Endoscopic Posterior Cervical Foraminotomy as a Treatment for Osseous Foraminal Stenosis

Joachim M.K. Oertel, Mark Philipp, Benedikt W. Burkhard

BACKGROUND: Posterior cervical foraminotomy is a valuable treatment option for cervical radiculopathy. Here the authors present their technique and results in the treatment of a series of patients suffering from osseous foraminal stenosis.

METHODS: Forty-three patients suffering from cervical osseous foraminal stenosis were operated on via a posterior approach with the EasyGO endoscopic system. Decompression was performed in 1 segment in 31 patients, in 2 segments in 11 patients, and in 3 segments in 1 patient. Bilateral decompression was performed in 4 cases. Twenty-four (55.8%) patients had been subjected to previous spine surgery. All procedures were video recorded and afterwards retrospectively analyzed. In addition, particular reference was given to previous cervical spine surgery, postoperative outcome, reoperation rate, and complications.

RESULTS: The endoscopic system was easy to handle intraoperatively in all procedures. No emergency stopping was required. Forty-one patients reported improved and/or even no remaining pain postoperatively (95%). Thirty-five patients (81.4%) regained full motor strength. Clinical success rate with respect to Odom’s criteria reached 39 patients (90.7%). One reoperation was needed due to postoperative hematoma (2.3%). One patient suffered from transient worsening of his preoperative paresis (2.3%). Neither dural tear nor nerve root injury was observed. Reoperation rate due to degenerative changes was 18.6% (8 of 43 patients).

CONCLUSIONS: This retrospective analysis shows that posterior endoscopic decompression is a successful option in the treatment of osseous cervical foraminal stenosis.

INTRODUCTION

The posterior cervical foraminotomy was first described by Scoville in 1945 and later further modified by Frykholm. For the first time, the nerve root was decompressed in a series of patients with cervical radiculopathy through partial resection of the medial margin of the facet joint.¹,² This technique represented a big step ahead for dorsal decompression of the cervical spine at that time.

However, posterior approaches had and have the disadvantage of detaching the extensor cervical muscles from the laminae and spinous processes. Detaching of the paraspinal muscles can lead to severe collateral damage to the muscles and can come along with postoperative complications like axial neck pain, shoulder pain, loss of lordosis, or even spinal instability.³,⁴ Nonetheless, the problem of the dorsal approach with the spinal cord being in the way for optimal access at the pathology was eluded through the introduction of the anterior approach to the cervical spine (anterior cervical disectomy and fusion [ACDF]) by Smith and Robinson and by Cloward in the 1950s.⁵,⁶ The anterior approach represented the gold standard in the treatment of cervical disk prolapse and cervical stenosis for decades while the posterior approach became more and more obsolete over time.

Recognition of ACDF’s disadvantages such as loss of motion due to bony fusion, approach-related morbidity, graft-related complications, and adjacent segment disease led to a widespread movement for rediscovering the posterior approach.⁷ Meanwhile, a multitude of studies have demonstrated that open...
microsurgical posterior foraminotomy is an effective treatment for cervical radiculopathy.\(^8,9,18-20\) Also, the iatrogenic approach-related trauma can be reduced by application of new minimally invasive endoscopic techniques.

There is still no consensus about the ideal surgical approach for the treatment of cervical radiculopathy till today. Endoscopic lumbar diskectomy has been shown to obtain comparable results with standard microsurgical diskectomy with the advantage of less muscular trauma and thereby less postoperative back pain.\(^17\) The technique of using endoscopic visualization with a tubular system can also be applied to the cervical spine. It enables surgeons to perform minimally invasive posterior foraminotomy for lateral disk prolapse or foraminal stenosis. In the past decade, equivalent results from tubular posterior cervical foraminotomy compared with standard open technique have been reported in the treatment for cervical radiculopathy due to lateral disk herniation.\(^8,9,18-20\)

However, only a few studies that investigated the effectiveness of minimally invasive cervical foraminotomy for cervical radiculopathy have included patients with foraminal stenosis.\(^9,11,18-24\) The number of studies that used an endoscopic technique is even smaller.\(^11,20,22,24\) A detailed description about the entity of foraminal stenosis among those studies is not available. The purpose of this article is to report results of clinical and functional outcomes after endoscopic posterior cervical foraminotomy for single and multilevel osseous foraminal stenosis.

**MATERIAL AND METHODS**

**Patient Population**

The cohort consists of 43 consecutive patients with osseous cervical foraminal stenosis treated with endoscopic posterior cervical foraminotomy at the Department of Neurosurgery, Saarland University Medical Center and Saarland University Faculty of Medicine, Homburg/Saar, Germany between 2011 and 2014. All procedures were performed with the EasyGO endoscopic system (Karl Storz company, Tuttlingen, Germany). Inclusion criteria for this retrospective study were a complete set of preoperative and postoperative patient records and video recordings of the procedure. Patients with central compression of the myelon, instability, and soft lateral disk herniation were not included in the study. A telephone interview was conducted to complete a standardized questionnaire as final follow-up before preparation of this manuscript.

The standardized questionnaire assessed Neck Disability Index (NDI) and the functional outcome according to Modified Odom’s Criteria (Table 1).\(^25,26\) “Excellent” and “good” results were defined as clinical success.

**Surgical Equipment**

All procedures were performed with the EasyGO spine system (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany). The endoscopic equipment consisted of a 30° Hopkins Forward-Oblique telescope that was 9.5 cm in length, an H3-Z Full HD Camera Head, and a Xenon Nova 300 cold light fountain. The intraoperative image was transmitted on a 26” HD Flat Screen. All intraoperative data were recorded via AIDA compact NEO data archiving system (KARL STORZ GmbH & Co. KG). For a detailed description of the spine system, please refer elsewhere.\(^17\)

**Surgical Technique**

After the induction of the status of general endotracheal anaesthesia, the patients were placed in prone position. The head was fixed in a 3-point Mayfield head holder with an elevated position and slightly inclined. To reduce intraoperative bleeding from epidural blood vessels, we kept the surgical field above heart level. The affected segment was identified by lateral fluoroscopy. Frequently the shoulders of the patient had to be pulled down and fixed by using medical duct tape for surgical field exposure on lateral radiograph. In single-level surgery, a straight approach from the skin incision to the neuroforamen was performed. In 2-level surgery, the skin incision was made halfway between the 2 affected segments (Figure 1A). In the rare case of a 3-level surgery, the skin incision was made in a straight trajectory to the middle segment. It was made craniocaudal about 2 cm lateral to the midline. After the skin incision, the muscle fascia was punctured and the muscles were subsequently dilated with the various dilators. The tip of each dilator was always in firm contact with the vertebral arch or the facet joint, respectively (Figure 1B). Then the selected work sheath was introduced. The whole application of the dilators and the working sheath was done under lateral fluoroscopy control. After introduction of the trocar, it was connected to the holder and thereby fixed to the surgical field (Figure 1C). In most cases, the 30° endoscope was introduced lateral pointing to the midline (Figure 1D) and bimanual microsurgical techniques could be applied (Figure 1E). An example of endoscopic posterior cervical foraminotomy is shown on Video 1.

After removal of some remnant soft tissue (Figure 2A), the lamina and facet joint were exposed (Figure 2B). The medial third of the facet joint was thinned with a diamond drill (Figure 2C) before the ligamentum flavum (Figure 2D) was resected. Through this technique the lateral section of the dural sac with its outgoing nerve root was depicted (Figure 2E). The nerve root was decompressed from medial to lateral far into the neuroforamen (Figure 2F). To control the intraoperative bleeding coagulation in a gentle fashion, compression by sponges and cotton or a combination of both techniques with additional application of surgical hemostatic agents for hemostasis was used. After

**Table 1. Modified Odom’s Criteria**

<table>
<thead>
<tr>
<th>Grading</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Excellent</td>
<td>All preoperative symptoms and abnormal findings improved.</td>
</tr>
<tr>
<td>Good</td>
<td>Minimal persistence of preoperative symptoms (neck tenderness only, otherwise no symptoms). Abnormal findings improved.</td>
</tr>
<tr>
<td>Fair</td>
<td>Definite relief of some preoperative symptoms. Other symptoms slightly improved (residual root irritation with transient pain).</td>
</tr>
<tr>
<td>Poor</td>
<td>Symptoms and signs unchanged or worse.</td>
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successful decompression of the root, the surgical field was irrigated and the working sheath was carefully pulled out. The wound was closed by fascia-, subcutaneous-, and subcuticular sutures.

RESULTS

Patient Demographics

A total number of 43 patients met the inclusion criteria of this retrospective study. Twenty-seven (62.8%) patients were male, 16 (37.2%) female. Age ranged from 29–82 years with a mean age of 55.3 years (standard deviation [SD] 11.7 years). The mean follow-up was 28.8 months (range 3.1–46.9 months). Patients’ demographics are summarized in Table 3. The indication for surgery was radicular pain resistant to conservative treatment and/or a radicular neurologic deficit. Preoperative imaging diagnosis revealed an osseous foraminal stenosis in all cases. Thirty-nine operations were done unilaterally, 4 procedures were conducted bilaterally, and 31 patients had single-level-surgery. Eleven patients had a 2-level procedure, and 1 patient had a 3-level foraminotomy. A bilateral approach was performed in 3 cases for single-level decompression and in 1 case of 2-level decompression. A total of 60 endoscopic foraminotomies was performed in 43 patients. A detailed presentation of all operated levels is given in Table 2.

Preoperative Clinical Findings

Forty-one patients received preoperatively a computed tomography scan and 33 magnetic resonance imaging. Thirty-one patients were subjected to both modes of imaging before surgery. Preoperatively, radicular pain was reported in 40 (93.0%) of the patients, motor weakness in 22 (51.2%) and sensory deficits in 29 (67.4%).

Intraoperative and Postoperative Findings

The endoscopic system was easy to handle in all cases. Six patients were operated on with the 15-mm sheath, and 37 patients were
operated on with the 19-mm working sheath. In all cases, the nerve root was exposed and decompressed including a partial facetectomy. No emergency stopping with switching to microsurgery was required. One postoperative hematoma occurred, which caused local pain and was subsequently evacuated. One patient had a transient worsening of his preoperative existing triceps paresis. The paresis was completely reversible within 5 months postoperative. No other intraoperative and postoperative complications such as cerebrospinal fluid fistula, root injury, or wound infection occurred. Mean overall operating time in all procedures was 77 minutes (range 22–272 minutes). For a single foraminotomy, the mean operating time was 68 (range 19–140 minutes).

Mean hospitalization time in the neurosurgery department after the operation was 4 days with a standard deviation of 2 days (range 2–15). Twenty-five (58.1%) of the patients left the hospital after 4 days or earlier, 15 patients (34.9%) left between 5 days and 1 week, and an additional 3 patients (7.0%) were discharged after 8 days. Aesthetic results were distinguished (Figure 1F).

### Postoperative Clinical Findings and Functional Outcome

In the postoperative examination, 40 patients (95.0%) reported to be pain free or with improved arm pain at the first postoperative day. At the first postoperative day, 15 patients (68.5%) reported an improvement in motor strength. At 6-month follow-up, 18 patients (81.8%) regained full motor strength. Four patients (18.2%)...
remained with a mild motor deficit until the last follow-up. None of the 4 patients reported limitation in their daily lives due to the residual paresis. At the first postoperative day, 23 of all patients (79.3%) reported an improvement of their preoperative sensory deficit. The mean Neck Disability Index was 18% (range 0%–72%). Clinical success was documented in 39 patients (90.7%) of all patients. These results remained stable until the last follow-up.

Reoperation after Endoscopic Posterior Cervical Foraminotomy

Nine patients had surgery after endoscopic posterior cervical foraminotomy; among those, 1 patient needed evacuation of a postoperative hematoma. Eight (18.6%) of all patients had additional surgery at the cervical spine due to degenerative changes. Five patients were operated on using conventional ACDF, 2 patients using endoscopic posterior cervical foraminotomy, and 1 patient using anterior cervical corpectomy and fusion followed by laminectomy with posterior instrumentation. Mean period to reoperation was 6 months (SD 5). Mean periods to reoperation at the index level and at adjacent level were 4.6 months (SD 2.4) and 9.7 months (SD 8.1), respectively.

Of the 5 patients undergoing ACDF revision surgery, 2 underwent ACDF at another level for new symptoms (foraminotomy C5/6, ACDF C6/7, foraminotomy C6/7, ACDF C5/6). One patient underwent another posterior endoscopic cervical foraminotomy at another level for new symptoms (first foraminotomy C6/7, second surgery C7/1Th1). Five (11.6%) out of 43 patients had repeat surgery at the index level. Of these 5 patients with revision surgery at the index level, 4 were subjected to a 2-level procedure posterior endoscopic foraminotomy initially. Three of these 5 cases developed neck pain after initial microendoscopic posterior cervical foraminotomy. Conservative treatment was not successful in all 3 patients. All 3 had anterior cervical fusion as repeat surgery with improvement of their facet joint–related problems. One of the 5 patients underwent a repeat endoscopic foraminotomy since there was inadequate decompression seen after initial surgery. This patient became symptom free after revision surgery. The last case of these 5 patients was subjected to anterior cervical fusion because of unchanged sensory deficits. However, this patient did not benefit from the anterior revision surgery.

### Table 3. Compilation of Studies for Minimally Invasive Posterior Cervical Foraminotomy

<table>
<thead>
<tr>
<th>Author</th>
<th>Kim et al., 2009</th>
<th>Ruetten et al., 2007</th>
<th>Adamson et al., 2001</th>
<th>Winder et al., 2011</th>
<th>Hilton et al., 2007</th>
<th>Holly et al., 2007</th>
<th>Fessler et al., 2002</th>
<th>Skovrlj et al., 2014</th>
<th>Lawton et al., 2014</th>
<th>Our Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients</td>
<td>22</td>
<td>100 (87)</td>
<td>100</td>
<td>42</td>
<td>222</td>
<td>21</td>
<td>25</td>
<td>70</td>
<td>38</td>
<td>43</td>
</tr>
<tr>
<td>Age (years)</td>
<td>54</td>
<td>43</td>
<td>46</td>
<td>49</td>
<td>49</td>
<td>51</td>
<td>49</td>
<td>50</td>
<td>49</td>
<td>55</td>
</tr>
<tr>
<td>Mean follow-up (months)</td>
<td>33</td>
<td>24</td>
<td>25</td>
<td>n.a.</td>
<td>26</td>
<td>23</td>
<td>4</td>
<td>32</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>1 Soft disk herniation</td>
<td>8</td>
<td>87</td>
<td>n.a.</td>
<td>n.a.</td>
<td>140</td>
<td>n.a.</td>
<td>n.a.</td>
<td>27</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>2 (Osseous) foraminal stenosis</td>
<td>14</td>
<td>13</td>
<td>n.a.</td>
<td>n.a.</td>
<td>81</td>
<td>n.a.</td>
<td>n.a.</td>
<td>36</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>3 Synovial cyst</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Combination of 1 &amp; 2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>n.a.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>7</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Analysis separated by diagnosis</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Odom's clinical success in %</td>
<td>86.4</td>
<td>n.a.</td>
<td>96.0</td>
<td>n.a.</td>
<td>94.6</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td>Neck Disability Index in %</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>21.7</td>
<td>24.0</td>
</tr>
</tbody>
</table>

### DISCUSSION

Traditional surgical techniques for decompression of the cervical spine include open anterior and open posterior approaches.5-27 The anterior approach is associated with the risk of certain complications and injury to the anatomic structures of the neck.26 The goal of this procedure is a preservation of cervical spinal motion, which could result in a greater risk of developing degenerative changes in the adjacent segment.52 Alternatively, posterior foraminotomy is an approach to the cervical spine that avoids many of the complications associated with anterior approach. Further avoiding fusion may preserve the normal motion in the spine. However, an open posterior approach requires subperiosteal dissection of the paraspinal musculature. As a result, cervical muscular pain and spasms can prolong the postoperative recovery time.15,30 During the past decade, minimally invasive techniques and approaches have been developed to achieve comparable results with traditional approaches with a superior aesthetic result compared with open foraminotomy.51 Besides a decreased muscle trauma, the posterior approach has a much lesser effect on the stability of the cervical spine compared with the anterior approach by allowing dorsal resection.35 Previous studies have stated that using a tubular dilatation system reduces the amount of postoperative discomfort, shortens the length of hospital stays, and reduces intraoperative blood loss, as well as need for postoperative pain medication.13 The authors are convinced that an approach via
a dilatation system decreases muscle and tissue trauma and thereby reduces postoperative neck pain. In the past, technical development with new high-definition visualization and 16:9 picture accounts for significantly better identification of anatomic structures in comparison with standard-definition imaging. Further, the endoscopic technique allows it to place the ray of light, as well as the camera with the adjustable 30° optic, directly in front of the pathology. This technical advantage results in a better illumination and enlarges the view on the surgical field compared with the microscope. Further instruments do not obstruct the view onto the surgical field as often seen by operating through a tube. In the present study the authors have described the surgical technique by using a 30° endoscope. Instead of a 30° endoscope, a 0° endoscope might be used for microendoscopic posterior cervical foraminotomy. In the past, a multitude of studies have reported clinical results after minimally invasive posterior cervical foraminotomy and microendoscopic posterior cervical foraminotomy. The results demonstrate that clinical and functional outcomes of both techniques are comparable with the standard open technique. In a recently published meta-analysis, McAnany et al. analyzed 8 studies and assessed the clinical outcome of minimally invasive techniques and standard open technique for posterior cervical foraminotomy with special focus on visual analog scale for arm pain and neck pain, blood loss, length of surgery, and clinical success (Odom’s or Prolo criteria) after surgery. The pooled outcome in both groups showed no difference. A recent systematic review from Clark et al. included 19 studies for comparison of endoscopic and open posterior cervical foraminotomy with special focus on blood loss, surgical time, pain medication use, and postoperative hospital stay. Clark et al. reported that the percutaneous group had reduced blood loss, pain medication use, surgical time, and hospital stay compared with the open group. McAnany et al. admitted that particularly within the group of minimally invasive studies, there was a lack of homogeneity and subgroup analysis for different minimally invasive techniques was not performed. For the authors of this study, this is an important aspect because results are based partially on full endoscopic technique at a patient collective with monosegmental disk herniation, while other results are based on microsurgical technique with a tubular system under either microscopic or endoscopic visualization at a patient collective with monosegmental to trisegmental cervical root compression from either disk herniation or foraminal stenosis. Apart from a different diagnosis, equipment and visualization of the dimension of decompression such as removal of the disk herniation, resection of osteophyte formations, a partial medial facetectomy, and additional drilling of the superomedial aspect of the caudal pedicle to create a wider corridor to access the pathology might have influence on the measured end points in these studies. Considering the pathophysiologic and biomechanical pathway of cervical spondylodiscitis, the degenerative process starts with disk desiccation, loss of annular fiber integrity, and disk herniation even before osteophyte formation emerge from the overload of the uncovertebral and facet joint, which then leads to osseous foraminal stenosis. Three out of 8 studies in McAnany et al.’s meta-analysis performed posterior cervical foraminotomy via a minimally invasive technique. A closer look at the mean age, diagnosis, and clinical outcome in this group reveals that the clinical success rate of surgery in 2 among those studies was between 96.6% and 97.0%; the mean age in both groups was between 43 and 46.6 years, while in the third study, clinical success was considerably lower (86.4%) and mean age considerably higher (54.4 years). Considering the pathophysiologic process, the bony foraminal stenosis is one of the last steps before progressive kyphosis begins. Besides the higher mean age, a reason for the lower clinical success rate might be that 63.6% of the patients had a foraminal stenosis, whereas Ruetten et al. excluded patients with foraminal stenosis without disk herniation and Adamson initially operated on patients with lateral disk herniation only before including patients with foraminal stenosis in his series. Clark et al. allocated 9 studies to the percutaneous group. Among those, 3 were selected by McAnany et al., too. Again, a closer look at the remaining 6 studies reveals the heterogeneity in diagnosis and mean age among those patients. In 1 study, no diagnosis was described, while Hilton reported about 140 patients with lateral disk herniation and 81 patients with bony foraminal stenosis; unfortunately, the results were not separated for both diagnoses, and no clinical success rate was reported. Ruetten et al. initially excluded patients with isolated neck pain or foraminal stenosis without disk herniation but mentioned 23 patients with osteophytes in the foraminal area and another 13 patients with bulging of the annulus and osteophytic foraminal findings. However, specific clinical outcome for these 36 patients has not been reported. Of the 3 remaining studies that were analyzed in Clark et al.’s review, none had included more than 25 patients, none had grouped patients by diagnosis, and none analyzed results separately. Table 3 summarizes the characteristics of the available literature.

The results of the present study show that a posterior endoscopic approach for decompression of osseous foraminal stenosis is a successful treatment option with low complication risks. The study also shows that the clinical success rate of endoscopic posterior cervical foraminotomy is lower in patients suffering from osseous foraminal stenosis than is compared with results of patients suffering from lateral disk herniation. It remains unclear whether the diagnosis of osseous foraminal stenosis or the age at initial surgery might have more influence to the clinical outcome. Considering the pathophysiologic, both factors might carry the same weight. Only a few studies reported reoperation rates after minimally invasive posterior cervical foraminotomy. The rate (18.6%) in our cohort was higher than the rate of 13.9% reported after open posterior cervical foraminotomy from a cohort with a mean age at surgery of 45.8 years. In 5 cases (11.0%) of this series the initial microendoscopic posterior cervical foraminotomy might be considered as a failure or wrong indication of surgery, because repeat surgery had been performed at the index level within the first 8 months. In 1 of these 5 cases the indication was correct but decompression was insufficient. This patient did benefit from the true revision surgery. Three patients did benefit from ACDF because of persisting neck pain. Thus the indication for endoscopic foraminotomy has to be carefully evaluated in the presence of any facet joint problems. One case underwent anterior revision.
but did not benefit, so this patient has to be considered surgical failure regardless of the applied surgical technique. Besides a high reoperation rate, clinical success was documented in 90.7% of cases. Limitations of this study are the retrospective design, small number of patients, and short follow-up. With an aging population, the number of cervical spine surgeries will increase. It is important that we understand which surgical technique offers the best clinical long-term success and has the lowest reoperation rate depending on the diagnosis. Postoperative results should be analyzed by not only their surgical technique but also their preoperative diagnosis and surgical history. The endoscopic posterior cervical foraminotomy with the EasyGO system is a safe, minimally invasive, and feasible procedure. The results of this study suggest that clinical success is lower and the reoperation rate is higher in patients suffering from osseous foraminal stenosis compared with patients suffering from lateral disk herniation.

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REFERENCES


Conflict of interest statement: Joachim Oertel is one of the inventors of the Easy GO system and acts as a consultant for the Karl Storz company.

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