Full-Endoscopic Cervical Posterior Foraminotomy for the Operation of Lateral Disc Herniations Using 5.9-mm Endoscopes

A Prospective, Randomized, Controlled Study

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Study Design. Prospective, randomized, controlled study of patients with lateral cervical disc herniations, operated either in a full-endoscopic posterior or conventional microsurgical anterior technique.

Objective. Comparison of results of cervical discectomies in full-endoscopic posterior foraminotomy technique with the conventional microsurgical anterior decompression and fusion.

Summary of Background Data. Anterior cervical decompression and fusion is the standard procedure for operation of cervical disc herniations with radicular arm pain. Mobility-preserving posterior foraminotomy is the most common alternative in the case of lateral localization of the pathology. Despite good clinical results, problems may arise due to traumatization of the access. Endoscopic techniques are considered standard in many areas, since they may offer advantages in surgical technique and rehabilitation. These days, all disc herniations of the lumbar spine can be operated in full-endoscopic technique. With the full-endoscopic posterior cervical foraminotomy a procedures is available for cervical disc operations.

Methods. One hundred and seventy-five patients with full-endoscopic posterior or microsurgical anterior cervical discectomy underwent follow-up for 2 years. In addition to general and specific parameters, the following measuring instruments were used: VAS, German version North American Spine Society Instrument, Hilibrand Criteria.

Results. After surgery 87.4% of the patients no longer had arm pain, and 9.2% had occasional pain. The clinical results were the same in both groups. There were no significant difference between the groups in the revision or complication rate. The full-endoscopic technique brought advantages in operation technique, preserving mobility, rehabilitation, and traumatization.

Conclusion. The recorded results show that the full-endoscopic posterior foraminotomy is a sufficient and safe supplement and alternative to conventional procedures when the indication criteria are fulfilled. At the same time, it offers the advantages of a minimally invasive intervention.

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Radicular symptoms with arm pain due to degenerative changes of the cervical spine arise typically from lateral disc herniations or osteophytes in the intervertebral foramen. Surgical decompression may become necessary if conservative therapeutic measures fail, or if there is paraparesis. Clinical symptoms were first classified with topographical reference to changes in cervical discs in the early 1940s. In that same period, posterior surgical access to the cervical spine was developed which was modified over time. Access anterior for the operation of cervical disc changes was described at the end of the1950s.

Anterior cervical decompression and fusion (ACDF) has now developed as a standard procedure in the operation of cervical radiculopathies. It is usually described as a safe and sufficient procedure with good fusion rates. Nonetheless, specific problems may occur, such as loss in height of the intervertebral space, pseudarthroses or access complications. Degeneration of adjacent segments is discussed as a particular disadvantage of fusion. Posterior foraminotomy is the most common alternative to the ventral procedure. It is performed without additional stabilization and thus preserves the mobility of the segment. The stability does not appear to negatively affected by surgery. Disc herniations and stenosis with exclusively lateral localization are taken as indications, since the cervical myelon must not be mobilized toward medial. Access-induced neck pain or intraoperative bleeding may be a problem. No reconstruction of the intervertebral space can be made.

Modifications to reduce the disadvantages of the ventral and dorsal procedures have been described, such as anterior cervical decompression without fusion, anterior foraminotomy in various techniques, or
posterior microscope-assisted or endoscope-assisted “keyhole foraminotomy.” The cervical disc prosthesis is intended to combine the advantages of the ventral access with the possibilities of total decompression and reconstruction of the intervertebral space, while preserving segment mobility.73–75

Endoscopic techniques are standard procedures in many areas of medicine. These days, all disc herniations in the lumbar spine can be operated in full-endoscopic technique.76–89 The development of new endoscopes and instruments enable sufficient bone resection and eliminate technical problems.90–92 Anterior, transdiscal endoscopic decompressions are performed in disc herniations in the cervical spine.93–103 An endoscopic posterior procedure was cited in 1999 without further specification.104

Although conventional procedures show good results, continuous technical optimization should be the goal. Minimally invasive techniques can reduce traumatization and its consequences.105,106 The goal for new or modified procedures is to achieve the clinical results of established standard procedures.107

The objective of this prospective, randomized, controlled study was to compare the results of cervical discectomy in lateral disc herniations in full-endoscopic technique via posterior foraminotomy with those of the conventional microsurgical ACDF.

### Materials and Methods

**Patient Characteristics**

In the prospective, randomized, controlled study we enrolled 200 patients with clinically-symptomatic lateral cervical disc herniation who underwent discectomies in 2004/2005. There were 132 female and 68 male patients whose age ranged from 27 to 62 years (mean, 43 years). The duration of pain ranged from 5 days to 8 months (mean, 94 days). One hundred and seventy-one patients had received a mean of 10 weeks conservative treatment. The indication for surgery was made due to intolerable radicular pain or neurologic deficits.

**Study Groups**

One hundred patients each underwent conventional microsurgical ACDF, or decompression via full-endoscopic posterior cervical foraminotomy (FPCF). Randomization was open, since the patients may identify the operation procedure.

Fulfillment of the inclusion criteria for the study and the presence of the general indication for decompression were determined by experienced physicians who were not involved in the operation. Randomized assignment to the ACDF or FPCF group was made by alternation in the order of presentation by nondoctors assisting in the study. All operations were performed by 2 surgeons with several years of experience with both techniques. Eighteen interventions were performed at the C4–C5 level (7 × ACDF, 11 × FPCF), 42 at C5–C6 (22 × ACDF, 20 × FPCF), 116 at C6–C7 (61 × ACDF, 55 × FPCF), and 24 at C7–Th1 (10 × ACDF, 14 × FPCF).

**Inclusion Criteria**

The following were the inclusion criteria for discectomy: unilateral radiculopathy with arm pain; in MRI/CT lateral or foraminal localized monosegmental disc herniation; Segments C2–C3–C7–Th1. Cranio-caudal sequestering was not taken as an exclusion criterion, as long as the lateral localization was maintained. Likewise, patients with secondary foraminal stenosis were included.

Patients with clear instabilities or deformities were to be excluded, but there were none in the patient collective. Medial localization of the disc herniation was an absolute exclusion criterion. Patients with isolated neck pain or foraminal stenosis without disc herniation were not included in the study.

**Operative Technique**

The conventional microsurgical ACDF was performed in known standardized technique using a microscope. A PEEK (polyetheretherketone) cage was used as the intervertebral implant, there was no additional ventral plating.7,12,13,21,108–111

The FPCF was performed under general anesthesia and radiographic control with the patient prone. The cervical spine was delordosated, the head fixed in place with tape. No frames, like Mayfield clamps, are necessary. The arms are positioned toward caudal on the body with gentle tension. The FPCF is a full-endoscopic uniportal technique, that means, the working canal for the instruments is inside the endoscope, so that no additional space is needed to insert the instruments, as is the case in a MED procedure, for example.

The operation is made principally following described conventional foraminotomy techniques.5–6 The line of spinal joints is marked under posterior-anterior radiographic control. From this point on, the operation is performed under lateral radiographic control. Determination of the segment, performance of skin incision and blunt insertion of a dilator onto the facet joint. Insertion of the operation sheath via the dilator; beveled opening. Removal of the dilator. After insertion of the optic, further operation is performed under visual control and continuous fluid flow with 0.9% saline solution. Preparation of the joint segment and the ligamentum flavum. Start of the foraminotomy by bone resection at the medial joint segments, resection of the lateral ligamentum flavum and identification of the lateral edge of the myelon and branching of the spinal nerves. Bone resection was made under visual control using 3-mm drills and bone punches, inserted through the intraendoscopic working canal. Bipolar radiofrequent coagulation of the venous plexus and preparation of the spinal nerve under particular attention to possibly separate motoric and sensory segments. Depending on the pathology in each case, the foraminotomy can be extended toward lateral or cranio-caudal (Figures 1–3).

Figure 1. The intraoperative C-arm control shows the working sheath with optics and a dissector on the dorsal anulus.
After all instruments are removed, direct closure of the skin. No drainage is required. All patients are given a soft brace for 5 days.

**Full-Endoscopic Instruments**

The rod-lens optics have an outer diameter of 5.9 mm. The optics contain an intracapsular, eccentric working canal with a 3.1 mm diameter, the light conductor system, a canal for continuous intraoperative lavage, and the optical lens system. The angle of vision is 25°. The working sheaths used have an outer diameter of 6.9 mm and a beveled opening, which enables creation of a visual and working field in an area without a clear anatomically-preformed cavity. All of the operating instruments and optics were products supplied by WOLF (Richard Wolf GmbH, Knittlingen, Germany).

**Follow-up**

Follow-up examinations were conducted at day 1 (200 patients) and at months 3 (191 patients), 6 (187 patients), 12 (184 patients) and 24 (175 patients) after surgery. All patients 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 2 physicians in the clinic, who were not involved in the operations. In addition to general parameters, other information was obtained using the following instruments: a VAS for neck and arm pain, the German version of the North American Spine Society Instrument,112–114 Hilibrand criteria115,116 based on Smith and Robinson.8 All patients underwent MRI and radiographs after the end of the follow-up period.

**Statistical Analysis**

The Wilcoxon’s 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 ACDF group versus the FPCF group at various times. The McNemar test was used to compare the characteristics of the groups. The descriptive assessments and analytical statistics were performed depending on the group characteristics with the program package SPSS. A positive significance level was assumed at probability of less than 0.05.

**Results**

**Baseline Characteristics**

One hundred and seventy-five (88%) (86 × ACDF, 89 × FPCF) patients were included in follow-up after 2 years (84 × ACDF, 91 × FPCF). The remaining cases were drop outs for the following reasons: 2 patients moved away and left no forwarding address, 13 patients did not respond to letters or telephone calls, 10 patients underwent revision surgery with conventional ACDF. The patient population was equal in the ACDF and FPCF groups. Overall there were no differences in results in dependence on the individual surgeon.

**Intraoperative Findings**

Fresh nucleus tissue was found in 176 patients (88%). Of these, 50 patients additionally presented with osteophytes in the foraminal area. In 24 patients (12%), there was only compression of the nerve due to bulging of the annulus and osteophytic foraminal stenosis. Bony foraminal stenosis was found in a total of 74 patients (37%). Nineteen patients (19% of the FPCF group) had a divided spinal nerve with separate motoric and sensory segments. This was only diagnosed in the FPCF group.

**Operative Technique**

The mean operating time in the ACDF group was 68 minutes,48–105 and thus significantly shorter ($P < 0.001$) than in the FPCF group at 28 minutes.19–50 The intra- and postoperative blood loss in the ACDF group, measured by intraoperative suctioning and postoperative drainage, was less than 10 mL. In the FPCF group, there was no measurable blood loss. Thanks to the full-endoscopic technique with continuous lavage and the possibility of radiofrequency, bipolar coagulation there is hardly any bleeding. Postoperative drainage is not necessary.

In the ACDF group, the bone harvested intrapleuratively in decompression sufficed to fill the cage in 21 cases, Spongiosa was obtained from the pelvis in percutaneous technique in 79 cases.

Access-related bone resection was necessary in all patients in the FPCF group, bone resection to dilate a foraminal stenosis in 39 patients. In the FPCF group there...
was no hindrance due to intraoperative bleeding thanks to continuous fluid flow and the possibility of bipolar preparation. The full-endoscopic operation was technically feasible in all patients. An intraoperative switch to a conventional procedure was not made in any case.

**Perioperative Complications**

There were no serious complications in either group, such as postoperative bleeding, hoarseness, injury to the nerve or Dura, damage to the myelon with hemi- or paraparesis or paralysis of the upper extremities.

In the ACDF group, transient difficulty swallowing occurred in 3 cases, there was 1 surface hematoma and 1 case of scar distortion which was cosmetically disruptive.

In the FPCF Group 3 patients (3%) showed transient, dermatoma-related hypesthesia.

There were no further complications, such as infection, spondylodiscitis or thrombosis. Deterioration of existing symptoms did not occur in any case.

**Recurrences/Revisions**

There were 3 revisions, 1 anterior and 2 posterior foraminotomies, in the ACDF group due to persistent arm pain. Implant failure occurred in 1 patient, in whom the ACDF was repeated with tricortical pelvic crest chip and additional ventral dynamic plate. The revision rate in the ACDF group was 4.7%.

In the FPCF Group 3 patients suffered a recurrence during the follow-up period after a pain-free interval. All recurrences were located lateral and were operated using the same technique. The operation time was 27 to 39 minutes. 2 patients were operated using conventional ACDF and 1 using FPCF due to persistent pain. These belonged to the group who did not show any free nucleus tissue intraoperative. The revision rate in the FPCF group was 6.7%.

The difference in the complication rate between the 2 groups was not significant.

**Radiologic Findings**

MRI and radiograph examinations at the end of follow-up did not reveal any new damage to adjacent discs in any patient. Nineteen patients showed progradience of adjacent disc degeneration which had existed preoperatively.

In the ACDF group, there was no clear radiologic signs of bony intrusion in the cage without correlation to the clinical result in 17 (18%) patients. Sintering to maximum 3 mm was found in 5 (5.8%) patients.

In the FPCF group there were no signs of increasing kyphosis or instability in the operated segment in any patient. Twenty-one patients (24%) showed signs of advancing degeneration in the disc.

**Clinical Outcome**

Figure 4 shows the course of arm and neck pain in both groups, rated using the VAS scale. There is a significant reduction of radicular pain symptoms. Figure 5 shows the values of the North American Spine Society Instrument Score, which also illustrates equal pain reduction in the ACDF group in Figure 6 and the FPCF group in Figure 7. Overall, the measuring instruments show constant and significant ($P < 0.001$) improvement in arm pain and activities of everyday living in both groups. Figure 8 shows the complete depiction of the radicular pain status after 2 years. One hundred and fifty-five patients (88.5%) no longer had arm pain, 13 (7.5%) occasional pain or clearly reduced pain and 7 (4%) no essential improvement. The differences in results between the groups were not significant. 9 patients (5.1%) suffered progredient neck pain (7 × ACDF, 2 × FPCF). Ten patients (5.7%) (4 × ACDF, 6 × FPCF) underwent revision due to persistent arm pain, recurrences or failure of the implant. Overall, 17 patients (9.7%) had poor results (7 × no essential improvement, 9 × poor results).

Figure 4. Mean values of VAS arm and neck in the ACDF and FPCF group.
One hundred and sixty-four patients (93.7%) reported subjective satisfaction and would again undergo the procedure (78 × ACDF = 91%, 86 × FPCF = 96%). Neurologic deficits were significantly (P < 0.001) reduced when the patient’s history of pain was less than 10 days.

Postoperative pain was significantly reduced in the FPCF group and operation-related neck pain did not require pain medication and lasted maximum 3 days. Mobilization was made immediately in both groups depending on the narcosis. Rehabilitative measures were not necessary except in existing pareses. All results were independent of general parameters, like gender, age, height, weight, occupation or secondary illnesses. The mean postoperative work disability in the FPCF group was 19 days, versus 34 days in the ACDF group (P < 0.01).

Discussion

ACDF is the standard procedure for treatment of cervical herniated discs.9–22 Posterior foraminotomy is used as the most common alternative in lateral pathologies, and appears to be gaining in focus with the development of minimally-invasive techniques.6,26,31–47 Both procedures bring good results when indications are taken into consideration. Problems with ACDF may include for example loss of height in the intervertebral space, pseudarthroses, access complications and adjacent degenerations due to the loss of mobility.23–25,27–30,117 Access-related neck pain, intraoperative bleeding, a lack of
reconstruction of the intervertebral space and the limitation of indication to lateral localization are considered disadvantages of the mobility-preserving posterior foraminotomy.5,38,46,48–52

The goal of surgery should be sufficient decompression under continuous visualization with concurrent minimization of operation-related trauma and its possible consequences. It was possible to achieve this goal in the lumbar spine by using full-endoscopic techniques.76–84,89–92 Publications on endoscopic operations of the cervical spine refer to the anterior, transdiscal technique.93–104 Despite technical limitations, good results are described. A posterior full-endoscopic technique has been mentioned to our knowledge only once in connection with anterior endoscopy without bone resection and without any more precise specification.104

In our study, the clinical results in the ACDF and FPCF group agree with the data in the literature.11,12,15,16,18,19,21,22,26,36–47 Traumatization, operating time and rehabilitation time are reduced compared to conventional procedures.12,16,18,19,22,26,40–47,118 No operation-induced neck pain or instabilities occurred. No patient suffered deterioration of existing symptoms, which corresponds to experience with a minimally-invasive epidural and intervertebral procedure in the lumbar spine.119–122 A significant and constant improvement was achieved in both groups without significant differences.
The recurrence rate in the FPCF group of 3.4% is within the results published for the standard foraminotomy.\textsuperscript{35,42,44,118} Revisions could be performed with appropriate indication using the same full-endoscopic technique. Negative effects due to opening of the anulus are discussed in connection with the lumbar spine.\textsuperscript{121,123–125} Unlike ACDF, real recurrences can never be totally ruled out.

The rate of complications and revisions in the ACDF group is comparable to published results and lower than for conventional foraminotomies in the FPCF group.\textsuperscript{1,11,12,15,16,18,19,21,22,26,35–47,118} The differences between the groups are not significant.

The FPCF was technically feasible in all cases. Surgery under continuous fluid flow is known to reduce intraoperative bleeding and enables very good vision in combination with the 25° optics.\textsuperscript{80–83,89–92} In combination with the possibility of radiofrequent, bipolar coagulation, this appears to reduce especially the epidural bleeding, which may be problematical in posterior procedures. Bone resection is required for access and usually necessary in foraminal stenosis. This applies for all direct decompression techniques which do not reconstruct the intervertebral space and can achieve indirect dilation of the Foramen via distraction. Thus, the possibility of bone resection is prerequisite to sufficient full-endoscopic decompression. This could be achieved in recent years thanks to further technical developments.\textsuperscript{83,90–92} For this reason, results of older studies are almost incomparable to today’s studies.\textsuperscript{104} Since the myelon may not be manipulated, posterior decompression can only be performed in lateral localization of the pathology.\textsuperscript{5,18,46,48–52} This applies to many cases with radicular pain due to disc herniation. We cannot agree without reservation to the statement that only indirect decompression is possible by means of posterior foraminotomy.\textsuperscript{39} Removal of nucleus material or dilation of the foramen corresponds to direct decompression. Indirect decompression occurs only in purely ventral compression due to hard tissue. The same problem may arise in ACDF with dorsal foraminal stenosis. Unlike in anterior procedures, cranial and caudal dislocated sequester in lateral localization can be resected under direct vision from dorsal. Given appropriate indication, revisions can be performed using the same technique. Revision by means of ACDF is not made more difficult by prior operation.

The present prospective study shows that predictable sufficient decompression in lateral disc herniations can be achieved by full-endoscopic posterior foraminotomy under continuous visualization in a short operation time. The clinical results of conventional procedures are achieved, while advantages of a minimally invasive procedure are given. We consider the technique described to be a sufficient and safe supplement within the spectrum of conventional procedures.

Comparison of the 2 techniques and comparison with the literature shows, in our opinion, the following advantages for FPCF: facilitation for the surgeon by excellent presentation of the anatomic structures, good illumination and expanded field of vision thanks to the 25° optics; economical procedure thanks to short operation time, rapid rehabilitation and low postoperative costs of care; reduced traumatization, no operation-related neck pain; reduced bleeding; reduced risk of access-related complications; maintained mobility; facilitated revision operations; monitor image as the basis for training of assistants; high patient acceptance. The following must be considered disadvantages: limited possibility to expand the operation in the event of unforeseen hindrances; indication limited to lateral localization of the pathology; no reconstruction of the intervertebral space; no direct decompression in ventrally-caused stenosis; high learning curve.

### Key Points

- The clinical results of the full-endoscopic posterior cervical foraminotomy are equal to those of the conventional microsurgical anterior decompression and fusion. At the same time, there are advantages in the operation technique and reduced traumatization.
- Indications for the full-endoscopic posterior cervical foraminotomy are radicular arm pain due to lateral disc herniation.
- The full-endoscopic technique is a sufficient and safe supplement and alternative to conventional microsurgical procedures.
- Open and maximally-invasive procedures are necessary in spinal surgery and must be mastered by surgeons so that they also overcome problems and complications encountered when performing full-endoscopic procedures.

### References


