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An Extreme Lateral Access for the Surgery of Lumbar Disc Herniations Inside the Spinal Canal Using the Full-Endoscopic Uniportal Transforaminal Approach–Technique and Prospective Results of 463 Patients

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Study Design. Prospective study of patients with lumbar disc herniations who were operated on with a full-endoscopic uniportal transforaminal approach using an extreme lateral access.

Objectives. To examine the technical possibilities of an extreme lateral access for full-endoscopic uniportal transforaminal surgery of lumbar disc herniations within the spinal canal. Also, to assess sufficient decompression, and the advantages and disadvantages of the minimally invasive procedure.

Summary of Background Data. Conventional prolapsed disc operations can result in consecutive damage as a result of traumatization. The usual transforaminal access is posterolateral, and is associated with problems in reaching the epidural space directly with unhindered vision and, thus, with problems of sufficient decompression in lumbar disc herniations within the spinal canal.

Methods. A total of 463 patients were observed for 1 year. In addition to general and specific parameters, the following measuring instruments were used: visual analog scale, German version North American Spine Society Instrumentarium, Oswestry low back pain disability questionnaire.

Results. There were no complications. Of the patients, 81% reported no longer having leg pain, and 14% had occasional pain. There was no worsening. The results were constant and are equal to those of conventional procedures. No patients presented with neural scarring; 7% had recurrence of the prolapse. The extreme lateral access was necessary to reach the sequestered material.

Conclusions. The technique presented is an adequate and safe alternative to conventional procedures, and has the advantages of a truly minimally invasive procedure. The extreme lateral access is required for the indications described. There are clear limitations outside these indications. The possibility of selecting an access from posterolateral to extreme lateral now enables surgery of lumbar disc herniations inside and outside the spinal canal.

Key words: discotomy, endoscopic nucleotomy, transforaminal nucleotomy, minimally invasive spine surgery, disc prolapse. **Spine 2005;30:2570–2578**

The goal of therapy in symptomatic lumbar disc prolapses is a successful conservative procedure. However, when these possibilities have been exhausted, an operation may be necessary. Despite sufficient results, experience with revision procedures has shown that scarring of the epidural space occurs,[1–6] although this may remain unremarkable in magnetic resonance imaging (MRI).[3,7] According to the literature, more than 10% of these cases may become clinically symptomatic.[4–6] Revision of such scars is demanding, apt to recur, and usually not completely possible. Even when a pain syndrome is present, an attempt is made to avoid such procedures.[4,6] An induced segment instability resulting from the necessary resection of ossary and ligamentary structures is discussed.[8–15] The route of access may injure stabilization and coordination systems, and encompass traumatization of the innervation area belonging to the dorsal segment of the spinal nerves.[1,16,17] These parameters are held co-responsible for the failure of revision procedures in the post-discotomy syndrome.[4,18,19]

Microscopic or endoscopic-assisted dorsal procedures can reduce the damage to the surrounding tissues, but not to the structures of the spinal canal. Postoperative pain syndromes can be treated with surgery, medication, or neuromodulative therapy.[2,20,21] Nonetheless, lumbar disc operations should be continuously optimized. Considering existing quality standards of conventional procedures, the goal should be to minimize operation-induced traumatization and negative long-term sequelae.

Minimally invasive techniques can reduce tissue damage and its consequences.[22–24] Endoscopic operations have advantages that raise these procedures to the standard in many situations. Working with lens optics under fluid enables excellent visual conditions. Bleeding can be reduced. The use of the laser or high-frequency bipolar current can be applied in the immediate vicinity of neural

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structures.[25,26] A prerequisite is that the technical possibilities of such operations guarantee that the surgical goal can be attained.[27]

Percutaneous operations of the lumbar discs, such as intradiscal decompression, were published in the early 1970s.[28] Optical systems only for inspection of the intervertebral space after completed open surgery have been used since the early 1980s.[29] Currently, the intervertebral disc can be reached with the full-endoscopic uniportal technique *via* a posterolateral access within the foramen intervertebrale, between exiting and traversing spinal nerves, without resection of bony or ligamentary segments.[30–34] By reducing intradiscal volumes and pressure, reduction of the disc-related compression should be achieved.[35] Removal of the intra-foraminal or extra-foraminal sequester is technically possible.[36] Resection of the prolapsed nucleus material within the spinal canal, such as a retrograde resection, performed intradiscally through the existing anulus defect has been described.[33,34,37–40] Most of these procedures are performed with the patient under local anesthesia.

The most frequent localization of lumbar disc prolapses are in the lower levels. The diameter of the foramen intervertebrale decreases in the lumbar area, from cranial to caudal. An additional narrowing may result from degenerative changes. Sequestered nucleus material is found within the spinal canal dorsal to the intravertebral disc in the ventral epidural space, medial to the medial pedicle line, and very often extending to the middle line or toward the contralateral side.

Clinical experience has shown that the anulus defect is often smaller than the diameter of the sequester volume, and, especially in dislocated sequesters, there is often no longer a continuous connection to intradiscal. In the case of badly degenerated discs or older disc prolapses, the sequester material often has no continuous substance any more but consists of a grainy substance or individual fragments. Removal in one piece is usually not possible in such cases. Thus, the intended retrograde sequester resection from intradiscal is often technically limited. Active flexible instruments that pass through the working canal of the endoscope in uniportal procedures are of very limited availability because of technical difficulties and, used from intradiscal, do not permit going beyond the disc level. For adequate decompression, the direct reaching of the ventral epidural space under visual control is frequently necessary. Especially at the lower levels with smaller foramen intervertebrale, this may be impeded in using the usual posterolateral approach in uniportal procedure, so that an unequivocal preoperative prognosis of adequate decompression is not always possible.[38] After access is created, directing the endoscope to reach the spinal canal tangentially is technically impossible because of the preceding passage through the soft tissue.

The objective of this study was to examine the technical possibilities of an extreme lateral access for full-endoscopic uniportal transforaminal surgery on lumbar disc herniations within the spinal canal. The focus was on sufficient decompression compared to the results of conventional procedures, possible effects of slighter traumatization with avoidance of resection of segments of the spinal canal, possible specific complications, and the technical creation of access depending on pathologic and anatomic correlates.

Materials and Methods

In this prospective study between 2001 and 2002, 2 surgeons operated on 603 patients with the full-endoscopic uniportal transforaminal technique *via* the extreme lateral access. A total of 86 patients did not speak German. The perioperative communication was either in English or with the help of an interpreter. Because the scores used for recording the results were, in part, specifically validated for German language use, they could not be used without reservations. Thus, these nonGerman-speaking patients were excluded from the study. Assessment of all parameters recorded preoperatively for these 86 patients showed no differences from the other patients. Thus, the study collectively consisted of 517 patients.

A total of 277 patients were women, and 240 were men. The age range was from 16 to 78 years, with a mean of 38 years. The load profile was evenly distributed regarding occupation and sports. A total of 87 patients were self-employed or did freelance work, and 76 were employed in the household. The educational status covered all ranges. No patient was retired as a result of the reported complaints. There were 32 patients who were unemployed, and 389 were on sick leave. A total of 112 patients had private hospital insurance, and 223 had insurance providing a daily hospital allowance. Height and weight were evenly distributed.

All patients presented with clinically symptomatic lumbar disc prolapse. A total of 479 had MRI, and 38 had computerized tomography (CT) because of positioned implants or claustrophobia. The pain duration ranged from 11 months to 1 day (mean 97 days). A total of 271 patients had neurologic deficits. There were 44 patients who had bilateral symptomatics, 13 a contralateral, and 46 presented with a bisegmental finding. In these patients, neurologic examination and interventional pain diagnostics were performed to verify the level. No patient had undergone prior surgery at the same level, and 31 had been previously been operated on at a different level. A total of 414 patients had received prior conservative therapy for a mean of 9 weeks. There were 103 patients who underwent an acute operation. Indication was founded in accordance with current standards on radicular pain symptomatics and existing neurologic deficits.[41,42] Back pain and spinal canal stenosis without disc prolapse were not considered indications for surgery. A total of 328 procedures were performed at level L4/5, 153 at L3/4, 27 at L2/3, and 9 at L1/2, whereby the term L4/5 indicates the definition of the penultimate-free level. Surgery was on the right 223 times and left 267 times. There were 27 cases that were operated bilaterally (sequentially first from 1 side then from the other), of which 14 were in bilateral symptomatics and 13 in contralateral disc prolapse. Each time, the uniportal technique was used, consisting of concurrent work with endoscope and instruments *via* 1 access.

At the start of the study, the surgical procedure was standardized. CT, cadaver trials, and completion of the usual learning phases, including experience with the posterolateral transforaminal and open retroperitoneal or transposase accesses, preceded the study. Lumbar disc herniations within the spinal canal were considered inclusion criteria for the extreme lateral access. There was no limitation to the ventrodorsal or laterolateral extent of prolapse or in intradiscal space reduction foramen or spinal canal stenosis. Based on experience regarding limited technical freedom of movement, the maximum limit of sequester dislocation was set caudal at the middle of the pedicle and cranial at the lower edge of the pedicle. Situations in which radiologic examination with strict lateral radiation showed that the pelvis on the corresponding side overlapped the foramen intervertebrale more than to the middle of the cranial pedicle were excluded from the study. Other than general surgical contraindications, there were no exclusion criteria regarding general illnesses. Surgery was performed 293 times with patients under local anesthesia, 224 times with them under general anesthesia.

The surgical access was created with the patient in the prone position under orthograde radiologic control in 2 planes. First, localization of the skin incision was marked. This procedure was oriented depending on anatomy and pathology to the target point (*i.e.*, localization of the prolapse). The smaller the foramen, the longer the pathway in the tissue between skin and foramen or, the more dislocated the sequester, the more lateral the skin incision had to be. The aim was to make tangential reaching of the spinal canal possible. For levels L3/4 and L4/5, the dorsal edge of the processus articularis inferior limited the area of entry toward ventral in lateral radiation. Paying attention to the more dorsal extension of the intra-abdominal or intrathoracic space, a more individual, less lateral access could be selected for L1/2 and L2/3 because of the enlargement of the foramen intervertebrale, which increases toward cranial. In these cases a preoperatively selective single slice CT including the whole intraabdominal structures and the skin was performed, especially in cases of narrowed foramen or retroperitoneal preoperations.

A 1.5-mm atraumatic spinal cannula is inserted *via* the skin incision through the foramen, directly toward the spinal canal into the target area (*i.e.*, the disc prolapse). The point of the needle lies in its final position in the lateral ray path at the level of the dorsal anulus, whereas in the anterior-posterior view, the middle line can be reached thanks to the lateral access and nearly horizontal needle positioning. Penetration of the needle point ventral to the dorsal anulus usually characterizes a too-sharp access angle. At the same time, it should be avoided that the needle point lies further dorsal because the dorsal anulus defines a safe area regarding the spinal canal structures. After insertion of a 0.8-mm lead wire, the cannulated dilator with an outer diameter of 6 mm is pushed to the start of the foramen.

At this point, the target wire may be removed so that further position correction toward dorsal in the direction of the epidural space can be made safely with the blunt dilator. The passage through the foramen intervertebrale was made for more precise control and possible expansion of the structures by hammering. The dilator is inserted to the medial pedicle line. A surgical sheath with a beveled opening and an outer diameter of 7 mm was then placed facing ventral over the dilatator at the start of the foramen to protect exposed nerves. After the opening was turned toward dorsal to protect the neural structures lying dorsal within the spinal canal, the surgical sheath was pushed through the foramen. From that time on, decompression was performed under visual control and gravity controlled liquid flow (Figure 1). If further penetration into the epidural space is necessary, it is performed under visual control to protect neural structures. WOLF (Firma Wolf, Knittlingen, Germany) is the manufacturer of the entire access instrumentarium, optics used, and mechanical instruments. The lens optic had a diameter of 6 mm, with a 2.7-mm working canal. In addition, semiactive-flexible bipolar probes with high-frequency current manufactured by Ellman (Ellman Innovations, Oceanside, NY) and Select Medizin Technik (Select Medizin Technik Herman Sutter GmbH, Freiburg, Germany) were used for preparation and coagulation.

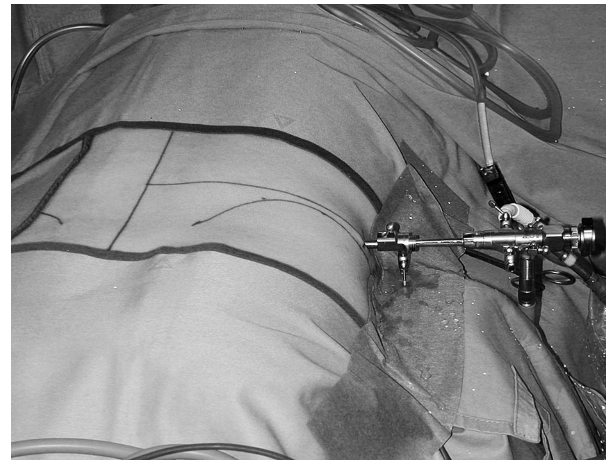

Figure 1. Extreme lateral access for a full-endoscopic uniportal transforaminal operation.

Examinations defined in the preoperative protocol were made 1 day, and 3, 6, and 12 months postoperatively. In addition, patient examinations were performed in the event of specific problems. In addition to psychometric tests of pain therapy, the following validated measuring instruments were used: visual analog scale (VAS) for back and leg pain (always for the period 1 week before post-examination), German version North American Spine Society Instrumentarium (NASS),[43,44] and Oswestry low back pain disability questionnaire.[45] (This score is not unequivocally validated for German language use but was used in a translation because it is widely used internationally.) Regarding general criteria, the following parameters predominated: sufficient decompression, complications, operating time, bleedings, scarring, postoperative pain, postoperative therapy, pain reduction, reduction of neurologic deficits, rehabilitation time, work disability, work fitness, sports fitness, recurrences, revisions, and subjective satisfaction.

To enable a high number of post-examined patients, considering the broad geographical area involved, all parameter and measuring instruments could be answered in the form of a questionnaire. In addition, it was possible to contact the study participants by telephone. Postoperative imaging was performed randomly or in the event of unusual occurrences, and a MRI was recorded 63 times after surgery. The descriptive assessment and analytic statistics were performed dependent on group characteristics using the program package SPSS (version 10.0.7, SPSS, Inc., Chicago, IL). A positive significance level was set at $P < 0.05$.

■ Results

A total of 463 (89.5%) patients were included in the complete postoperative examination. There were 3 reasons for the 54 subjects to dropout: (1) death unrelated to surgery, (2) 12 moved with no forwarding address, and (3) 38 did not respond to letters or telephone calls. All results obtained were independent of gender, age, height, weight, educational level, and insurance status, status on the job market, or secondary illnesses.

The operating time in a unilateral procedure was between 16 and 47 minutes (mean 27). No measurable blood loss occurred. There were no surgery related complications in any patient. No postoperative pain medication was necessary. Mobilization was possible without exception within a few hours after surgery. All patients were provided with a stabilizing lumbar orthosis for 6 weeks. Rehabilitative measures were performed only in patients with persistent pareses.

A total of 181 patients (39%) presented intraoperatively with extensive epidural adhesions that could not be diagnosed before surgery. Contrary to the MRI finding, in 43 patients (9%), only hard tissue, histologically corresponding to anulus, ligament or knotty nucleus tissue could be found. In these patients, there was a significant relationship with the existing back pain and duration of complaint longer than 6 months. Of these patients, 31 were reoperated on with spinal canal decompression, and 4 with fusion.

Thirty-two patients (7%) had recurrent disc prolapse, of these, 29 had it during the first 5 months. There were 4 revisions made by a microscopic-assisted technique, 3 times because of pronounced sequestering, once at the patient's request. A total of 28 recurrences were operated on using the same technique. In these cases, there was another recurrence in 4 of 463 (0.86%), which were endoscopically operated on in 3 and conventionally in 1 case. These 4 patients had presented at the start with kyphotic deviation in the segment and collapse of the intravertebral space over the course. The collected material from the recurrent prolapses was histologically examined, considering the possible effect of complete excavation of the intravertebral space on the recurrence rate. Endplate material was diagnosed to at least 75% in each case. The rest consisted of degenerated nucleus tissue. The pathologists did not find any anulus tissue.

Table 1. Individual Results of the Measuring Instruments

	VAS Leg	VAS Back	NASS Pain	NASS Neurology	Oswestry
Preop					
Min	45	0	2.2	2	36
Max	100	75	5.1	6	100
0	71	18	4.2	3.1	78
1 Day					
Min	0	0	—	—	—
Max	35	80	—	—	—
0	4	14	—	—	—
3 Mos					
Min	0	0	1	1	0
Max	45	55	3.4	3.6	64
0	8	18	2.4	2.0	22
6 Mos					
Min	0	0	1	1	0
Max	55	45	5.3	3.8	52
0	9	16	2.5	2.1	24
12 Mos					
Min	0	0	0.1	1	0
Max	50	45	4.5	3.8	68
0	8	16	2.4	1.9	20

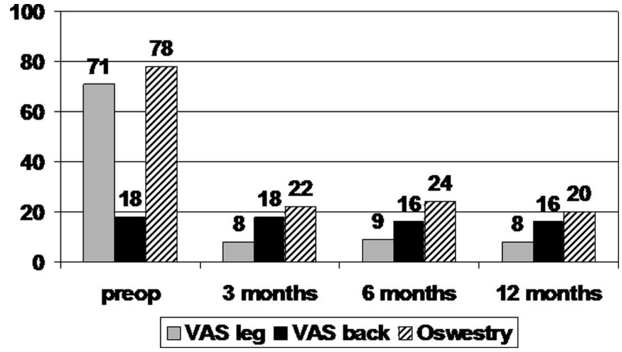

Figure 2. The mean values of VAS leg and back, and Oswestry.

The results of the measuring instruments of the 396 patients with nonrecurrence are presented in Table 1 and Figures 2, 3. The 35 open spinal canal decompressions and fusions, as well as the 32 patients with recurrent prolapse are not included. A constant improvement is seen with the exception of isolated back pain assessment. Reduction refers especially to leg pain and activities of daily living. A total of 322 patients (81%) had no more leg pain, 53 (14%) had occasional or considerably reduced leg pain, and 21 (5%) had no essential improvement. The latter belonged without exception to the group of those patients with intraoperatively diagnosed epidural adhesions or hard tissue. No significant influence was observed on back pain. With the exception of the first postoperative day, there was no significant surgery related deterioration in back or leg pain. Regression of neurologic deficits was significant only with a history <7 days; there was no correlation to electromyography or nerve conductance speed. Hypesthesias were less often regradient than paresis. There was significant dependency between poorer results and longer history of back pain, and degenerative epidural adhesions.

Of all 463 patients, 409 (88%) had subjective satisfaction and would undergo the procedure again. This statement applies to 379 (96%) of the 396 patients with nonrecurrence. A total of 353 patients who were not unemployed or retired continued their jobs or sports, ad

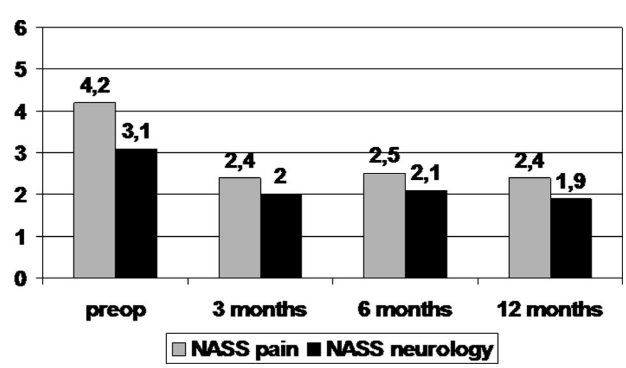

Figure 3. The mean values of NASS pain and neurology.

16 were incapable of doing so because of persistent paresis. The postoperative work disability lasted between 5 and 24 days (mean 12). There were no significant differences regarding degree of stress or occupational status.

The routine performance of postoperative MRI for pure study purposes without clinical symptoms was not possible in the authors' health system because of costs as a result of the number of patients involved. A total of 78 postoperative MRI was performed, including 66 after a period of at least 3 months. Of these were 32 patients with recurrent disc herniation after a free clinical interval, 35 patients were treated later with spinal decompression or fusion and 11 patients without clinical symptoms. All MRI was performed using contrast dye. Radiologists who had preoperative MRI in hand made the assessment. Considering the clinical situation and imaging, the findings of the 32 patients with recurrent complaints after a clinically free interval were diagnosed as having recurrent disc prolapse. The 35 patients with an intraoperative finding of only hard tissue had no changes from the earlier finding. No further disc prolapse could be diagnosed on the 11 MR images of patients without clinical symptoms. Intra-foraminal changes, which could be rated as caused by surgery, were diagnosed 31 times. No intra-foraminal or extra-foraminal changes in neural structures, such as scar distortions, were observed. No scars were observed inside the spinal canal in the epidural space; this was confirmed in revision procedures. The cover and base plates, as well as neighboring vertebral bodies showed no increased reactions compared to preoperative measurements, such as those observed after conventional disc operations with excavation of the intradiscal space. No difficulties in subsequent procedures as a result of the primary operation were observed. Clinical symptoms of surgery related scarring, such as a post-discotomy syndrome, did not occur.

There were no differences in results within the various levels. A resection of bony segments could be avoided without exception. The use of bipolar high-frequency probes was necessary in all cases for preparation and to arrest bleeding. For the controlled complete resection of the sequester material under visual control, the extreme lateral access was necessary without exception. The results of the temporally sequential bilateral procedures in uniportal technique did not differ from those of the purely unilateral operations. There was no difference in results between local and general anesthesia. Measurements of lavage inflow and outflow showed maximum 100-mL fluid remaining in the body.

Discussion

The goal of the surgical treatment of lumbar disc prolapse is sufficient decompression, with minimization of surgery induced traumatization and its consecutive sequelae. The present study results show that the full-endoscopic uniportal transforaminal operation *via* the extreme lateral access offers therapeutic possibilities, even of disc prolapses sequestered within the spinal canal. As 1 of the main therapeutic criteria, the constant reduction of leg pain can be rated as a causal of success of sufficient sequester removal under visual control. For this, selection of the lateral access was necessary. The results of microscopic-assisted operations, which are between 75% and 100%, are attained.[14,46–51] The possibility of sufficient decompression with the endoscopic transforaminal technique equal to that of conventional procedures is also shown in a prospective randomized study with specific inclusion criteria.[52] Operating time, tissue traumatization, and complications, such as dural injury, nerve damage, bleeding, or infections, are minimized.[2,53–59] The remaining levels in the NASS pain and Oswestry result from the lack of reduction in back pain, which is to be expected in these indications.[14,49,51,54,60]

Corresponding to the published advantages of a minimally invasive intervertebral and epidural procedure,[61–64] there was no increase of existing symptoms. The possibility to dispense with bony and ligamentary resection, and the selective evacuation of the intervertebral space serve according to today's knowledge to prevent surgery induced instabilities.[14,62,63,65–72] The desirable comparison with a nonoperated control group would be difficult to perform using the present indications. The not clearly predictable reduction of neurologic deficits[4,73] showed better response in shorter history and in paresis than in hypesthesias. Surgery related rehabilitative measures are not necessary. There is a comparatively high return to the occupational and athletic level of activities.[74] Criteria like gender, age, height, weight, educational status, insurance status, or status in the job market had no influence. There was no increased morbidity with secondary factors.[53,55,58] There are no differences in results between of the temporally sequential bilateral procedures in uniportal technique and the purely unilateral operations.

The recurrence rate of 7% is in the framework of selective sequestrotomy[75–78] and decreases after the fifth postoperative month. Multiple recurrences occurred in segmental kyphotic deviations as part of a degeneratively caused collapse of the intravertebral space. Revisions can be performed using the same technique. The extreme lateral access makes entry into the intravertebral space difficult with the stiff instruments used. The negative effects of complete resection of a degenerated nucleus, with its questionable biomechanical worth, have not yet been completely elucidated.[1,4,63,79] Minimization of the anulus defect may have a higher protective influence than nucleus preservation.[79] Because evacuation of at least the dorsal area appears to reduce the frequency of recurrence, the authors used new flexible instruments to resect the nucleus material with minimal trauma, depending on the structure of the anulus defect. According to our own results, this reduced the recurrence rate to less than 1%. Complete prevention of recurrence cannot be expected because of the proportion of more than 75% endplate material.

Not one case of a post-discotomy syndrome occurred during the entire post-observation period. Epidural scars, which would be expected with conventional techniques and which, in up to more than 10% of patients, may lead to clinical symptoms,[1,3–7] were not detected either on MRI examinations or during revision surgery. Subsequent endoscopic or conventional procedures can be performed without difficulty and show none of the extended operating time described.[80] Moreover, the epidural lubricating tissue is preserved. This effect corresponds to the descriptions of better results with reduced traumatization of the ligamentum flavum.[81,82]

A risk of neural damage while performing the procedure with the patient under general anesthesia was not confirmed and has already been published.[83] With the given indication, there is no necessity for intraoperative stimulation and operation in local anesthesia. This, complied with the patient's wishes, shortened the operating time and simplified the intraoperative procedure. The use of semiactive-flexible bipolar probes and high-frequency current was an essential instrument for preparation and stopping bleeding. In light of the minimally invasive procedure, the authors do not currently consider the general relationship between longer anamnesis and poorer pain reduction as a reason to decide on early operation. Patients with poor results in the present study all presented with additional secondary factors such as degenerative fibroses, which could not be unequivocally diagnosed by imaging,[7,84] as known from endoscopic operations even when no disc prolapse is present.[84–86]

Various investigators describe the removal from the epidural space of prolapsed discs lying within special indication criteria, such as retrograde resection, performed intradiscally *via* the anulus defect.[33,34,37–40] Some investigators describe resection of all forms of disc prolapse.[33,34] In contrast, considering the inclusion criteria in the introduction, the authors are of the opinion that complete and safe resection of prolapsed discs within the spinal canal must be performed under visual control because they frequently are not conjoined and cannot be removed from intradiscal retrograde *via* the anulus defect. This applies especially to transligamentary and sequestered prolapses. Even if certain disc prolapses can be resected with posterolateral access, it is the authors' opinion and experience that this cannot be predictably guaranteed with the inclusion criteria defined for this study, and that should be the basic premise for comparison with conventional surgical procedures. The necessity of the lateral access in reaching the epidural space was also found in the present study. Various investigators[39,40,87–91] have already discussed and described the necessity, and possibility of increased laterality of the transforaminal access. In addition, the examinations showed that there are clear exclusion criteria, even in using the lateral access, as explained later. This means that in the authors' opinion, not all disc prolapses can be operated on with the transforaminal technique, even with lateral access. As long as bony resections can be minimized, the authors see the necessity of the extreme lateral access as a given because of possible consecutive damage and considering the goal of a minimally invasive procedure. The increase in size of the foramen at L1/2 and L2/3 usually makes a less lateral procedure possible, so that the internal organs are protected. A large or sequestered herniation, a long approach through the soft tissue and especially cases of narrowed foramen demand a lateral access. Safety must take precedence in such cases (*i.e.*, prevention of complications, such as injury to abdominal structures). If preoperative, layer image diagnostics are initiated by the authors, an appropriate width of the scan window in the segment to be operated on is demanded to permit assessment of the approach pathway. In patients with diagnostics performed at other hospitals, the window size of the scan often only permits evaluation of the spinal column structures. In such cases, at least a preoperative selective single CT with a broad window should be performed to define the safe access pathway. This procedure applies especially for patients in whom retroperitoneal operations were performed earlier. At level L5/S1, the extreme lateral access is usually not possible because of the pelvis. Overall, anatomy and pathology determine the operative access so that a less lateral up to even a posterolateral access is necessary (*e.g.*, in intraforaminal or extra-foraminal disc prolapses) in intradiscal procedures or fusions (Figures 4, 5).

The optics used with a 2.7-mm working canal and corresponding not actively moveable instruments do not enable larger resections of hard tissue and cause a limited radius of action within the bony foramen intervertebrale. Cranial, the protruding spinal nerve limits mobility. Thus, problems occur as a result of compressions by hard tissue and the sequesters that extend beyond the limits of cranial and caudal dislocation.

Considering individual pathology and anatomy, the guiding indication for the present technique is radicular compression symptoms caused by disc prolapse. There are no limitations as to ventrodorsal and laterolateral extension of the prolapse or in additional reduction of

Figure 4. Posterolateral access for the full-endoscopic transforaminal operation.

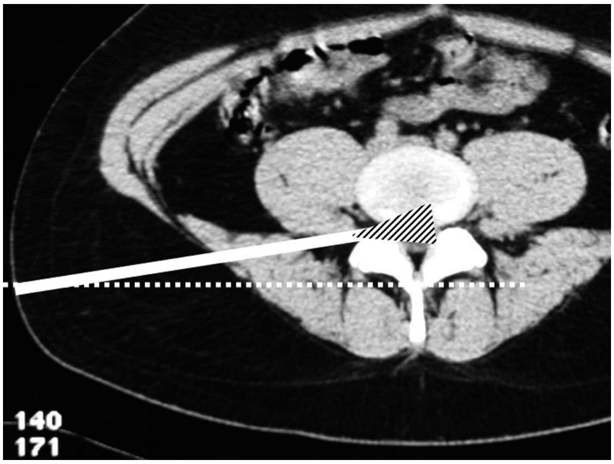

Figure 5. Working area shifted by extreme lateral access into the spinal canal.

intradiscal space, foramen, or spinal canal stenosis. The craniocaudal sequester dislocation cranial should not exceed the lower edge of the pedicle and caudal, the middle of the pedicle. Radiologically, the foramen intervertebrale should be covered in strict lateral radiation maximally to the middle of the cranial pedicle. Isolated spinal canal stenoses and back pain are not an indication. Considering these criteria, the extreme lateral access enables predictably sufficient decompression and its visual control. Outside these criteria or with a purely posterolateral access, the authors see clear limitations to the procedure, contrary to conclusions in various publications.[33,34,37–39]

■ Conclusion

The present study results show the possibility of sufficient decompression equal to that of conventional procedures, which must be attained as a minimum with any new procedure.[27] At the same time, all the advantages of a truly minimally invasive procedure with lower traumatization and shorter operating time are given. Scarring is avoided, and the intra-epidural lubricant structures remain intact. A post-discotomy syndrome or other surgery related deteriorations do not occur. Revisions are not made more difficult. As far as yet is known, the procedure causes no surgery induced destabilizations. Complications or increased morbidity in older patients are slight. Shorter hospitalization, more rapid rehabilitation, and high patient acceptance are observed. There are problems caused by the instruments during resection of hard tissue, evacuation of the intradiscal space, and mobility with the consequence of a risk of recurrence and limitation in compression because of hard tissue and in sequesters dislocated craniocaudal beyond the borders. The authors consider the presented technique to be a sufficient and safe alternative to open, microscopic, or endoscopic-assisted procedures. The extreme lateral access is necessary for the indications described to guarantee predictable, complete decompression. With the possibility of selecting the access from posterolateral to extreme lateral, lumbar disc herniations outside and inside the spinal canal can now be adequately operated on with the full-endoscopic uniportal transforaminal technique, considering the pertinent criteria.

Although data are now available for a maximum of 4 years, we have presented only the 1-year results for better comparability. The statements can be made without absolutely requiring a control group, thanks to the patients included and the study design. Nonetheless, studies have already been started with prospective randomized control groups, but these can be performed only in partial areas in the present indications for medical and ethical reasons.

Thus, newly developed optics, larger and flexible instruments, shavers and burrs reduce the problems of the procedure in light of available results of their own studies. In transforaminal-technically inoperable disc prolapses, the authors used a full-endoscopic uniportal interlaminar access. Overall, a development potential was seen in technical aspects, which may lead to expanded indications also regarding spinal canal decompressions and fusions. However, total avoidance of known problems in spinal column operations can hardly be imagined. In addition, open procedures will remain as indispensable in the future as they currently are now.

■ Key Points

- The extreme lateral access is necessary to enable the full-endscopic transforaminal operation of lumbar disc herniations within the spinal canal, with clear vision in a sufficient and predictable manner.
- The results of decompression are equal to those of open, microscopically- or endoscopically-assisted procedures, taking the indication criteria into consideration, and possess the advantages of a truly minimally-invasive procedure.
- The procedure has clear limitations outside the indication criteria.
- At level L5/S1 and often above, the necessary lateral access is usually not possible due to the iliac crest.
- With the possibility of selecting an access from posterolateral to extreme lateral, lumbar disc herniations can now be sifficiently operated outside and inside the spinal canal in a full-endoscopic transforaminal technique.

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