine, different methods, only trauma	2× pulm. embolism, 3× wound healing disorder, 1× liquor fistula
Sasso & Cotler 1993 [60]	70	?	23 Luque rod system, 23 AO-plate system, 24 Harrington rod system, only trauma	High infection rate: Luque rod system 26%; AO-plate system 4%; Harrington rod system 9%
Spivak et al. 1994 [63]	91	48 (53%)	48 one-stage combined, 43 two-stage combined, mixed patient group	Minor complications included; complication rate ("major complications"): 25 out of 91 (27%)
Wawro et al. 1994 [66]	14	2 (14%)	Posterior, internal fixator (only mono segmental), only trauma	1× intraop. lesion of pleura with cons. pleura drainage; 1× rev. wound infection

derwent revision on the 3rd postoperative day, with laminectomy and decompression of the spinal canal.

The neurological status deteriorated by one grade in two patients (from Frankel/ASIA E to D). One of these was a 49-year-old patient with burst type fracture (A 3.2.1) of L1 (no neurological deficit, in addition rib fractures, injury of one leg), who was stabilised posteriorly on the 4th day after the accident (Wolter plate-fixator, transpedicular intercorporal fusion) and a rear wall fragment was removed via laminotomy. There was no operative revision; on leaving hospital the patient was able to walk with motor function grade 4 of all muscles of the lower extremities. The second patient had suffered a burst type fracture (A 3.2.1) of L2, with an additional pelvic injury with symphysiotomy, fracture of the sacrum and a left femoral fracture. On the day of the accident the patient was stabilised posteriorly (USS, no decompression, scheduled for two-stage combined operation). Postoperatively, a reduction of force on the left side was observed, and during anterior approach 11 days later, decompression via partial corporectomy was performed. Due to concomitant injuries, there is a possibility that the patient had suffered an initial neurological deficit, which had been overlooked.

In five patients, a peripheral nerve or root lesion occurred. In one, the right-hand L2 root was injured through a wrongly positioned screw; in another the right-hand L3 root was injured when a fragment of the rear wall was pushed back; in a third, the long thoracic nerve was damaged because of malpositioning on the right side; in a fourth, the ilioinguinal nerve was damaged without any further information being reported; and in the fifth, the lateral femoral cutaneous nerve was damaged during bone harvesting at the left iliac crest. Four patients suffered a temporary neurological restriction: three patients suffered bladder/rectum problems, and one had a problem in the leg, but no further information was reported. One patient complained about intractable burning paresthesia, with no further information reported.

Discussion

Due to its design, the study presented here is not without disadvantages. One disadvantage is that it is a multicenter survey, and therefore the findings will be affected by differences in operating methods and criteria of judgement between participating clinics. We would like to emphasize that members of the Spine Study Group (Arbeitsgemeinschaft “Wirbelsäule”, DGU) in a first step, which required a great and united effort, initiated the planning of the study. A complex protocol for the documentation of treatment and follow-up data was developed, so that collection of data could take place according to certain standards [32, 33, 34]. This allowed us to look at a large group consisting of nearly 700 patients. Only operations on acute and traumatic lesions of the thoracolumbar spine were taken into account. Criteria for inclusion in this study were further supervised through the process of entering data into the databank.

The literature contains many very different reports about complications in the surgical treatment of thoracolumbar injuries. Table 8 presents an overview of this topic. Many studies report on non-homogeneous patient groups with different indications, among whom trauma patients constitute only a part [14, 21, 26, 63]. Another disadvantage with regard to the comparability of studies in this field is that complications are of varying importance in the respective contributions, and that complications are listed from a certain severity onwards [14, 50, 58]. Some authors distinguish between “minor” and “major” complications [63]. The studies also differ with regard to the length of the observation period. Therefore, complications occurring later on, or during the follow-up period, which are not analyzed

Table 9 Summary of a survey [3] analyzing individual intraoperative measures in cases of a complications (questionnaire answered by 31 surgeons of 13 clinics within the Spine Study Group of the German Trauma Association)

Question/Measure in case of...	Most frequently chosen answer (no. of surgeons, *n*=31)
Intraoperative measures in case of perforation of the medial pedicle wall	Drilling of corrected canal (14/31) Correcting the screw when tightening it through “lateralisation” (13/31)
Intraoperative measures in case of perforation of the lateral pedicle wall	Correction of screw through “medialisation” (12/31) Leaving the screw in a tight position, or redrilling (11/31)
Intraoperative measures in case of liquor flow from the drill hole	Lateralisation or redrilling (16/31) Laminotomy, eventually dura suture (12/31) Laminotomy, eventually fibrinous glue, Tabotamp or Lyostypt (4/31)
With regard to screw position, have you ever experienced consequences from postoperative CT images of the thoracic (T1–T10) or thoracolumbar area (T11–L5) that could not have been achieved using conventional images or image converter examination?	Thoracic “yes” (17/31) Lumbar “yes” (8/31)
Would you consider postoperative CT necessary in a routine case, for the sole purpose of controlling screw position?	Yes (10/31) No (21/31)

in our study, are taken into account in different ways in different studies [12, 19, 21, 23, 26, 31, 50, 58, 60].

When evaluating the studies, it must also be taken into account that some authors report on their own methods or instrumentation [14, 15, 18, 31, 53]. Details of the variability of operative treatment among the small group of spinal surgeons within the German Trauma Association were described by Bastian et al. in a study based on a survey conducted in 1995 [3]. Thirty-one spine surgeons from 13 clinics participated in filling in a questionnaire about the individual measures they took against intraoperative complications. Only half of the answers to each of the 17 questions were in agreement, and could therefore be taken to reflect prevailing opinion. Of course, personal experience and habits play a major role in selecting a technique. Therefore, rarely used variants should not be seen as “inferior”. The most frequently given answers are summarized in Table 9.

Dickson et al. [19], McAfee and Bohlman [50], and Riebel et al. [58] reported high rates of complications after use of the Harrington rod system. Since the introduction of the internal fixator, this implant is no longer of any importance for spinal treatment in the German-speaking countries – a finding that is also clearly proven by this study [32]. Complication rates when using the internal fixator seem to be significantly lower [7, 8, 9, 14, 15, 32, 43, 45, 53].

In comparison with published reports in the literature, the complication rate in our study can be categorized as low. With regard to frequency, the large percentage of patients with additional injuries (*n*=287; 42%) must be taken into account, as should the fact that it is a prospective and extensive documentation of all complications, which includes complications that were not revised. Only in three patients, free of any neurological complications, did a pulmonary embolism occur without any reason, and there was one fatal case, which presented with neither neurological problems nor severe additional injury or previous illness.

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