

## Surgical Management of Neurogenic Claudication in 100 Patients with Lumbar Spinal Stenosis Due to Degenerative Spondylolisthesis

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### Summary

100 consecutive patients with neurogenic claudication due to segmental spinal stenosis in degenerative spondylolisthesis have been analyzed prospectively with respect to their clinical presentation, radiological and intra-operative findings, operative techniques and surgical results.

By including 6 patients who had to be operated upon again overall results were excellent in 91, good in 4, satisfactory and moderate in 2, respectively, and poor in 1 patient (mean period of post-operative observation: 2.9 years).

Three different techniques of spinal instrumentation are evaluated with respect to the surgical results. After microsurgical decompression of the neural elements 38 patients were fixed using the translaminar screw fixation method according to Magerl (re-operation necessary in 5), in 9 patients spondylodesis was achieved by the plate fixation method according to Louis (re-operation necessary in 1) and in 53 patients (as well as in the 6 patients who had to be re-operated on) primary Cotrel-Dubousset instrumentation was used.

The best surgical results were obtained by laminectomy and Cotrel-Dubousset fixation. Instrumentation of more than 1 motion segment was restricted to patients with additional scoliosis or severe degenerative changes of the lumbar spine.

**Keywords:** Degenerative spondylolisthesis; pseudospondylolisthesis; neurogenic claudication; spinal fusion; CD-instrumentation.

### Introduction

Neurogenic claudication due to segmental spinal stenosis represents a common spinal disorder in cases of degenerative spondylolisthesis (DS) in whom Neurosurgeons and Orthopaedic Surgeons get frequently involved.

Whereas the classical neurosurgical treatment consisted in decompressive laminectomy without spinal stabilisation<sup>1, 5, 6, 9, 11, 12</sup> modern surgical treatment consists in a combination of both decompressive and stabilizing procedures<sup>2, 3, 8, 9, 10, 12</sup> because degenerative spondylolisthesis has been recognized to be the origin

of spinal stenosis and a single decompressive procedure would increase the risk of further olisthetic movement of one vertebra on the other.

Therefore DS with spinal stenosis and neurogenic claudication has become a classical neuro-orthopaedic domain and while the operative technique of decompressive laminectomy remained classical, the mode of spinal stabilization and especially the choice of the type of instrumentation is still under debate and handled differently in different spinal centers<sup>2, 3, 8, 9, 10, 12</sup>.

The aim of this presentation is to report the experiences with different spinal implants and the demonstration of our present therapeutic concept in a prospectively studied large series of DS operated by one surgeon (Markwalder) using modern neuro-orthopaedic techniques.

### Clinical Material and Methods

100 consecutive cases with DS were investigated according to the protocol described below. There were 60 female and 40 male patients with ages varying from 47 to 83 years (average age: 64 years). DS with spinal stenosis was located at the L2/L3, L3/L4, L4/L5, L5/S1 and multiple levels in 2, 11, 74, 1, and 12 instances, respectively, according to the classification of Meyerding<sup>20</sup>. DS was of Grade I, Grade II, and Grade III – type in 15, 84, and 1 patient, respectively.

#### *Clinical Features and Examination*

Apart from the classical neurological examination, signs of spinal instability according to the previously described diagnostic approach were looked for<sup>16, 19</sup>.

#### *Radiological Investigations*

Conventional x-rays of the lumbar spine, including functional studies were undertaken. Maximal forward and backward bending was done for detection of translational and rotatory instability along the z- and x-axes, respectively. The degree of spondylolisthesis was

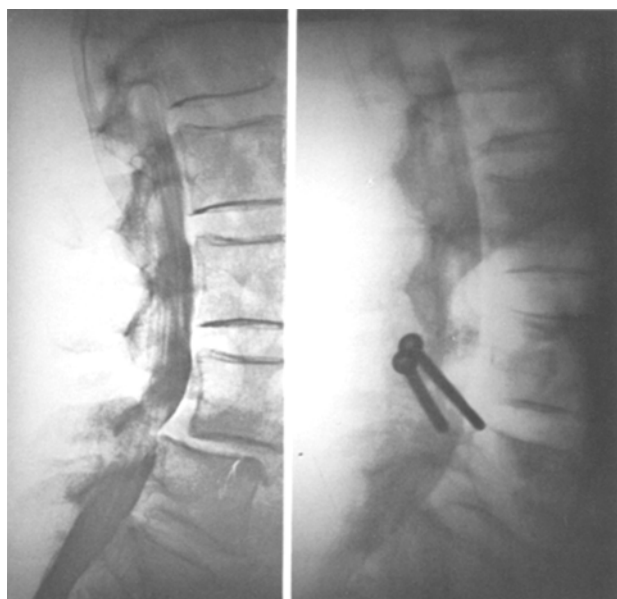


Fig. 1. Pre- and post-operative radiographs of the lumbar spine in a case with DS operated on using the translaminal screw fixation technique. Reolisthesis occurred after mobilization of the patient (see text)

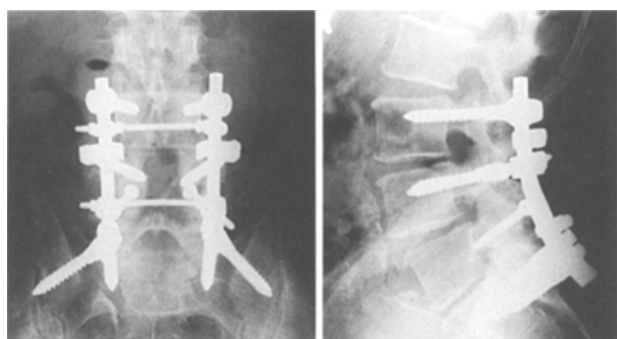


Fig. 2. Post-operative radiographs of the lumbar spine in a case with DS L4/L5 operated on using an extensive CD-implant

measured according to Meyerding<sup>20</sup>. In cases of additional degenerative scoliosis of the lumbar spine bending tests in the AP-view were performed in order to characterize the rigidity of the curves. The neuroradiological work-up consisted in lumbar myelography, completed by CT-scanning. Since 1991 nuclear magnetic resonance imaging (MRI) as a single non-invasive investigation became the investigation of choice more and more.

#### Indication for Surgical Treatment

Operative treatment was indicated when the patients suffered from neurogenic claudication and vertebral instability which considerably restricted their daily and, in some instances their sportive activities, in the presence of DS with neuroradiological demonstration of significant spinal stenosis.



Fig. 3. Pre-operative radiograph of the lumbar spine in a case of DS

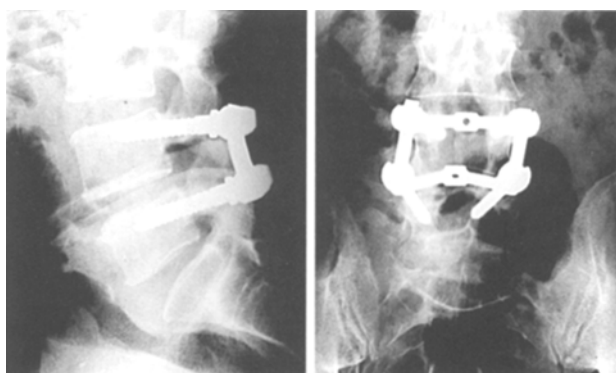


Fig. 4. Post-operative radiographs of the patient presented in Fig. 3. "Short" instrumentation by CD-implants with interpedicular plates according to Chopin

#### Surgical Techniques

Microsurgical techniques were used for surgery within the spinal canal and, if necessary, for the removal of the intervertebral disc.

In cases of translaminal screw fixation according to Mageri<sup>15, 17</sup> decompression of the dural sac and nerve roots was obtained by bilateral fenestration and medial arthrotomy (Fig. 1).

In cases of plate fixation according to Louis<sup>13, 14</sup> and Cotrel-Dubouset-instrumentation (CD, 4) a classical laminectomy with operative reduction of the hypertrophied facet joints was performed.

In cases of translaminal screw fixation and internal fixation with screw plates axial traction was used during surgery [the head of the patient was fixed to a frame using a Crutchfield-clamp and traction was achieved by extension on the lower limbs (up to 30 kg)]. In CD-instrumentation reduction of the olisthetic vertebra was achieved by the use of double-threaded screws and reposition hooks (Fig. 2). While in cases of translaminal screw fixation the stabilization was restricted to the olisthetic motion segment, one vertebra above was frequently included and the instrumentation was extended to the sacrum in cases of plate fixation or CD-techniques.

More recently I was satisfied with fixation of the olisthetic segment alone using CD and interpedicular plates according to Chopin<sup>4</sup> (Figs. 3 and 4). In all instances the fixation was completed by posterolateral bony fusion. Intra-operative myelography was performed in all cases of plate fixation and CD-instrumentation in order to confirm the correct position of the pedicular screws.

#### *Post-Operative Management*

In cases of translaminar screw fixation and plate fixation the patients were externally immobilized in a removable plastic jacket during a three month's period. In cases of CD-stabilisation a simple belt with metal grips was used.

#### *Controls and Evaluation of Results*

Clinical evaluation was done at discharge, 1.5 and 3 months after operation. At the time of final evaluation the patients were contacted by telephone and if they did not describe their state of health as being good, they were re-examined and, in 6 instances, re-operated using CD-techniques (see below).

Radiological evaluation by plain x-rays was done at discharge, 1.5 and 3 months post-operatively. The criteria for evaluation of the surgical results were as follows: Excellent = Normal working capacity in previous or comparable activity, nor or only occasional residual pain; Good = Normal working capacity in previous or comparable activity, mild residual low-back pain or dysaesthesia in lower limb(s); Satisfactory = Reduced working capability, but working in less heavy activity, residual low-back pain and pain in lower limb(s); Moderate = Incapable of work, low-back pain and pain in lower limb(s) slightly improved; Poor = Incapable of work, pain unchanged or worse.

## **Results**

### *Clinical Presentation*

When examined at rest, the neurological status revealed no abnormalities in 52 patients. In 48 patients radicular symptoms were present and varying from abolition of tendon reflexes alone to severe paresis of the lower limbs in cases with DS with additional degenerative scoliosis of the lumbar spine. A typical instability pattern was found in 24 patients, predominantly in cases of DS with scoliosis. Additional pseudoradicular symptoms due to irritation of facet joints were

only present in the scoliosis group and absent in the patients with DS only although instability could be proved in all instances through reposition of the olisthetic vertebra by intra-operative traction or direct instrumentation (Table 1).

### *Radiologic Findings*

There was a consistency between radiological, neuroradiologic and intra-operative findings in 100% of the cases. The functional x-ray studies allowed one to detect translational instability in the z- and rotational instability in the x-axes in 30 patients although instability was proven to be present by the fact that reposition could be achieved by intra-operative traction or direct instrumentation in all instances. Especially in cases with additional scoliotic deformities of the lumbar spine. Myelographic studies completed by CT scanning proved to be the most useful pre-operative investigation. Otherwise lumbar myelography and MR-imaging were judged as being equal diagnostic tools for the detection of spinal stenosis in DS.

### *Intra-Operative Findings*

In all cases the vertebral arch of the olisthetic vertebra was responsible for posterior compression of the dural sac. Lateral compression (particularly the compression of the respective nerve root at the affected level) was due to hypertrophy of the ligamentum flavum and median hypertrophy of the facet joints whose joint axes were newly oriented from the sagittal to the frontal plane. Anterior compression was due to bulging of the intervertebral disc in all instances, discectomy however was necessary in 12 patients in whom despite intra-operative traction or instrumental distraction (CD-technique) sufficient reduction of disc bulging could not be achieved because of additional disc herniation.

Table 1. *Clinical Findings in Degenerative Spondylolisthesis with Neurogenic Claudication (n = 100)*

Clinical findings	No. of patients
Neurogenic claudication	100
Neurological status at rest:	
– normal	52
– discrete radicular signs	25
– severe cauda equina dysfunction	23
– additional pseudoradicular symptoms	15 (all with additional scoliosis)
Typical instability pattern	24 (all with additional scoliosis)

### Clinical Results

By application of the evaluation criteria mentioned above and including the final results of the 6 patients who were submitted to reoperation, excellent, good, satisfactory, moderate, and poor results were obtained in 91, 4, 2, 2, and 1 patients, respectively (Table 2). The period of post-operative observation varied between 3 months and 6 years (mean period 2.9 years). Because overall results include patients who had to be re-operated upon an analysis of the results with respect to the technique of internal fixation is mandatory.

The first 38 patients were treated surgically by bilateral fenestration, facet joint reduction and translaminar screw fixation with posterolateral bony fusion (Fig. 1). In all of these patients intra-operative reduction of the olisthetic vertebra was achieved, however about 10 days later, after mobilization of the patient, and at 3 months, the degree of olisthesis was nearly of the same amount as pre-operatively on check x-ray films. 33 of these patients were free of symptoms in spite of the olisthetic position of the affected motion segment. Solid posterolateral bony fusion had occurred 3 months after the operation. However, in 5 of these patients, neurogenic claudication re-appeared and myelographic studies again demonstrated a compression of the neural elements necessitating another intervention which now consisted in laminectomy and CD-fixation because of insufficient decompression and pseudoarthrosis formation. Among the 38 patients operated on by translaminar screw fixation the results were as follows: 32 were judged as excellent, 1 was judged as good, 4 were judged as moderate and 1 was estimated to represent a poor result. The four patients judged as

moderate and the patient with a poor result were re-operated on using CD-fixation leading to 4 excellent results and an unchanged condition in the patient with a primary poor result (a patient with severe osteoporosis and scoliosis of the lumbar spine, Table 2).

Another 9 patients were primarily treated by laminectomy and plate fixation according to Louis, combined with a posterolateral bony fusion because of heavy body weight necessitating a more rigid instrumentation. Among this group of patients 8 excellent and one moderate result were obtained. Again the patient with the moderate result was operated on using CD-techniques leading to an excellent result (Table 2).

CD-instrumentation (Figs. 2-4) has primarily been used for the last 53 patients and in the 6 cases who had to be re-operated upon because of insufficient decompression and/or pseudoarthrosis formation. Among these 53 patients primarily operated on by laminectomy and CD-instrumentation 48 patients had an excellent result, 4 were judged as good and 1 as moderate (subsequent investigation demonstrated degenerative spondylolisthesis of the adjacent motion segment with spinal stenosis and reappearance of neurogenic claudication, Table 2).

Intra-operative correction of olisthesis was maintained up to the time of posterolateral bony fusion.

### Complications and Special Post-operative Events

Table 3 shows the complications and unusual post-operative courses in our patients.

Dural tears occurred in 3 instances, complicated by pseudomonas meningitis in one patient. In this patient the dural leak was secondarily closed using a muscle

Table 2. Surgical Results in Degenerative Spondylolisthesis and Neurogenic Claudication with Respect to the Type of Spinal Instrumentation (n = 100)

	Translaminar screw fixation (n = 38)	Plate fixation (n = 9)	CD-tech- niques (n = 53)	Total* (n = 100)
Excellent	32	8	48	91
Good	1		4	4
Satisfactory	—	—	—	2
Moderate	4	1	1	2
Poor	1	—	—	1
Re-operation (CD-techniques)	5	1	—	
	— 4 excellent	— excellent		
	— 1 poor			

\* Results following re-operation; Criteria for evaluation of results: see text.

Table 3. *Complications and Special Post-operative Events in 100 Patients Operated on for Degenerative Spondylolisthesis with Spinal Stenosis*

Complications	No. of patients
Infection	1
Dural tear	3
Transient neurologic deficit after correction of additional scoliosis	11
Breakage of CD-implant	2
Insufficient decompression / pseudoarthrosis formation necessitating re-operation by CD-techniques	6

patch which was attached to the dura by fibrin glue and meningitis was successfully treated by intravenous antibiotics.

In one patient (with DS L4/L5 and severe scoliosis of the lumbar spine with myelographic evidence of complete vertebral canal obstruction and foot drop on the left side) laminectomy and CD-fixation with correction of the scoliotic deformity was followed by complete remission of the severe back pain, partial remission of the foot drop but a post-operatively apparent transient paresis of L3-innervated muscle groups on the right. It is most likely that the latter was due to the correction of the scoliosis with tightening of nerve roots on the now corrected concave side of the scoliotic curve. Similar phenomena occurred in 10 other patients who presented with transient cauda equina symptoms after reposition of the olisthetic vertebra and scoliosis correction. However, complete restoration of neurological dysfunction occurred in all these patients (these transient neurological deficits after CD-stabilisation will be object of a separate report).

Breakage of osteosynthetic implants occurred in two instances with CD-instrumentation, however, the breakage of the pedicle screws occurred only after bony fusion had already taken place making its withdrawal unnecessary.

Apart from the cases which had to be re-operated on because of insufficient fixation with the translaminar screw technique there was no case of malunion. Implant removal was restricted to the 6 patients who were re-operated on by CD-techniques.

## Discussion

The physiopathological background of spinal stenosis in degenerative spondylolisthesis is an insufficiency of the facet joints of arthrotic origin leading to anterior displacement of one vertebra on the other. It typically affects motion segments in which the joint

axes are predominantly oriented in the sagittal plane as it is the case in the L4/L5, L3/L4, and L2/L3 segments. The motion segments which are situated at the apex of lumbar lordosis are most commonly affected (L4/L5 in 74%, L3/L4 in 11%, L2/L3 in 2%, L5/S1 in 1% and multiple levels in 12% in our series). The biomechanical reaction of the body is to produce an increase of the frontal orientation of these joint axes leading to median hypertrophy of the facet joints and together with anterior displacement of the vertebral arch and hypertrophy of the ligamenta flava to segmental spinal stenosis which is the origin of neurogenic claudication.

Surgical treatment of DS with spinal stenosis has to follow these physiopathologic aspects and simple decompressive procedures will additionally increase the risk of translational instability and only treat the neurologic part of the symptomatology leaving many patients with severe pain due to instability<sup>9</sup>. However, Loew has presented a group of 25 patients in whom the operation only consisted in decompressive laminectomy (n = 23) or foraminotomy (n = 2) in combination with arthrotomy (50%) with good results in 90% of the patients. He suggests that a single decompression-procedure should be done as a first stage. We question this therapeutic attitude because DS represents per se an unstable condition of the lumbar spine. This became obvious in the series of patients operated on under axial traction which in every case led to realignment of the olisthetic vertebra.

The radiological work-up of this patient series demonstrated that myelography with additional CT-scanning proved to be the most accurate pre-operative investigation in cases with additional scoliosis, otherwise being equal to MRI-studies. Functional x-rays demonstrated instability in only 30% of the cases, most probably because of considerably high muscular tonus of the spinal muscles which is similar to our series of isthmus spondylolisthesis<sup>18</sup>.

The clinical presentation of this series of patients (Table 1) was that of classical neurogenic claudication. The neurological status at rest was normal in 52 patients, 25 had discrete radicular signs and severe nerve root dysfunction with a cauda equina syndrome encountered in 23 patients. The latter patients suffered from considerable vertebral discomfort due to additional scoliosis of degenerative origin. It is interesting that DS was never accompanied by pseudoradicular signs due to facet irritation as is the case in the failed back surgery syndrome<sup>8, 16</sup>. It can be argued that the latter are related to rotatory instability of the facet joints along the y-axis as is the case in postdiscectomy-related instability. Patients with additional lumbar scoliosis on the contrary presented with pseudoradicular symptoms which is in favour of our assumption because scoliosis is a rotatory malposition of the spine in its y-axis. Lumbar scoliosis which necessitated additional operative restoration of spinal balance was present in 15 cases.

The crucial question in the operative management of DS remains the type of internal fixation after having effected neural decompression.

In the first 38 patients internal stabilization was achieved using the translamina screw fixation technique proposed by Magerl<sup>15</sup> and largely applied by ourselves in the management of the failed back surgery syndrome<sup>16-18</sup> (Fig. 1). Although excellent and good long term results had been achieved in 32 and 1 patient, respectively, 5 patients had to be re-operated on using of CD-techniques because of re-appearance of neurogenic claudication or pseudoarthrosis.

Translamina screw fixation provides a stabilization of rotatory hypermobility along the y-axis which is the origin of instability in postdiscectomized patients but does not provide stability for combined translational hypermobility along the z-axis and rotatory hypermobility along the x-axis. Therefore the translamina screw fixation method has been completely abandoned in cases of DS and primary CD-instrumentation<sup>4</sup> is now preferred.

The plate fixation technique according to Louis<sup>13, 14</sup> is an adequate internal fixation method but requires intra-operative traction in order to achieve reposition of the olisthetic vertebra and does not allow correction of additional scoliotic curves.

In our opinion CD-fixation<sup>4</sup> represents an ideal vertebral implant in patients with DS (Figs. 2-4). Intra-operative traction is unnecessary, the olisthetic vertebra can be realigned using double-threaded screws or sim-

ple distraction and additional scoliotic curves can be corrected. Furthermore the use of distraction and contraction devices in the frontal plane as well as the interpedicular plates allow sufficient stabilization of the osteoporotic spine up to the age of 90 years.

The surgical results clearly demonstrate this attitude by the fact that 48 patients showed excellent, 4 had good and 1 patient a moderate result after primary CD-instrumentation in 53 patients. Although the mean period of post-operative observation is still rather short (2.9 years) it can be stated that degenerative spondylolisthesis with spinal stenosis and neurogenic claudication is a pathological entity amenable to satisfactory treatment when modern neuro-orthopaedic surgical techniques, especially CD-stabilisation, are applied.

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