Posterior Cervical Foraminotomy 14

Christopher Brenke and Kirsten Schmieder

Contents

14.1 Pathophysiology

In the cervical spine, neural impingement can occur in two main locations: within the spinal canal, affecting the spinal cord, the nerve root(s), or both, or within the neuro foramen, where the exiting nerve root can be affected. Cervical radiculopathy (CR) is the condition where one or more nerve roots are mechanically compressed. Degenerative disorders like cervical soft disk herniation, osteochondrotic bone spurs with consecutive foraminal stenosis, or a combination of both are the most common causes.

Degenerative soft disk herniation occurs when intervertebral disks desiccate and the disk space reduces with consequent protrusion of the annulus fibrosus or prolapse of the nucleus pulposus through a defect in the annulus fibrosus.

The location of the compressive pathology (soft disk herniation and/or osteochondrotic bone spurs) in relation to the cervical nerve root course causes symptoms and needs to be considered in the surgical approach. Other causes of CR not focused on in this chapter include trauma, instability, and tumor.

14.2 Diagnosis

14.2.1 Clinical Diagnosis

Patient history: Pain that radiates into one or both upper extremities is the chief complaint. This is often accompanied by paresthesia and projects

C. Brenke, MD • K. Schmieder, MD (✉)
Department of Neurosurgery,
Knappschaftskrankenhaus Bochum, Ruhr-University of Bochum, Bochum, Germany
e-mail: kirsten.schmieder@umm.de

E. Van de Kelft (ed.), *Surgery of the Spine and Spinal Cord. A Neurosurgical Approach.*
DOI 10.1007/978-3-319-27613-7_14

into the corresponding dermatome of the affected cervical nerve root.

- *Examination*: Testing muscle strength, reflexes, and sensory function of the skin allows detecting neurological deficits. Intersegmental anastomosis of cervical dorsal roots may result in aberrant levels of innervation with clinical variations such as overlapping sensory symptoms (up to 50 % of the classical dermatomal areas). This is particularly true for the C5/C6 and C6/C7 segments; hence, other than C6 symptoms, a C5/C6 disk herniation may present as C7 symptoms. CR can be associated with neck pain and impairment of the range of motion. Extension of the cervical spine or lateral bending to the affected side can provoke symptoms due to foraminal occlusion.
- *Electrophysiologic testing* supplements clinical diagnosis of CR especially for the differentiation to peripheral nerve entrapment syndromes.

14.3 Therapy

14.3.1 Conservative Treatment

- CR is assumed to be a self-limiting condition; however, the natural course without any treatment is unknown. The majority of patients improve over time with nonsurgical treatment options [1].
- There are no studies based on high evidence criteria or using standardized validated outcome measures to support the superiority of a particular conservative treatment modality [2].

14.3.2 Surgical Treatment for CR

- Persistent radicular pain, despite conservative treatment, is a relative indication for surgery. Motor deficits with functional impairment can warrant earlier surgical intervention.

14.3.2.1 Posterior Cervical Foraminotomy (PCF)

PCF is also known as keyhole foraminotomy, lamino-foraminotomy, or the Frykholm procedure [3]. It is characterized by a dorsal approach and direct visualization of the cervical nerve root but no direct access to the cervical disk. Furthermore, it is considered to be a non-fusion technique. There is, however, no evidence that this non-fusion technique prevents from late-onset adjacent level disease.

14.3.2.2 Indications

- Posterolateral and/or foraminal soft disk herniation
- Foraminal stenosis due to spondylotic spurs of the uncovertebral joint and/or the facet joint (Fig. 14.1)

14.3.2.3 Contraindications

- Centrally located soft disk herniation
- Spondylotic cervical stenosis with myelopathy

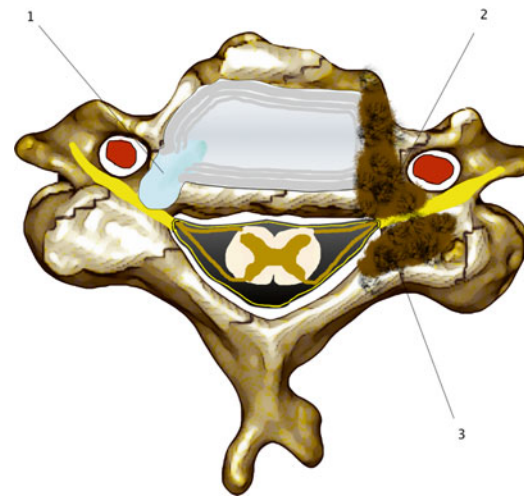

Fig. 14.1 Artistic illustration of cervical nerve root compression due to pathologies that may be addressed by a PCF: posterolateral cervical soft disk herniation (*1*), bone spurs of the uncovertebral joint (*2*), bone spurs of the facet joint (*3*)

14.3.2.4 Surgical Technique

Surgical Anatomy

- Essential to consider are the components of the intervertebral foramen (IF), the dimensions of the massa lateralis (ML), and the course of the cervical nerve root in relation to the disk space and the sequestrated disk material.
- The IF is defined by the ML posteriorly, the disk space anteriorly, and the pedicles above and below. It can be divided into an entrance and an exit zone where the nerve root runs ventrally. The narrowest part is the entrance zone and therefore the most likely location for nerve root compression.
- Compared to the dorsal root, the ventral root of the cervical nerve emerges further caudally from the thecal sac. The ventral root with its motor fibers is thinner and runs along the caudal boundaries of the IF. The dorsal root ganglion lies outside the foramen.
- The ML of the upper and lower cervical vertebrae form the facet joint. The axial or mediolateral dimensions of the ML range from 10.3 to 12.8 mm. The distance from the medial border of the ML to the lateral rim of the thecal sac is 5.1–7.1 mm [4].
- The anatomic relation between the cervical nerve root and the corresponding disk space depends on the spinal level. The disk space C4/C5 lies in more than 50 % of cases directly anterior to the C5 root, whereas the disks C5/C6 and C6/C7 lie below the root, making the compression of the C6 and C7 roots by soft disk herniation/bony spurs an axillary type. Predominantly the C8 root has no contact to the rostrally positioned disk space at its entrance zone into the IF [5]. Therefore, most disk fragments are found in the axilla of the nerve root in the caudal part of the surgical exposure.

Preoperative Planning

- Although magnetic resonance imaging (MRI) is the modality of choice in medical imaging (to confirm the diagnosis but also to exclude other pathologies such as intradural pathology), computed tomography with three-dimensional reconstructed images may be useful for preoperative planning especially in cases with severe degenerative changes.
- *Technical equipment comprises*: High-speed drill, microscope, fluoroscopy, Mayfield clamp, self-retaining retractor, and microsurgical instruments (Fig. 14.2).

Patient Positioning

- Under general anesthesia the patient is positioned prone on the operating table (Fig. 14.3). Sitting position harbors the risk of air embolism necessitating special monitoring.
- The chest and the iliac crest are cushioned with pillows or rolls. Extremities are padded to prevent pressure neuropathies. The head is fixed in a three-point Mayfield skull clamp. The cervical spine is aligned neutral or slightly flexed. A sufficient distance between the chin and the table has to be checked and eyeball compression has to be avoided. For maximum fluoroscopic visualization of the cervical spine, arms are tucked at sides and shoulders are pulled down with tapes.

Intraoperative Steps of PCF

- Thirty minutes prior to skin incision, a single shot of prophylactic antibiotics is administered.
- The desired spinal level is identified via C-arm fluoroscopy by using a fine needle that is inserted perpendicularly to the skin.
- A midline skin incision of 3 cm is performed above the target level.
- Subcutaneous tissue, the ligamentum nuchae, and cervical muscles are divided in the relatively avascular midline down to the spinous process.
- Then muscle fascia incision follows with subsequent subperiosteal paraspinal muscle detaching from the targeted spinous process and lamina. The interlaminar window, the half

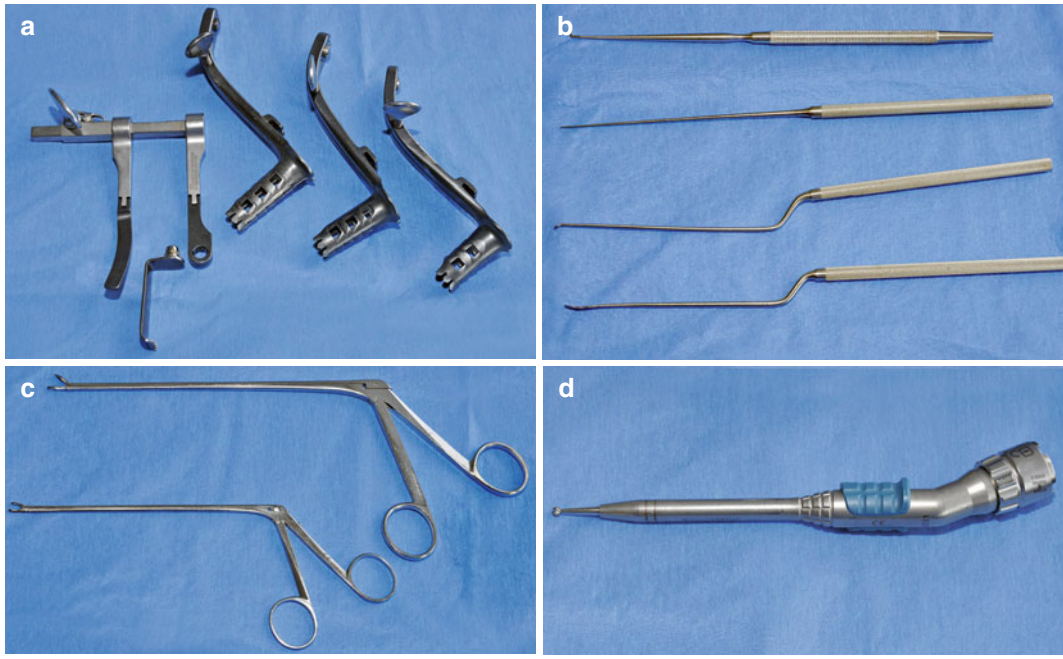

Fig. 14.2 Technical equipment. Self-retaining retractor (**a**), fine microsurgical instruments (**b**), small forceps (**c**), high-speed drill (**d**)

Fig. 14.3 Patient in prone position for PCF (see text)

of the upper and lower laminae, and the facet joint with the upper and lower ML are then exposed.

- A self-retaining retractor (Fig. 14.2a) is placed to maintain exposure.
- The correct spinal level is confirmed with C-arm fluoroscopy.
- Bone removal is started at the junction between the medial portion of the facet joint and the cervical lamina (Fig. 14.4), using a high-speed drill (Fig. 14.2d) under microscopic view. The extent of bone removal is about one-third of the upper and lower lamina. The amount of resection of the medial

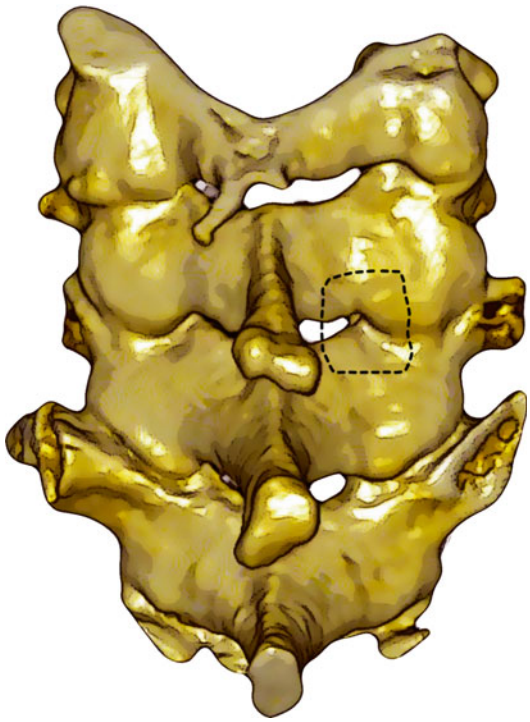

Fig. 14.4 Anatomic illustration featuring the amount of bone removal for PCF (*dotted line*)

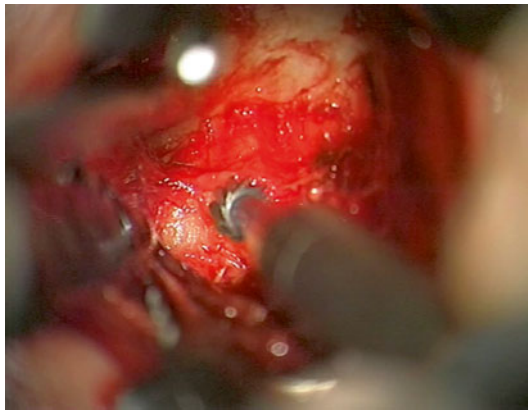

Fig. 14.5 Intraoperative view of starting bone removal at the junction between ML and lamina

part of the facet joint as well as the resection in craniocaudal direction depends on the underlying pathology but should never exceed 50 % of the ML (Figs. 14.5 and 14.6) in order to preserve segmental stability and/or prevent postoperative segmental kyphosis. At least a keyhole foraminotomy of 8–10 mm must be performed in order to achieve adequate decompression.

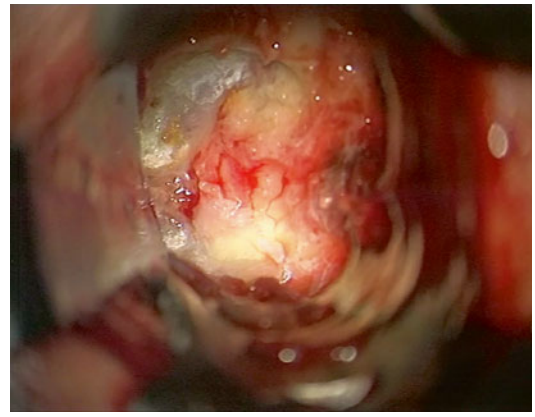

Fig. 14.6 Intraoperative view after bone drilling

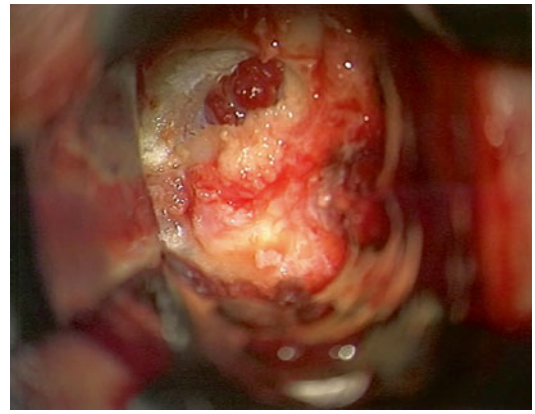

Fig. 14.7 Intraoperative view showing congested epidural venous plexus

- The flaval ligament is resected using a fine Kerrison rongeur with a thin footplate exposing the lateral border of the dura. Subsequently, the nerve root is identified. This step is often complicated by epidural bleeding from the perineural congested venous plexus (Fig. 14.7). A clear view is gained either by targeted bipolar coagulation of these vessels or by the use of hemostatic agents (e.g., collagens with very small sponges). Coagulated vessels should be dissected with microscissors. Coagulating the perineural venous plexus can cause nerve root damage and should only be performed if this tissue can be lifted away from the nerve root with a blunt nerve hook.

- The nerve root axilla, being the most common location for the sequestrated disk fragment, is examined using a fine blunt nerve hook, and the nerve root is gently retracted. The dural sheath sometimes adheres to the perineural tissue, but cautious dissection will reveal the ventral and dorsal roots in their separate sleeves.
- Freely sequestered disk fragments can then be removed. In case of subligamentous sequestrated disk herniation, a small blade is used to transect the posterior ligament, and the herniated disk is freed and pulled out using a small forceps (Fig. 14.3c).
- Epidural bleeding at this stage of intervention often indicates the removal of the offending disk material. Usually, hemostasis is only achieved by means of collagen and sponge compression.
- The course of the nerve root is then further explored checking for sufficient decompression with the nerve hook.
- In the case of osseous foraminal stenosis, additional bony resection of parts of the superior (underlying) facet joint may be necessary to allow nerve course exploration.
- Wound closure is performed in layers, considering hemostasis and wound irrigation.

14.3.3 Tips and Tricks

- Mild reverse Trendelenburg positioning (20–30° head up) facilitates venous drainage and reduces bleeding. Flexion of the neck is crucial since this exposes the underlying superior facet.
- Drilling the lamina from cranial to caudal and parallel to the course of the nerve root from medial to lateral reduces the risk of nerve root injury.
- Decompressing the C8 root may require more caudal as well as lateral bone removal of the facet joint because of the longer and more caudal direction of this nerve root. At the C7-Th1 junction, this might predispose to instability/kyphosis.
- Partial removal of the superomedial portion of the inferior pedicle enlarges the space for axillary nerve root preparation and decreases the extent of nerve root retraction (Fig. 14.8) [6].
- In cases where a sequestrated disk fragment cannot be mobilized due to excessive bleeding or a nerve root that is fixed on top of the disk fragment, blind coagulation or extensive nerve retraction should be avoided. Either pain relief is attained as a result of the dorsal decompression or an anterior approach has to be considered as a second intervention.
- The extent of the facet joint bone removal, which may lead to spinal instability, is always a question for debate. The load transmission of the cervical spine occurs mainly through the facet joints and the posterior column. Loss of its integrity can shift the weight-bearing axis anteriorly leading to cervical kyphosis over time. Zdeblick et al. found in a biomechanical cadaveric study that a significant segmental hypermobility occurred when more than 50 % of the facet joint or ML was resected [7]. Overall it is safe to remove up to 5–6 mm starting from the medial border of the facet joint, laterally for visualization and decompression of the nerve root. Some authors report that up to 75 % facet joint resection is feasible without increasing the risk of spinal instability provided the anterior column is

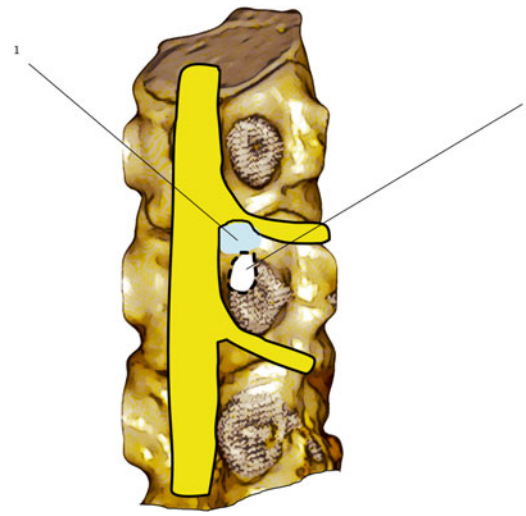

Fig. 14.8 Artistic illustration in oblique view of axillary disk fragment (*1*) and accessory bone removal of the superomedial part of the inferior pedicle (*2*)

intact [8]. For soft disk herniation, the resection extent can usually be limited to the recommended 50 %. However, in cases of spondylotic foraminal stenosis, this resection limit requirement may have to be exceeded. Undercutting resulting in an oblique removal of the facet joint may enlarge the IF while preserving its integrity [9].

14.3.4 Complications

- PCF complications include cerebrospinal fluid leaks, motor or sensory palsy due to nerve root or spinal cord injury, hematoma, vertebral artery injury, and superficial/deep wound infection.
- Although the overall reported complication rate is low, the most frequent encountered one is motor palsy due to nerve root injury. In three large studies, the rate of postoperative motor palsies was 1.2–2.3 % [8, 10, 11]. In most cases, the C5 root was affected. This is attributed to its thin caliber and anatomic course covering the entire disk space C4/C5, which needs more retraction when removing disk fragments.
- Symptom relapse, referred to as same-segment disease, may be attributed to recurrent soft disk herniation or progressive spondylotic degeneration. Clark et al. followed up 303 patients with single-level PCF and reported a 5- and 10-year risk rate of same-segment disease of 3.2 % and 5.0 %, respectively [12].
- Although considered to be a non-fusion technique, PCF can be associated with adjacent-segment disease. Clark et al. reported a calculated 10-year rate of adjacent-segment disease of 6.7 % [12]. This adjacent level disease, as seen on medical imaging however, does not correlate well with clinical symptoms.
- One concern with PCF is the development of postoperative kyphosis secondary to partial resection of the facet joint. Jagannathan et al. reported a postoperative loss of lordosis after PCF in 20 % and a spinal instability on dynamic radiographic imaging in 4.9 % of cases. Yet still the majority of patients were asymptomatic and did not require new surgery. They found out that patients aged above 60 years, with previous posterior surgery and preexisting loss of lordosis, were at a higher risk for developing this postoperative deformity [8].

14.4 Evidence for PCF

14.4.1 Evidence for Surgical Treatment for CR

- There is no study that compares the effect of conservative treatment of CR with that of PCF. Therefore, no evidence-based guidelines can be given when considering surgery versus conservative treatment. Only one RCT comparing conservative treatment with surgery when treating CR exists [13]. Patients treated with anterior cervical decompression and fusion (ACDF) and adjuvant physiotherapy showed a more rapid relief of pain than those patients treated with physiotherapy alone but no better reduction of arm pain after 2-year follow-up.
- PCF itself is highly effective in treating CR. Resolution of CR is reported in more than 90 % of cases. However, neck pain showed a less favorable course.

14.4.2 Open Versus "Minimally Invasive Procedures"

- Full endoscopic procedures or so-called minimally invasive tubular procedures became popular because of their advantage of limited muscular damage. An RCT showed that full endoscopic PCF brings equal results as compared to ACDF [14]. Data from studies that compared open to minimally invasive procedures showed that clinical outcome was similar and only secondary parameters like blood loss, hospital stay, and postoperative pain medication were reduced [12]. However, in the only randomized clinical trial, the sole reported difference was the length of the skin incision that was 4 mm shorter over the 3.6 cm opening during open procedures [15].

14.4.3 Anterior Versus Posterior Approaches

- Centrally located soft disk herniations or spondylotic bone spurs are favored for an anterior approach whereas foraminal pathologies can be addressed either by a PCF or anterior approach with anterior cervical diskectomy alone (ACD) or ACDF. To date there are no randomized, controlled studies supporting one or the other approach for foraminal pathology. Available data report both approaches to achieve comparably successful clinical outcomes for single-level degenerative cervical radiculopathy.
- Therefore, the choice of approach for intraforaminal pathology depends on the one hand on the surgeon's preference and on the other hand on secondary factors that may favor one approach. PCF can be considered in cases of technical limitations for the anterior approach, e.g., C2/C3 or C7/Th1 pathologies and also in patients with a short neck or when the segment to target has received prior anterior surgery.
- We prefer a PCF mainly for true intraforaminal located soft disk herniation, particularly for the C7/Th1 segment. In case of osseous foraminal stenosis that results predominantly from bone spurs of the uncovertebral joint, we perform an ACDF. This allows direct decompression of the nerve root due to removal of the bony spurs and also restoration of the disk and foraminal dimensions.

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