Use of newly developed instruments and endoscopes: full-endoscopic resection of lumbar disc herniations via the interlaminar and lateral transforaminal approach

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Object. Even with good results, conventional disc operations may result in subsequent damage due to trauma. Endoscopic techniques have become the standard in many areas because of the advantages they offer intraoperatively and postoperatively in rehabilitation. The goal of this prospective study was to examine the expanded technical possibilities of full-endoscopic transforaminal and interlaminar resection of herniated lumbar discs in which the authors used newly developed optics and instruments. The focus was on questions of achieving sufficient decompression, as well as the advantages and disadvantages of the minimally invasive procedure.

Methods. Two hundred thirty-two patients underwent follow up for 2 years after undergoing surgery. In addition to general and specific parameters, the following measuring instruments were used: a visual analog scale, the German version of the North American Spine Society instrument, and the Oswestry Disability Index of low-back pain disability.

Postoperatively 84% of the patients no longer had leg pain, and 12% had only occasional pain. The results of decompression were equivalent to those of conventional procedures. The incidence of traumatization was reduced. Epidural scarring was minimized. The recurrence rate was 6.0%. No serious surgical complications were observed. Resection of the herniated disc was technically possible in all cases in which the new instruments were used.

Conclusions. The authors view the aforedescribed techniques, which offer the advantages of a truly minimally invasive procedure, as a sufficient and safe supplementation and alternative to conventional procedures, when the appropriate indication criteria are heeded. The new endoscope with its 4.2-mm working channel and corresponding instruments significantly reduced the technical problems.

KEY WORDS • endoscopic nucleotomy • endoscopic discectomy • transforaminal nucleotomy • interlaminar nucleotomy • lumbar disc herniation • minimally invasive spine surgery

The goal in patients with symptomatic lumbar disc herniation is successful conservative therapy, but when conservative possibilities have been exhausted, an operation may be necessary. Conventional surgeries have been associated with good results,5,24,28,37,57,69,75,114 Nonetheless, one operative consequence is scarring of the epidural space,5,30,58,62,90,96 which may not be apparent on MR imaging6,30 but becomes clinically symptomatic in 10% or more of cases,30,58,96 Revision of such scars is demanding, when the lesion is apt to recur, and usually not completely possible. Even when a pain syndrome is present, an attempt is made to avoid such surgical procedures.58,96 An analysis of study results has revealed the occurrence of operation-induced destabilization due to the necessary resection of spinal canal structures,1,35,40,45,53,56,57,98 The point of access influences the stabilization and coordination system in the nervous area of the dorsal nerve roots of the spinal nerves.17,62,110 The combination of these parameters may explain poor revision-related results in patients with a post-discectomy syndrome,36,54,58 The use of microsurgical techniques has reduced tissue damage and its consequences.76,95,111 Although conditions of postoperative pain are treatable,21,80,96 continuous technical optimization should be attempted. The goal of a new procedure must be to achieve results commensurate with current results63 while minimizing traumatization and its negative long-term consequences.

Open interlaminar access has been used since the early 20th century.2,21,70,79,102,104 Thirty years after its introduction, alternative methods for the surgical treatment of disc pathological entities were developed.41 The posterolateral access for vertebral body biopsy was described in the late 1940s,109 Percutaneous operations—in the sense of mechanical intradiscal decompression or chemonucleolysis—have been applied since the early 1970s,12,34,38,49,64,100 In the late 1970s, a microsurgical procedure involving a microscope was developed to gain interlaminar access,12,31,32,116 Endoscopes have

Abbreviations used in this paper: MR = magnetic resonance; NASS = North American Spine Society; ODI = Oswestry Disability Index; VAS = visual analog scale.
been used since the early 1980s to inspect the intervertebral space after completed open surgery. The full-endoscopic transforaminal operation with posterolateral access evolved out of this. Endoscope-assisted interlaminar procedures were reported in the literature in the late 1990s. The lateral access in the full-endoscopic transforaminal surgery to optimize the route to the spinal canal under continuous visualization has been performed since the late 1990s. The development of the full-endoscopic interlaminar access procedure was seen at the same time.

Minimally invasive techniques can reduce tissue damage and its consequences. Endoscopic operations while maintaining continuous fluid flow have become the standard in many areas. The most widely used full-endoscopic procedure in patients with lumbar disease is trans- or extraradicular surgery, conducted via the posterolateral approach and with a predominantly intradiscal and foraminal working area. Resection of the sequestered nucleus pulposus material within the spinal canal—that is, a retrograde resection performed intradiscally through the existing anular defect—has been described in the literature. Nonetheless, difficulty in achieving an adequate resection of herniated discs within the spinal canal cannot always be excluded. With the newly developed lateral approach, the spinal canal can be reached more sufficiently under direct and continuous visualization, but the osseous perimeter of the foramen, the pedicle, and the exiting nerve can limit the working mobility and excision of dislocated herniated material. Moreover, the pelvis may block access to the lower levels. Thus, contrary to what has been reported in several publications, we recognize limitations of the transforaminal procedure. The full-endoscopic interlaminar access procedure has been developed to enable the extirpation of pathological entities not successfully achieved using the transforaminal technique.

Problems have been associated with the small and not actively flexible instruments coupled with a small intradiscal working channel. Insurmountable difficulties could arise in the resection of hard tissue, in anatomical access, in mobility, and in elevated recurrence rate. New optics with an intraendoscopic 4.2-mm working channel and corresponding instruments, as well as shavers and burs, were developed with the objective of permitting full-endoscopic surgery under continuous visual control.

The goal of this prospective study was to examine the increased technical possibilities of full-endoscopic interlaminar and lateral or posterolateral transforaminal resection of herniated lumbar discs in which newly developed optics and instruments are used. The focus of our study was on questions of sufficient decompression, possible effects of decreasing the incidence of trauma, possible specific complications, and the technical creation of an access route depending on pathological and anatomical correlates.

Clinical Material and Methods

Patient Characteristics

In the prospective study, we enrolled 264 patients who underwent surgery between January and June 2004 in which the full-endoscopic interlaminar and transforaminal technique was used to treat lumbar disc herniation. There were 151 female and 113 male patients whose ages ranged from 17 to 72 years (mean 41 years). The profile of occupation and sports involvement was evenly distributed in the population. None of the patients had retired as a result of their symptoms. Eighteen patients were unemployed and 174 were on sick leave. Height and weight were evenly distributed.

All patients presented with clinically symptomatic disc herniation. Two hundred fifty-three patients underwent MR imaging, and 11 underwent computed tomography scanning because they either had indwelling implants or were claustrophobic. The duration of pain ranged from 1 day to 15 months (mean 68 days). One hundred fifty-seven patients presented with neurological deficits. Thirteen patients had bilateral symptoms. Fourteen patients had undergone previous microscope-assisted surgeries at a different vertebral level. Two hundred eight patients had received a mean of 7 weeks of conservative treatment; 56 patients with uncontrollable pain symptoms or pronounced acute paralysis underwent surgery immediately. The indication for surgery was defined according to present-day standards based on radicular pain symptoms and existing neurological deficits. One hundred fifty-three patients (58%) underwent an interlaminar procedure and 111 (42%) a transforaminal procedure. One hundred two interventions were performed at the L5–S1 level (98 interlaminar and four translaminar), 85 at L4–L5 (27 interlaminar and 58 translaminar), 59 at L3–L4 (22 interlaminar and 37 translaminar), 16 at L2–L3 (six interlaminar and 10 translaminar), and two at L1–2 (two translaminar); in the present study L4–5 is taken as the primary route because of its lower incidence of trauma.

Inclusion Criteria

We included all cases in which the herniated disc was located intra- and extraforaminaly (38 cases) and within the spinal canal (226 cases). Only patients with cauda equina syndrome underwent conventional surgery (that is, a microscope-assisted procedure). We chose the transforaminal access as the primary route because of its lower incidence of trauma.

All cases of extra- and intraforaminal disc herniation were considered for transforaminal access. Based on our earlier experience with limited technical mobility with the space, we applied the following exclusion criteria if the herniated disc was within the spinal canal: 1) sequestering of material located cranially beyond the lower edge of the cranial pedicle or caudally over the middle of the caudal pedicle; and 2) lateral radiological evidence that the foramen was overlaid by the pelvis beyond the middle of the cranial pedicle. The new surgical devices did not limit the sagittal or transverse extent of the herniated material; nor did they limit the intervertebral space resection or foraminal/spinal canal stenosis due to the technical possibility of bone resection.

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The indications for interlaminar access were herniated discs located mainly inside the spinal canal, which in our experience were difficult to treat using the transformaminal technique given the aforementioned criteria. The new surgical devices also posed no limitations regarding the extent or dislocation of the lesion due to the possibility of bone resection.

Isolated back pain or spinal canal stenosis in cases in which disc herniation was absent was not considered an inclusion criterion. Beyond general surgical contraindications, there were no exclusion criteria with reference to general illness.

Operative Technique: Lateral Transforaminal Approach

In the lateral transforaminal approach, the surgical access is created with the patient in the prone position while under orthograde two-plane radiological control. First, the location of the skin incision is marked. The aim is to make the tangential reaching of the spinal canal possible (Fig. 1). For the L3–4 and L4–5 levels, the dorsal edge of the inferior articular process normally limits the area of entry to the ventral on lateral radiography. Especially at the higher vertebral levels, safety must take precedence to prevent complications such as abdominal or thoracic injury. In such cases, a preoperative selective, single broad-window computed tomography scan should be obtained to define the safe access pathway, particularly in patients in whom retroperitoneal operations have been performed. In these cases a more individual, less lateral access route has to be selected.

A 1.5-mm atraumatic spinal cannula is inserted via the skin incision directly into the target area. After insertion of a 0.8-mm lead wire, the cannulated dilator (outer diameter 6.9 mm) is pushed in. At this point, the target wire may be removed so that further position correction can be made safely with the blunt dilator. A surgical sheath, with beveled opening and an outer diameter of 7.9 mm, is placed over the dilator. Thereafter, decompression is performed while maintaining visual control and constant irrigation (Fig. 2). If additional penetration into the epidural space is necessary, it is performed under visual control to protect the neural structures. If the anatomical osseous diameter of the intervertebral foramen does not permit direct entry into the spinal canal, the opening is expanded using burs to resect bone material. If the position of the exiting nerve is not clear—for example, cases of intradural or extradural herniations or in foraminal stenosis—access is made on the caudal pedicle as a safe zone and further preparation toward the herniation is conducted under visual control.

Operative Technique: Interlaminar Approach

In the interlaminar approach, surgical access is created with the patient in the prone position while under orthograde two-plane radiological control. The skin incision is made as nearly medial in the cranio-caudal middle of the interlaminar window as possible. A dilator, 6.9 mm in outer diameter, is inserted bluntly to the lateral edge of the interlaminar window and an operating sheath, with 7.9-mm outer diameter and beveled opening, is directed toward the ligamentum flavum. Thereafter, the procedure is performed under visual control and constant irrigation. A lateral incision of approximately 3 to 5 mm is made in the ligamentum flavum.
tum flavum; to allow access to the spinal canal, the defect in the ligament is widened further (Figs. 3 and 4). The operating sheath with beveled opening can be turned and used as a nerve hook. Mobility within the spinal canal is controlled using a handle on the optics that functions comparably to a joystick. If the anatomical osseous diameter of the interlaminar window does not allow direct access into the spinal canal through the ligamentum flavum, the opening is expanded further using a bur to resect bone. In cases involving wide dislocated sequestered fragments, which cannot be completely resected from one level without an extensive bone resection, additional access to the spinal canal can be achieved via the neighboring level.

Operative Instruments

The rod lens optics has an outer diameter of 6.9 mm and a usable length of 165 mm for interlaminar and 205 mm for transforaminal access. The optics contains an intraendoscopic, eccentric working channel with a diameter of 4.2 mm, inlets for light and rinsing fluid, as well as the optical system itself. The angle of vision is 25°. The working sheaths have a 7.9-mm outer diameter and a beveled opening, both of which enable creation of visual and working fields in an area without a clear, anatomically preformed cavity. Various instruments are available that are familiar to surgeons in a similar, larger form in conventional spine surgery (Fig. 5). The new large intraendoscopic working channel enables the use of larger auxiliary instruments. Among other things, this has made sufficient bone resection under visual control possible with burs or bone punches. All of the instruments and optics were products supplied by Richard Wolf GmbH.

Follow Up

Follow-up examinations were conducted at Day 1 (264 patients) and at Months 3 (254 patients), 6 (251 patients), 12 (243), and 24 (232 patients) after surgery. All patients were reminded by telephone of their follow-up appointment and received the appropriate questionnaire by mail 4 working days in advance. They came personally to the clinic for follow-up examination. The examinations were performed by two doctors in the clinic. In addition to general parameters, other information was also obtained using the following instruments: a VAS for back and leg pain, the

Fig. 3. Intraoperative C-arm images.  A: The dilator is bluntly inserted, and the operative sheath inserted through the dilator with beveled opening toward the intervertebral space.  B: The ligamentum flavum is incised and held medial with a dissector; epidural fat is visible below it.  C: The ligamentum flavum is opened laterally, and the traversing spinal nerve (short arrows) is shifted dorsally through the sequestered disc material (long arrow).  D: After decompression, the dura of cauda equina (short arrows) and traversing spinal nerve (long arrow) with axilla can be seen.
German version of the NASS, and the ODI measuring low-back pain.

Statistical Analysis

The Wilcoxon rank-sum test and the Mann–Whitney U-test were applied for the comparison of pre- and postoperative global results and comparison of results in the transforaminal and interlaminar groups at various times. The McNemar test was used to compare the characteristics of the two groups.

The descriptive assessments and analytical statistics were performed depending on the group characteristics with the program package SPSS (version 10.0.7). A positive significance level was assumed at probability of less than 0.05.

Results

Two hundred thirty-two patients (88%) were included in follow up. The remaining cases were excluded for the following reasons: two operation-unrelated deaths, nine patients moved away and left no forwarding address, and 21 patients did not respond to letters or telephone calls.

Analysis of the results showed no dependence on sex, age, height, weight, employment status, or concomitant diseases. The operating time ranged from 13 to 46 minutes (mean 23 minutes). There was no measurable blood loss or serious complications, such as postoperative bleeding, dural injury, or nerve injury. Nine patients developed a transient postoperative dysesthesia. No additional complications, such as infection, thrombosis, postoperative urinary retention, or postoperative catheterization, occurred. Postoperative pain medication was not required. Mobilization was immediate, depending on the level of narcosis. No rehabilitative measures were undertaken except in patients with pareses. The patient population was equal in the interlaminar and transforaminal groups. No significant differences between the two groups were found when assessing the results of all parameters.

Intraoperative Findings

One hundred five (42%) of 250 patients had epidural adhesions, despite their not having undergone prior surgery. These adhesions varied in significance. They were located exclusively in the area of the traversing nerve medial to the axilla or lateral to the recess, and they were in the anterior epidural space. In addition, the numbers of blood vessels in these areas were increased. The purely visual impression was of an inflammatory process. Preparation and mobilization of the nerve was limited or impossible without resecting the adhesions. There was no adhesion to the ligamentum flavum in any case. Histological examination of the

Fig. 4. Photograph (left) and artist’s drawing (right) demonstrating the full-endoscopic operation with interlaminar access.

Fig. 5. Photograph showing the various instruments that are known in a similar, larger form in conventional spinal surgery.
adhesion material yielded no explanatory findings, especially because of the technical difficulties in obtaining adequate material. In 21 cases (8%), contrary to the MR imaging findings, we observed only hard-tissue compression. Histologically, this compressive force was exerted by the anulus fibrosus, disc, or cartilage. Back pain and symptom duration for longer than 6 months showed a significant relationship to this finding (p = 0.033). Of these patients, six underwent revision surgery entailing conventional spinal canal decompression and four underwent fusion.

**Recurrent Herniations**

There were 14 recurrences (6.0%) during the follow-up period after a pain-free interval; patients with these recurrences underwent reoperation in which the same operative technique was used. Three patients suffered another recurrence. Histological examination revealed that the material consisted of at least 75% endplate material.

**Clinical Outcome**

The bar graphs in Fig. 6 show VAS pain scores, ODI scores, and NASS scores. There was constant and significant (p < 0.001) improvement in leg pain and daily activities. There was no influence on back pain. After 2 years, 195 patients (84%) no longer had leg pain, 28 (12%) had pain occasionally or the pain was greatly reduced, and nine (4%) experienced no essential improvement. Three patients without improvement had undergone a previous operation at a different spinal level, and six had hard-tissue compression. There was no significant operation-related deterioration in leg or back pain. Neurological deficits were significantly (p < 0.001) reduced when the patient’s history of pain was less than 6 days. In an additional follow-up examination of the 15 patients who suffered recurrence, 12 reported having no leg pain after the revision surgery and three reported occasional or greatly reduced pain. Two hundred six (93%) of 222 patients who did not undergo a conventional revision surgery reported subjective satisfaction with the procedure and would undergo the operation again. Conventional revision operations included spinal decompression (six cases) and fusion (four cases). Overall, 19 (8%) of 232 patients had a poor result in terms of no leg pain reduction (nine patients) or had to undergo open surgery later for persistent leg or back pain (10 patients). Two hundred four patients returned to their occupation or sports activities. Sick leave following hospitalization ranged from 5 to 41 days (mean 22 days). There were no clinical symptoms in the sense of a postdiscectomy syndrome.

**Operative Technique**

No access-related osseous resection was required in 231 (87.5%) of 264 cases. In the transforaminal group, in 12 cases (11%) we had to excise bone segments of the undersurface of the superior articular process or the cranial segment of the caudal pedicle. In the interlaminar group, in 21 cases (14%) we had to resect bone segments of the inferior articular process and the cranial lamina.

Technically, surgical removal of the herniated disc was possible in all cases. Intraoperative conversion to a conventional procedure was not required in any case. The use of bipolar high-frequency probes was necessary in all cases for preparation and cauterization. Measurement of the lavage fluid in- and outflow showed maximal 100 ml that remained intracorporeal.

**Discussion**

The goal of surgical treatment of herniated lumbar discs is sufficient decompression with minimization of operation-induced trauma and its sequelae. In the present study we found that the full-endoscopic transforaminal and interlaminar operation can offer therapeutic supplementation or alternative.

Full-endoscopic transforaminal and interlaminar surgery achieves results similar to those of microscope-assisted procedures—that is, between 75 and 100%. The possibility of sufficient decompression with the endoscopic transforaminal technique equal to that of conventional procedures has also been shown in a prospective randomized study in which specific inclusion criteria were used. When resection of spinal canal structures is avoided or the extent reduced, the minimally traumatic disc resection appears capable of reducing operation-induced segment instability. Operative time, tissue trauma, and complications are reduced compared with conventional procedures.
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operative activity level is regained.\textsuperscript{22} Operation-related rehabilitative measures are not necessary. There is no surgery-induced aggravation of existing symptoms, which is consistent with the minimally invasive epidural and intervertebral procedure.\textsuperscript{8,27,71,84} Concomitant diseases do not lead to increased morbidity.\textsuperscript{81,83,103} The reduction of neurological deficits cannot be predicted on the basis of known results.\textsuperscript{7,58} The epidural adhesions found intraoperatively in our patients also occur in those who have not undergone prior surgery and cannot always be unequivocally diagnosed on imaging studies. The adhesions can occur as a result of degenerative inflammatory processes and influence the operative outcome.\textsuperscript{55,81,92,93} Although all patients underwent surgery after the induction of general anesthesia in the present study, the use of a local anesthetic is also possible.\textsuperscript{15,16,61,108,120}

When using the transforaminal approach and nonflexible instruments, a lateral route makes an entry into the entire intravertebral space difficult. When using the interlaminar approach, resection of the intradiscal nucleus material is frequently constrained because of the divergent level between the interlaminar window and the intervertebral space. This may be partially responsible for the 6.0% recurrence rate, which is higher than the published rate associated with conventional nucleotomies but lower than that for selective sequestrectomy.\textsuperscript{9,39,101,112} Revision surgery can be conducted using the same technique. In cases involving a large anular defect, we attempt as complete a resection as possible of the dorsal third of the nucleus space. Due to the histologically proven high concentration of endplate material in the recurrent disc matter, a recurrence will not be entirely avoidable. The possible negative effects of excising a degenerated nucleus of questionable biomechanical function have not yet been completely elucidated.\textsuperscript{58,62,71,122} Minimization of the operation-related anular defect, which is attained in the technique presented here, has been discussed as a protective biomechanical factor.\textsuperscript{122}

During the revision procedures, we found no scarring in the access area and only slight scarring in the spinal canal or foramen. The epidural fat, which acts as a lubricant, is largely preserved. The revision procedures, unlike those following conventional techniques, were neither made significantly more difficult nor required longer operative time.\textsuperscript{106} By contrast, epidural scarring, which may become clinically symptomatic in up to 10% of cases, is expected after the use of conventional techniques.\textsuperscript{6,30,58,62,93,96} Reduced trauma of the ligamentum flavum appears to have certain advantages.\textsuperscript{7,19} When the ligament is incised to insert the endoscope into the spinal canal, the opening can be limited to a maximum of 5 mm. One must remember, however, that epidural scarring may not be demonstrated on MR images.\textsuperscript{6,92,93} Overall, full-endoscopic transforaminal and interlaminar surgery appeared to reduce scarring based on two observations: 1) absence of clinical symptoms; and 2) intraoperative findings at revision surgery.

The new optics with the 4.2-mm intraendoscopic working channel and corresponding new instruments, shavers, and burs expands the indication spectrum. Working space is increased by the possibility of bone resection and thus the surgical treatment of every disc herniation is technically possible. Parameters such as the osseous diameter of the interlaminar window or the extent of cranio-caudal sequestration of the disc material are no longer contraindications to surgery. Likewise, the larger instruments enable removal of so-called hard-disc herniations and more sufficient clearing of the intervertebral space. The technical limitations of the old systems and the resultant contraindications can be overcome using the present technique.\textsuperscript{85,87–89} Although bone resection was not performed in 87.5% of the cases, a definitive determination of its necessity is not always possible based on preoperative imaging. Thus, the new instruments offer considerable advantages in guaranteeing that intraoperative obstacles to access can be overcome.

To guarantee complete decompression, herniated discs usually have to be resected under visual control, even when a full-endoscopic technique is used. In terms of transforaminal access, various authors have described the removal of sequestered discs from the epidural space via resection from inside the disc through the annulus defect.\textsuperscript{47,50,51,105,107,119} Some authors have described the resection of all forms of disc herniations.\textsuperscript{3,107,117–119} We, however, see limitations in performing transforaminal procedures, even with a lateral approach, which can enable better access to the spinal canal.\textsuperscript{36} Successful decompression under visual control must be a basic prerequisite when comparing results with those of conventional operations. For this reason, the indications and contraindications for the transforaminal access, as previously described, could be helpful. Thus, sufficient surgical treatment of disc herniations may be limited in the transforaminal technique.\textsuperscript{16,50,59,88,97}

Therefore, we use the interlaminar approach in cases in which the herniated herniations are, in our opinion, technically inoperable were the transforaminal technique to be used. Overall, we found no differences between the transforaminal and interlaminar approach. Nonetheless, surgery involving transforaminal access can be viewed as causing less trauma because the ligamentum flavum is not opened.

Taking individual disease and anatomy into account, the overriding indication for the present techniques is symptomatic radicular compression caused by disc herniation. The new optics and instruments offer the possibility of achieving sufficient bone resection and avoiding the access-related limitations with respect to accompanying osteochondrosis such as narrowing of the intravertebral space, foraminal stenosis, or recess stenosis. Bilateral and bisegmental procedures, which may also be required in conventional techniques, are technically possible, taking the indication criteria under consideration.

Conclusions

The results of the present prospective study show that predictably sufficient decompression under visual control in a short operative duration is possible using the full-endoscopic transforaminal and interlaminar technique. Results equivalent to those of conventional operations, taken as the minimum prerequisite for new techniques, can be attained. In the transforaminal procedure the use of the lateral access is often necessary. The new endoscope with its 4.2-mm working channel and corresponding instruments has largely overcome the technical problems associated with other devices. In our opinion, the following advantages are offered: facilitation for the operator due to excellent visualization of anatomical structures, good illumination, and expanded field of vision with 25° optics; cost-effective pro-
cEDURE due to short operating time, quick rehabilitation, and low postoperative costs of care; reduced anatomical trauma; reduced bleeding; facilitation of revision operations; use as a training basis for assistants; and high patient satisfaction. The following must be considered disadvantages: the possibility, albeit limited, of extending the surgical session in the event of unforeseen hindrances; the need for limited preparation of the intervertebral space; high learning curve; in the transfornaminal technique, the theoretically elevated risk of injuring exiting nerves; and narrow indication criteria due to limited mobility in dispensing with extensive bone resection.

We view full-endoscopic transfornaminal and interlaminar surgery as a sufficient and safe supplement and alternative to conventional procedures. With the new endoscopes and instruments and the possibility of selecting an interlaminar or transfornaminal postterolateral-to-lateral procedure, lumbar disc herniations outside and inside the spinal canal can be sufficiently removed using the full-endoscopic technique, when taking the appropriate criteria into account.

Nonetheless, open and invasive procedures are necessary in spinal surgery today and will remain so in future. These must be mastered by surgeons so that they also overcome problems and complications encountered when performing full-endoscopic procedures. Full-endoscopic techniques do not represent a replacement of existing operative standards but rather an alternative to be used within spinal surgery.

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