

Retrospective Review

Operation of Soft or Calcified Thoracic Disc Herniations in the Full-Endoscopic Uniportal Extraforaminal Technique

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Background: Surgery for thoracic disc herniation and stenosis is comparatively rare and often demanding. The goal is to achieve sufficient decompression without manipulating the spinal cord and to minimize surgical trauma and its consequences. Individual planning and various surgical techniques and approaches are required. The key factors for selecting the technique are anatomical location, consistency of the pathology, general condition of the patient, and the surgeon's experience.

Objectives: The objective of the study was the evaluation of the technical implementation and outcomes of a full-endoscopic uniportal technique via the extraforaminal approach in patients with symptomatic soft or calcified disc herniation of the thoracic spine, taking specific advantages and disadvantages and literature into consideration.

Study Design: Retrospective study

Setting: A center for spine surgery and pain medicine.

Methods: Between 2009 and 2015, decompression was performed on 26 patients with thoracic disc herniation or stenosis with radicular or myelopathic symptoms in a full-endoscopic uniportal technique with an extraforaminal approach. No patients underwent additional posterior stabilization. Imaging and clinical data were collected in follow-up examinations for 18 months.

Results: Sufficient decompression was achieved in the full-endoscopic uniportal technique in all cases. The individual selection of the respective approach made it possible to reach the target area without manipulating the spinal cord. One patient experienced deterioration of a myelopathy. No other serious complications were observed. All patients, except one, experienced regression or improvement of symptoms. No evidence of increasing instability was found in imaging.

Limitations: This is a retrospective study. The limited number of cases must be considered.

Conclusions: The full-endoscopic uniportal technique with an extraforaminal approach was found to be a sufficient and minimally invasive method with the known advantages of an endoscopic procedure under continuous irrigation for monosegmental disc herniations. The inclusion criteria must be taken into consideration. If they are not met, an alternative full-endoscopic approach (interlaminar, transthoracic retropleural) or decompression in a conventional method must be selected. Additional stabilization does not appear to be necessary due to the low level of trauma.

Key Words: Extraforaminal approach, thoracic disc herniation, giant disc herniation, Full-endoscopic, minimally invasive, thoracic spine

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Thoracic disc herniations are rare and constitute only 0.15% to 4% of all nucleotomies of the spine. They may be soft or calcified (1-3); a special form termed giant disc herniation has been described (4) that displaces more than 40% of the spinal canal (3,5,6). Depending on the location from intraforaminal to intraspinal, radicular and/or central neurological (myelopathic), symptoms may occur (3,7,8). Atypical symptoms (e.g. gastrointestinal, cardiopulmonary, abdominal) have also been reported (9,10). MRI is the diagnostic imaging method of choice; due to the frequently existing calcification or ossification, an additional CT scan should always be considered (5,11).

Conservative treatment is possible, especially for lateral disc herniation (12,13). Intolerable and/or persistent pain or acute or progressive radicular or central neurological deficits are criteria for the indication for surgery, which can also be considered for atypical symptoms (8,14,15). In decompression, the surgical manipulation of the thoracic spinal cord must be avoided. Therefore, depending on the location and consistency of the pathology, various anterior approaches and non-anterior approaches are used, which cover the entire area around the spinal cord (16-25). The non-anterior approaches may involve difficult or inadequate visualization or handling of the area anterior to the spinal cord and approach-related destabilization of the posterior structures (26,27). Anterior approaches allow sufficient and direct access to the anterior spinal canal, but may lead to problems due to opening the thoracic and pleural cavity (3,28,29) and have a higher rate of complications (28,29). Overall, there are no clear standards; in literature, an anterior approach is usually preferred for anterior pathologies, but sometimes non-anterior approaches are also considered the method of choice (29). In general, an attempt is made to achieve adequate results and reduce problems with minimally invasive modifications (20,24,30-33).

Good outcomes and advantages of full-endoscopic uniportal operations under continuous irrigation have been described for surgery of herniated discs and spinal stenoses in the lumbar and cervical spine (34-38). This study evaluated the technical implementation and outcomes of a full-endoscopic uniportal technique via the extraforaminal approach in patients with symptomatic soft or calcified disc herniation of the thoracic spine, taking specific advantages and disadvantages and literature into consideration.

Methods

Patient Characteristics

The routinely collected prospective data of all operations of the thoracic spine (T1-T12) due to disc herniation or spinal canal stenosis were evaluated retrospectively. The research protocol for this study has been reviewed and approved by the Hospital Institutional Review Board. A specific patient consent was not required regarding to the federal data privacy act because this retrospective study is on the basis of intradepartmental medical records. Of these, 26 consecutive patients (16 females, 10 males, with a mean mean age 58, ranging from 23 to 82, were included. Patients were decompressed in a full-endoscopic uniportal technique via an extraforaminal approach between 2009 and 2015. The locations of the pathologies were at T6-7 (1 case), T7-8 (1 case), T8-9 (3 cases), T9-10 (5 cases), T10-11 (11 cases), T11-12 (5 cases). There were 4 intraforaminal disc herniations, 5 soft and 15 calcified intraspinal disc herniations, and 2 giant disc herniations. The leading symptoms were radiculopathy in 7 cases and myelopathy in 19 cases. Four patients also reported atypical symptoms and 15 patients had thoracic axial pain. The average duration of the symptoms was 11 weeks (3-34) for the radiculopathies and 9 weeks (<1-61) for the myelopathies.

Inclusion Criteria / Selection of Approach

There were the following criteria for a full-endoscopic extraforaminal technique: monosegmental soft or calcified disc herniation, persistent or progressive radicular and/or central neurological symptoms, axial pain not pronounced, no high-grade deformity/instability or prior surgery in the target segment.

For the selection of the surgical technique, comparable with a conventional method, the pathology and thus the target area were determined and assessed. Depending on the assessment, it was determined whether the extraforaminal approach would allow the target region to be reached and decompressed while avoiding manipulation of the thoracic spinal cord. The larger, more medial, or more calcified the disc herniation was, the more likely it was that a transthoracic approach was selected. Taking the individual situation into consideration, the full-endoscopic extraforaminal approach was used for intra-/extraforaminal, mediolateral, and medial intraspinal soft or calcified disc herniations.

Full-endoscopic Instruments

The endoscope used has an oval shaft cross section measuring 6.9 x 5.9 mm, a working length of 165

mm, and is introduced through a working sheath. The view angle is 25°. For a uniportal technique, an intra-endoscopic, eccentric working channel with a diameter of 4.1 mm, light guide, inflow for continuous irrigation, and a rod lens system are needed. For coagulation and tissue ablation, a bipolar articulating probe is used that applies the radiofrequency current of 4 MHz, which reduces the transmission of heat to adjacent tissue structures (39). The endoscopic system is used as an open system (34-37), so that for the length of the working sheath, a maximum pressure of the irrigation fluid of 14.3 mmHg can be reached even in a closed working channel. On average, the CSF pressure in the high cervical region is 15.5 mmHg (40), thus minimizing the risk of compression or leakage of the irrigation fluid into the CSF system. All surgical and optical instruments are products of RIWOspine (RIWOspine GmbH, Knittlingen, Germany) (Figs. 1, 2).

Extraforaminal Surgical Technique

The technique is the same as that already described for the lumbar spine (36,41-43). The operation is performed in general anesthesia in prone



Fig. 1. Endoscope with a 25° view angle and intra-endoscopic working channel.



Fig. 2. Full-endoscopic uniportal extraforaminal operation.

position on a radiolucent table under orthograde radiologic guidance in two planes. Pre-operatively, the approach angle is measured medial to the ribs and pleura. Under orthograde radiological guidance, the target segment is marked and the skin incision made. The dilator, the working sheath, and then the endoscope are introduced bluntly into the extraforaminal area or to the vertebral joints. The further procedure

is full-endoscopic and uniportal, i.e. all surgical instruments are introduced under continuous visual control and irrigation through the intra-endoscopic working channel. The foramen with pedicle, facets, discs, and spinal nerve is dissected. The foramen is widened by resection bone with a cutter and punches and the spinal canal is entered (Fig. 3). The precise extent of bone decompression depends on the respective finding. Sequestered disc tissue and the annulus may need to be resected. If there is intraspinal or medial calcification, paradiscal resection of bone segments from the posterior edge of the vertebral body ("box-shaped" resection) is necessary. This allows indirect and direct anterior decompression from the ipsilateral to contralateral side without manipulation of the spinal cord (Figs. 4, 5). Free-floating dura mater in the irrigation fluid is a sign of sufficient decompression. The instruments are withdrawn and the incision closed (Figs. 6, 7).

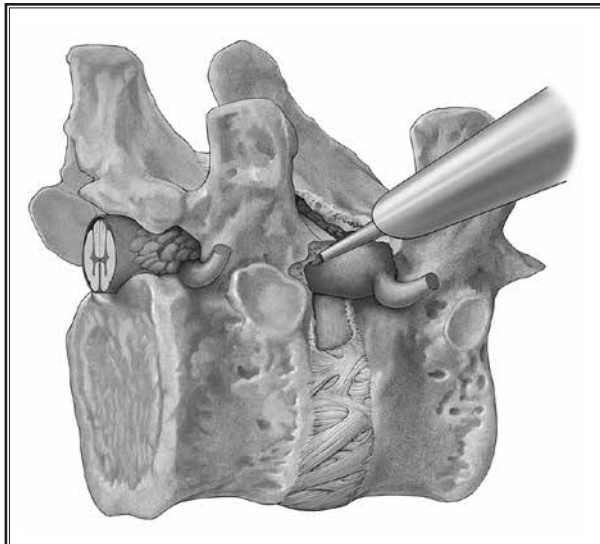


Fig. 3. The foramen must generally be widened by bone resection to allow access to the foramen or spinal canal.

Follow-up and Analysis

The data were routinely recorded pre- and postoperatively and after 6 weeks, 6 months, and 18 months. The patients came to follow-up in person. In addition to clinical and radiological parameters, the VAS (visual analog scale) for thoracic back pain and arm pain, the classification according to Nurick and the JOA (Japanese Orthopedic Association) adapted to the evaluation of thoracic pathologies (mJOA) for patients with

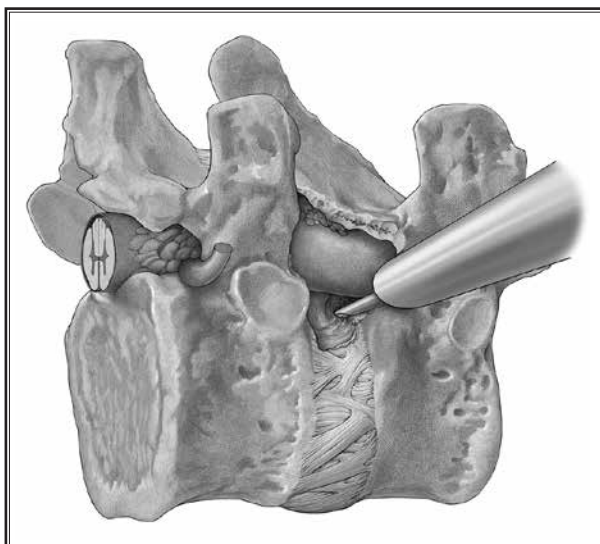


Fig. 4. The foramen is widened, start of bone resection at the posterior edges of the vertebral body for decompression of hard medial disc herniations.

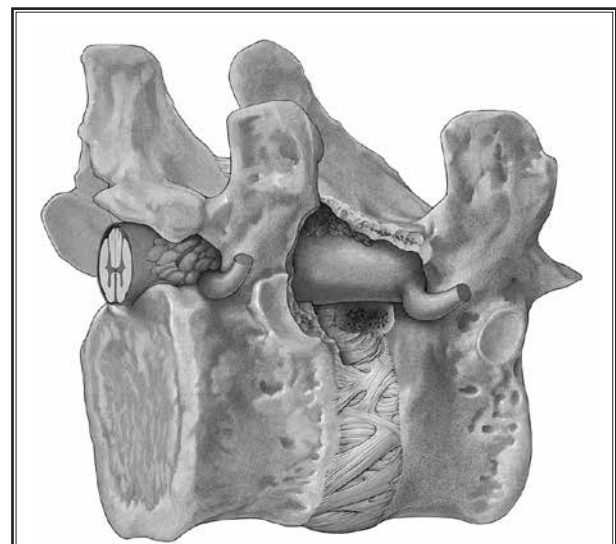


Fig. 5. Box-shaped resection and decompression of the spinal cord.



Fig. 6. Compressed spinal cord due to hard disc tissue; the electrode points to additional sequestered segments.

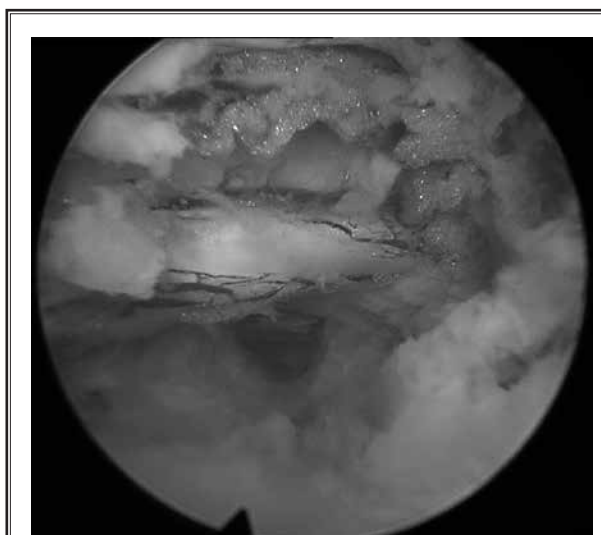


Fig. 7. View of the spinal cord after decompression.

a myelopathy (3,20), and the German version of the North American Spine Society Instrument (NASS) with the sub-scales pain and neurology for patients with radicular pain were used. Pre-operatively, postoperatively, and during follow-up, X-rays and MRI or CT scans were made depending on the finding. Some 25 patients (96%) were available to follow-up in the designated period. The Wilcoxon test and the Mann-Whitney U test were applied for comparison of pre-operative and postoperative global results and for the comparison of results in the groups at different times. McNemar's test was used to compare characteristics. Depending on the group characteristics, the descriptive assessments and analytical statistics were performed with the SPSS software package. A positive significance level was assumed at $P < .05$.

Results

Surgical Technique / Intraoperative Findings

Sufficient decompression was achieved in the full-endoscopic uniportal technique in all cases. The individual selection of the respective approach based on the inclusion criteria made it possible to reach the target area without manipulating the spinal cord. The combination of an angled field of view and the range of movement of the endoscope using a joystick technique allowed a sufficient working area in all directions that exceeded the requirements. All not sequestered disc herniations (9) that showed no calcification in the

pre-operative imaging (9) were found to have at least partial hard consistency intra-operatively, which made resection more difficult. Adhesions between the dura and the pathology were found once with a calcified disc herniation.

The rib and pleura caused restriction in the lateral direction, which prevented a flat angle during access. Bone resection at the facets was therefore necessary to enter the spinal canal or the foramen. The angle of the endoscope could be flattened later in the procedure. The region anterior to the spinal cord was easily reached due to the 25° view angle and articulating instruments. The extraforaminal approach had a broad range of indications for anterior pathologies. Performing indirect "box-shaped decompression" before the direct decompression for medial calcified pathologies allowed manipulation of the spinal cord to be avoided. Particular care had to be taken to resect up to the contralateral side in this case, as the 25° field of view allowed a good view below the anterior spinal cord and there was a tendency to carry out less contralateral decompression (Fig. 8). Free-floating dura mater in the irrigation fluid was evidence of sufficient decompression. Overall, working with a 25° view angle and continuous irrigation resulted in good visibility with the corresponding field of view and working area. No specific problems of the full-endoscopic uniportal technique were found.

Intra- and peri-operative data / complications

The mean operation time was 90 minutes (40-155).

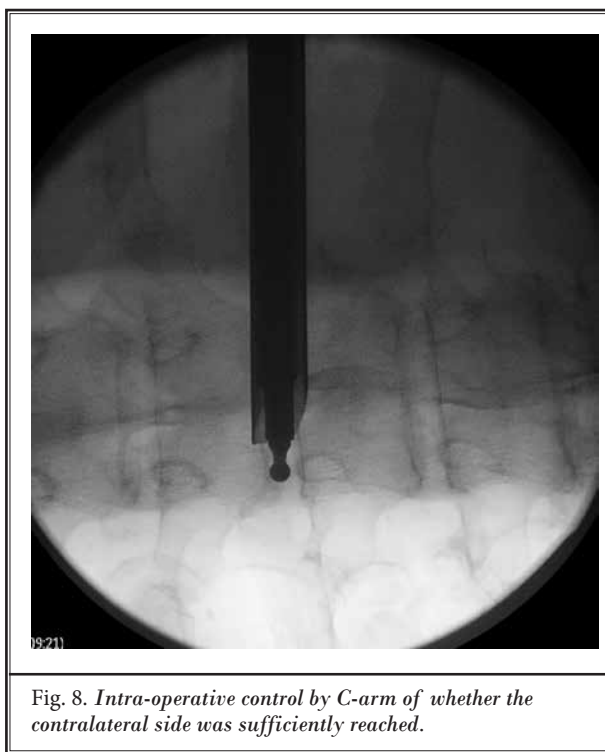


Fig. 8. Intra-operative control by C-arm of whether the contralateral side was sufficiently reached.

The intra-operative blood loss was so low that it could not be measured due to the continuous irrigation. All patients were extubated immediately postoperatively and mobilized immediately depending on the effect of the anesthesia. The mean hospital stay was 3 days (2-6). No surgery/approach-related pain medication was required. There was one postoperative epidural hematoma with radicular pain that was treated conservatively (pain medication) with subsequent freedom from pain. Two patients had persistent temporary intercostal neuralgia (for 2 + 7 days) also treated conservatively (pain medication). One anterior dural leak occurred during the resection of a calcified disc herniation with adhesions. It could not be sutured and was therefore covered with dural substitute and a fat flap as known in other techniques and required no further treatment. One patient had postoperative clinical deterioration of the myelopathy symptoms from giant disc herniations. No other serious problems requiring treatment such as post-thoracotomy pain syndrome, pleural effusion, impaired wound healing, infections, thrombosis, etc. occurred. No other complications were observed during follow-up examinations; no patient died. No recurrence was found during the follow-up period. The rate of all complications was thus 20%, that of more serious complications 8% (epidural hematoma, deterioration of symptoms).

Clinical and Radiological Outcome

All patients with a radiculopathy showed regression of the symptoms. The mean improvement in the VAS for radicular pain was from 77.9 to 2.1. In 3 patients with T12 deficits (two with 4/5 and one with 3/5 muscle strength in the abdominal wall), no weakness was found in the further course. Among the patients with myelopathy, one patient showed deterioration (mJOA -2, Nurick +1). Otherwise, all patients presented here showed regression or termination of the symptoms. The average improvement of the Nurick score was 1.1, of the mJOA score 2.6. The patients with a shorter duration of the myelopathy had less pronounced symptoms and achieved better outcomes, but this was not statistically significant. The results were achieved 21 times after 6 weeks and 4 times after 6 months and remained stable in the further course. No surgery- or approach-related increase in thoracic pain was reported. Overall, pre-operative thoracic back pain was improved, but improvement was not significant. The imaging follow-up showed sufficient decompression of bone and soft tissue in all cases. No signs of increasing instability were detected during the entire follow-up period.

Discussion

Disc herniation and degenerative spinal canal stenosis can lead to compression syndromes in the thoracic spine (44,45). Thoracic disc herniations are rare (incidence 1/1,000,000) and constitute only 0.15% to 4% of all nucleotomies of the spine. They can be soft or calcified, frequently occur at lower levels, and usually lead to anterior compression of spinal nerves or the spinal cord (1-3). In our study, all disc herniations were calcified or hard. A special form termed giant disc herniation has been described(4) that displaces more than 40% of the spinal canal, is often calcified, erodes the dura mater, and causes a myelopathy. The pathophysiology of its development is unclear (3,5,6).

Due to thoracic kyphosis, limited mobility of the spinal cord due to the dentate ligaments, and limited blood supply in the terminal arterial territory, the thoracic spinal cord is especially vulnerable for anterior compression (46,47). Depending on the location from intraforaminal to intraspinal, radicular and/or central neurological (myelopathic) symptoms may occur (3,7,8). Radiculopathies are usually caused by disc herniation and can cause intercostal pain. T1 compression, which did not occur in our patient group, can also cause pain in the arm and weakness of the intrinsic hand muscles (48). T12 compression (subcostal nerve), which affected

4 patients in our study, can cause weakness of the muscles of the abdominal wall (7,8). Myelopathies are caused primarily by compression of the anterolateral funiculus and can show signs of central neurological deficits (3,8). Atypical symptoms (e.g. gastrointestinal, cardiopulmonary, abdominal) have also been reported (9,10).

MRI is the diagnostic imaging method of choice. Due to the frequently existing calcification or ossification, an additional CT scan should always be considered, as the consistency of the pathology can also affect the surgical technique/approach, for example (5,11). Conservative treatment, in this case with injections, is also possible, especially for radiculopathies due to lateral disc herniation (12,13). However, there is only limited evidence in available data, mainly concerning thoracic back pain (49). Intolerable and/or persistent pain (usually radicular) or acute or progressive radicular (usually T1, T12) or central neurological deficits (myelopathy) are criteria for the indication for surgery, which can also be considered for atypical symptoms (8,14,15).

In decompression, the surgical manipulation of the thoracic spinal cord must be avoided. Therefore, depending on the location and consistency of the pathology, various anterior approaches and non-anterior approaches are used to cover the entire area around the spinal cord (16-25). The non-anterior approaches may involve difficult or inadequate visualization or handling of the area anterior to the spinal cord with an increased risk of injury and approach-related destabilization of the posterior structures (26,27). Anterior approaches allow sufficient and direct access to the anterior spinal canal, but may lead to problems due to opening the thoracic and pleural cavity (3,28,29) and may be more difficult due to anatomical or pathological conditions (3,28,29). In comparison with non-anterior approaches, anterior approaches also have negative aspects, probably approach-related, e.g. higher overall complication rates in the hospital, a higher mortality rate, longer hospital stays, and higher hospital costs (28,29). However, the complication rates for anterior approaches (e.g. 11% to 26.8%) and non-anterior approaches (e.g. 9.6% to 15%) are assessed using different methods and uniform definitions are not used (8,28,29,50).

The rate of all complications in our study was 20%, of serious complications 8% (1 epidural hematoma without revision, 1 deterioration of myelopathy) and was thus as low as or lower than the rate in the literature (3,8,51-53). The risk of deterioration of a myelopathy appears to be higher especially for giant disc

herniation (3,8,53), as was also the case in our patient collective. In this case, the use of neuromonitoring is also limited, as it has no advantages for decompression of already existing central neurological symptoms (54). No other problems or complications requiring treatment occurred. Overall, a low rate of complications or problems can be achieved with the full-endoscopic technique; however, the validity is reduced by the cumulative number of cases and length of experience with the full-endoscopic technique for thoracic pathologies such as these.

In general, an attempt is made to achieve adequate results and reduce problems with minimally invasive modifications (20,24,30-33). The full-endoscopic uniportal technique allows technically sufficient compression and results correspond with the clinical and radiological outcomes in published studies (3,8,52,53). This is consistent with the experience of other full-endoscopic operations of disc herniations and spinal canal stenosis in the cervical and lumbar spine (35,55,56). The combination of an angled field of view and freedom of movement of the endoscope using a joystick technique results in an adequate working area. The duration of surgery is shorter than with the methods described in the literature (3,51,52). The intra-operative blood loss is so low that it cannot be measured due to continuous irrigation, but is also not considered to be problematic in other techniques (51,52). No surgery-related thoracic spine pain was observed immediately postoperatively or in the follow-up period. The hospital stay is comparatively short (52). No recurrences were observed and are also not described as a frequent problem in the literature (8,52), which could be due to the generally only medium-term examination periods. One specific intra-operative problem can be the adhesion of the pathology to the dura, which can involve the risk of injury to the dura (4,5,53,57). In one patient, an anterior dural leak was detected intra-operatively. Such injuries cannot be sutured and, as in other full-endoscopic or conventional spine operations, can be covered, e.g. with a synthetic dural substitute and a fat flap (34,36,37). Lateral or posterior injuries of the dura can also be additionally sutured in a full-endoscopic technique.

The individual selection of the respective full-endoscopic approach allows the target area to be reached without manipulation of the spinal cord for the various monosegmental pathologies. The extraforaminal approach is used for intra-/extraforaminal disc herniations and intraspinal mediolateral or medial disc herniations. The rib and pleura prevent a flat angle

during the approach, therefore bone resection at the joint facets is usually necessary to enter the spinal canal and the foramen. During the operation, the endoscope angle can be flattened so that the region anterior to the spinal cord can always be easily reached with the 25° view angle and articulating instruments. Performing indirect “box-shaped decompression” before the direct decompression for medial calcified pathologies allows manipulation of the spinal cord to be avoided. This opening of the disc can increase the recurrence rate theoretically, so an attempt should be made to clear out the intervertebral space as much as possible. Therefore, when the criteria are met, giant disc herniations can also be operated with an extraforaminal approach as is also described in the literature with other posterolateral approaches (17,26,58). The extraforaminal technique has the broadest range of indications for anterior pathologies and is also the method most often used by the authors of this study.

Overall, there are no clear standards in literature with respect to the surgical technique. An anterior approach is usually preferred for anterior pathologies, but sometimes non-anterior approaches are also considered the method of choice (29). To minimize the risk of surgical damage to the spinal cord, the approach must be individually adapted to the pathology (24,27). The surgeon must therefore be competent in different approaches. The same applies to full-endoscopic techniques. Within the inclusion criteria, the extraforaminal approach described here allows sufficient decompression of soft and hard disc herniations, both intraspinal and extraspinal, which has previously been described only for soft pathologies (59-62). The inclusion criteria described have proven to be a good guideline for selecting the technique, nevertheless the indication for the extraforaminal approach must be made for each pathology on a case-by-case basis. If the inclusion criteria for a full-endoscopic extraforaminal approach are not met, an alternative full-endoscopic approach (interlaminar, transthoracic retropleural) or decompression by means of a conventional method must be chosen.

The full-endoscopic uniportal technique under continuous irrigation has the proven technical advan-

tages known from arthroscopies or other endoscopic spine operations such as an enlarged visual field due to the 25° view angle, excellent illumination and visualization, reduced bleeding due to continuous irrigation, low complication rates, etc (34,36-38,55,63). It is a real minimally invasive procedure that can reduce surgery-induced trauma. For the operator, the uniportal technique with an angled visual field can be unfamiliar at first. The same applies to the two-dimensional work at the monitor. One general disadvantage for endoscopic procedures is the steep learning curve (64) which, however, can be overcome with new or modified techniques. No other technical disadvantages were noted in the pathologies operated on in this study.

Conclusion

Surgery for thoracic disc herniation is comparatively rare and often demanding. The goal is to achieve sufficient decompression without manipulating the spinal cord and to minimize surgery-induced trauma and its consequences. Individual planning and various surgical techniques and approaches are required. The key factors for selecting the technique are anatomical location, consistency of the pathology, general condition of the patient, and the surgeon's experience. Various techniques are available for this today; other alternative procedures are also being developed. The full-endoscopic uniportal technique with an extraforaminal approach described here allows technically sufficient decompression of monosegmental soft and hard disc herniations with minimal trauma, has technical advantages, and a low rate of complications and destabilization. It is an alternative or complementary surgical technique that can have advantages. To avoid surgery-induced damage to the spinal cord, strict inclusion criteria must be met. If they are not met, an alternative full-endoscopic approach or decompression in a conventional method must be selected. Overall, there is also only limited clinical and technical experience in the literature due to the low incidence of the pathologies named and in addition because the non-homogeneous patient collective makes it difficult to form control groups.

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