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Posterior Cervical Foraminotomy - a viable approach for cervical radiculopathy: A review

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ABSTRACT

In recent decades, posterior cervical foraminotomy (PCF), a procedure addressing cervical radiculopathy, gave its way to anterior discectomy and fusion (ACDF), which, while effective, is associated with both early and long-term complications. Whereas the ACDF remains a procedure of choice, in many cases of cervical radiculopathy PCF is a viable alternative and the purpose of this narrative review is to evaluate the literature regarding its efficacy. A comprehensive review of the literature was carried out throughout 21 studies from January 2010 to August 2024, including clinical trials, cohort studies, systematic reviews and meta-analyses that evaluate and thoroughly investigate the efficacy of these surgical approaches. The results suggest that posterior cervical foraminotomy is a viable option for the management of a range of patients with cervical radiculopathy, given its efficacy and cost-effectiveness compared with anterior cervical discectomy and fusion. Revision of this technique in relation to the clinical indications for cervical radiculopathy with foraminal nerve compression may improve the success rate of surgical evaluation and potentially avoid the adverse effects associated with cervical motion segment fusion and anterior approach.

Keywords: Posterior cervical foraminotomy, PCF, anterior cervical discectomy and fusion, ACDF, cervical radiculopathy

1. INTRODUCTION

Cervical radiculopathy affects around 83–85 cases per 100,000 people (Radhakrishnan et al., 1994; Malanga, 1997). It is a condition featuring the presence of pain and neurological deficits resulting from compression of a spinal

nerve root or roots in the cervical spine, usually as a consequence of degenerative processes associated with discopathy and spondylosis (Abbed and Coumans, 2007). While 90% of patients are able to recover without surgical intervention, in some cases an operative route is inevitable (Saal et al., 1996).

Surgical techniques date back to the middle of the past century, with these using the posterior cervical approach predating those using anterior access (Spurling, 1944; Frykholm, 1951; Smith and Robinson, 1958; Cloward, 1958). An alternative was sought with the introduction of cervical disc arthroplasty in the 1960s, Fernström, (1966) which addressed the complications of motion segment fusion, but yet the anterior cervical discectomy and fusion (ACDF) has remained the most common surgical treatment of cervical radiculopathy for the past few years (Iyer and Kim, 2016).

Recently, however, due to the risk of complications arising from the surgical technique itself, spinal motor unit fusion and from the very premise of using implants, attention has recently turned to other, less radical surgical approaches, returning to techniques such as posterior cervical foraminotomy (PCF). Although these techniques are not equivalent, as they differ in part in their indications for surgery, in many cases posterior cervical foraminotomy can be a favorable surgical alternative (Riew et al., 2007; Liu et al., 2016; Dodwad et al., 2016; Fang et al., 2020; Broekema et al., 2023).

2. METHODS

A thorough review of the literature was carried out using digital databases, including Pub-Med, Google Scholar, as well as specialist literature regarding neurosurgery and spine surgery, mainly focusing on articles that address posterior cervical foraminotomy as well as anterior discectomy and fusion from January 2010 to August 2024. Search terms included: “posterior cervical foraminotomy”, “PCF vs. ACDF”, “cervical radiculopathy”, “anterior cervical discectomy and fusion”, “posterior cervical laminoforaminotomy”. A total of 33 studies were included in the following review, regarding the older studies that remain the pinnacle of approach for cervical neuropathy and surgical techniques discussed in this article, as well as 21 most recent studies, including clinical trials, cohort studies, systematic reviews and meta-analyses that evaluate and thoroughly investigate the efficacy of surgical approaches.

3. RESULTS AND DISCUSSION

Surgical management of cervical radiculopathy

Anterior cervical discectomy and fusion (ACDF) – the most common surgical approach

Anterior cervical discectomy and fusion (ACDF), described by Smith and Robinson, (1958) and also by Cloward, (1958) is currently the most common surgical treatment for patients affected with cervical radiculopathy who fail nonoperative measures (Iyer and Kim, 2016). The key points of surgery consist of securing the access by dissecting between anterolateral structures of the neck, including muscles, trachea, esophagus and carotid artery to reach the cervical spine, removing altered intervertebral disc and osteophytes, thus decompressing the nerve root, placing the interbody graft in intervertebral space and optionally stabilizing using the cervical plate.

Nowadays, options for graft materials include autograft, allograft and synthetic materials like polyether ether ketone (PEEK), with allografts now preferred due to reduced donor-site morbidity. Cervical plates, introduced in the 1990s, enhance stability, reduce the risk of pseudoarthrosis and help maintain spinal alignment. While plating is not essential for single-level fusions, it significantly improves outcomes in multi-level procedures. However, it may increase risks like dysphagia and implant complications, though modern designs have mitigated these issues.

Depending on the intraoperative situation, drainage may be placed in the wound to reduce the risk of hematoma formation and facilitate healing. After surgery, the patient's neck is secured with an orthopedic rigid collar. Complications for ACDF include dysphagia, hematoma, hoarseness, recurrent laryngeal nerve palsy, pseudarthrosis, adjacent segment disease and wound infection (Liu et al., 2016).

Posterior cervical foraminotomy (PCF)

Posterior decompression for cervical radicular pain, first described by Spurling, (1944), predates anterior decompression techniques. This evolved into posterior cervical foraminotomy (PCF), introduced by (Frykholm, 1951). PCF involves minimal bone removal of the lamina and facet joint, to decompress the nerve root exiting through the foramen. The procedure, effective for posterolateral soft disc herniation and neuroforaminal stenosis, is performed with the patient in a prone position.

After subperiosteal dissection exposes the lamina, a hemilaminotomy and partial facet joint removal (<50%) are performed under microscopic visualization to access and decompress the nerve root, if needed, part of the pedicle may be resected to address soft disc herniations (Decker, 2011). Lately, a minimally invasive approach with endoscopy has become popular, though the most recent studies seem to deny its superiority, stating that both techniques, open and minimally-invasive posterior foraminotomy are similar in efficacy, complication rates as well as hospitalization length (Platt et al., 2022). Complications of PCF most commonly include neck pain, wound infection and durotomy (Church et al., 2014; Sahai et al., 2019; Broekema et al., 2023).

Indications for surgery

Cervical radiculopathy arises from irritation of the nerve roots due to compression and inflammation, most commonly caused by cervical disc herniation and cervical spondylosis (Abbed and Coumans, 2007). Patients with cervical disc herniation can improve without surgery in over 90% of cases (Saal et al, 1996). Surgical symptoms can be relieved during recovery with physiotherapy, pain and anti-inflammatory medication, and steroid injections. Indications for surgery in cervical radiculopathy relate to severe or progressive neurological deficit and/or significant, unremitting pain in patients that fail to improve despite nonoperative treatment methods (Yoon, 2011).

The aim of surgery for cervical radiculopathy is to decompress the affected nerve root. Depending on the orientation of the mass, being most commonly a herniated disc, osteophyte mass, or both combined, the type of surgery is considered. The crucial part of the surgical qualification is the physical examination, which should determine the anatomical distribution of signs and symptoms and remain in correlation with radiographic imaging (Decker, 2011). PCF is contraindicated in patients with signs of instability, signs of myelopathy, and in cases of diffuse anterior disc herniation or osteophyte disease where posterior access is limited and anterior approach is recommended. If the symptoms of radiculopathy are present bilaterally, there are relative contraindications for PCF because of potential risk of causing instability due to violation of both facet joints (Dodwad et al., 2016).

PCF vs. ACDF in literature

PCF avoids traumatizing structures in the anterior of the neck, such as the carotid artery, trachea, esophagus and recurrent laryngeal nerve, lowering the risk of complications such as potential dysphagia or dysphonia, typical for ACDF surgery and these directly related to the use of implants. Furthermore, decompression of the nerve roots without fusion of the motion segment, while preserving at least 50% of the facet joint, allows maintaining mobility in the cervical spine without causing instability, potentially lowering the risk of adjacent segment degeneration (Church et al., 2014; Woods and Hilibrand, 2015; Dodwad et al., 2016).

Analyzing the rate of adjacent segment degeneration (ASD), the studies report a lower incidence of ASD after PCF, with a cumulative rate of 0.9% per year (Clarke et al., 2007; Skovrlj et al., 2014) comparing to ACDF with results 2.4-2.9% per year (Hilibrand et al., 1999: Buttermann, 2018) and in another study 1.6-4.2% per year (Lawrence et al., 2012). Although the rates of ASD seem to be lower for posterior cervical foraminotomy, suggesting that PCF is superior in that aspect due to preserving the motion in cervical spine (Church et al., 2014: Cho et al., 2014), some studies conclude that the rate of ASD after ACDF may be similar to the natural history of cervical degeneration (Lawrence et al., 2012).

Over the past few years, retrospective cohort studies with long-term follow-up have emerged evaluating the efficacy of PCF in patients with cervical radiculopathy. A 2014 study by Church et al., (2014) which evaluated 1085 cases of cervical laminoforaminotomy in 1039 patients and collected 338 questionnaires with a 10-year follow-up. They found resolution of symptoms in 90% of respondents, while 93% of patients who could not work or perform daily activities were able to return to them after the procedure. The complication rate was 3.3%, of which more than half (1.8%) were related to infection of the operated area. The rate of reoperation of the primary segment among respondents was 6.2%.

The authors note that the posterior approach has a similar success rate to ACDF, a lower rate of early and distant complications, and a shorter recovery time and lower cost compared to ACDF (Church et al., 2014). Another 2014 study by Bydon et al., (2014) of the long-term effects of PCF in 151 patients, showed overall improvement in radiculopathy in 85% of patients after 4.15 years, with the majority (91.4%) experiencing improvement as early as one month after surgery. Among patients who initially experienced an improvement in symptoms, 16.1% experienced a recurrence of radiculopathy symptoms at an average of 7.3 years after the original surgery.

Although the reoperation rate among patients included in the study was ultimately 9.9%, with a mean reoperation time of 2.4 years, the rate increased to 16.4% at the 2-year follow-up and 24.3% at the 10-year follow-up. In the study, the reoperation rate of the primary segment was 6.6%, statistically significantly ($p=0.05$) higher than reoperation of an adjacent or distant segment (Bydon et al., 2014). Recently, studies have appeared that directly compare the posterior approach to surgery for cervical radiculopathy with the anterior approach, one of them being a study analyzing the medical data of 35 studies available in the literature, involving 6,000 patients operated on with anterior access for cervical radiculopathy due to cervical disc herniation, with a follow-up of at least 2 years (mean 7.1 years).

The long-term effects of surgery were compared based on the percentage of good/excellent results assessed by patients and physicians. Among the studies, 80% of patients operated on from anterior access rated the improvement after surgery as good/excellent, while in operations from posterior access the percentage was 94%. This 14% difference proved to be statistically significant ($p<0.05$) (Dohrmann and Hsieh, 2014). Another study, a systematic review of 3 randomized controlled trials and 7 retrospective comparative studies, found no significant differences in outcomes, complication rates (mean complication rate 7% for ACDF and 4% for PCF) or reoperation rates (mean reoperation rate 4% for ACDF and 6% for PCF within 2 years of the initial surgery) recorded (Liu et al., 2016).

A different study, a systematic review and meta-analysis of 1216 cases to compare minimally-invasive PCF and ACDF in patients with unilateral radiculopathy, found comparable results in postoperative neck disability index (NDI) and visual analog scale VAS-neck scores and significantly greater improvement in VAS-arm score in PCF group, with relative complications rate and reoperation rates (Sahai et al., 2019). Another study, a major meta-analysis emerged that included a total of three randomized controlled trials (RCT) and twelve retrospective studies, analyzing over 50,000 cases to compare ACDF and PCF for single-level unilateral cervical radiculopathy.

It found comparative results in postoperative NDI and VAS scores. The complication rates were 4.23% in the ACDF group and 4.55% in the PCF group, the reoperation rates were lower in the ACDF group with statistical significance. In 2023, a multi-center, randomized clinical trial involving 265 patients was published directly comparing ACDF and PCF for the treatment of cervical radiculopathy, demonstrating the non-inferiority of the posterior approach. The study found an 88% success rate in the PCF group versus 76% in the ACDF group (Broekema et al., 2023).

Comparison of rates of adverse events showed a 22% rate of events in the posterior group, compared to 18% in the anterior group – such results are higher than those previously mentioned in the literature, which varied from 3,3-4,55% in PCF and 4.23%in ACDF, Church et al., (2014), but yet were associated with type of approach, including complications like dysphagia in anterior group and wound infections in posterior group. The researchers concluded that the results of the two procedures were comparable and that PCF was in fact non-inferior to ACDF.

More studies addressing other aspects between ACDF and PCF in a direct manner emerge, bringing the results of the posterior approach being a technique with shorter operating time, more minor blood loss as well as decreased length of patient's hospital stay, Abdalla and Elaleem, (2019), Scholz et al., (2018) meanwhile other studies deny these statements, finding no significant difference in the duration of surgery, nor the blood loss or postoperative stay length (Tumialán et al., 2010). The differences in outcomes vary among the literature. The trials call for another aspect of surgery to be analysed with a high level of evidence, namely cost-effectiveness (Liu et al., 2016; Broekema et al., 2023).

A study by Tumialán et al., (2010) found the average direct cost of PCF surgery to be $3570, compared to $10,078 for ACDF, addressing the economic aspect of choices in surgical approach. Though the limitations of this particular study are significant, as the subject of research was within the military group, it gives some perspective regarding the cost-effectiveness of these surgeries. Respectively, another cost analysis claim is that ACDF is 89% more expensive than PCF, with mean total direct costs being $8192 and $4320, with significant differences for direct costs and operating room supply costs (Mansfield et al., 2014). The key differences between ACDF and PCF are summarized in the table below (Table 1).

Table 1 Key differences between ACDF and PCF surgeries.

The key differences	ACDF	PCF
Premise of surgery	Requires an implant, leads to fusion of the cervical motion segment	Requires no implant, preserves the mobility cervical of the motion segment
Indications	Cases with instability, myelopathy, diffuse anterior disc herniation/osteophyte disease, bilateral radicular symptoms	Cases with no instability, unilateral radicular symptoms with posterolateral disc herniation/ostephyte disease
Complications	The most common complications: dysphagia, hematoma, hoarseness, recurrent laryngeal nerve palsy, pseudarthrosis, adjacent segment disease and wound infection	The most common complications: neck pain, wound infection, durotomy
Average direct cost:	$8192-$10,078	$3570-$4320

There is a discernible trend in literature regarding surgery for cervical radiculopathy, to evaluate the efficacy of less-invasive surgical treatments such as posterior cervical foraminotomy. Although anterior cervical discectomy and fusion has been shown to be effective in its indications, the idea of fusion in the cervical motion segment raises the question of whether it is necessary in so many cases and, if not, how to avoid it. The literature suggests that PCF is non-inferior in patients with posterolateral disc herniation and/or spondylosis causing nerve root compression. The efficacy of ACDF and PCF has been proven to be similar, with outcomes of posterior cervical foraminotomy being even slightly better in the most recent studies (Scholz et al., 2018; Sahai et al., 2019; Broekema et al., 2023).

Aspects like operating time, blood loss and total length of hospitalization remain unsettled, with some studies claiming better results of PCF and others finding no significant difference between the two. However, the cost-effectiveness of these procedures appears to present a substantial disparity. Nowadays, it is important to assess not only the raw medical aspects of these surgeries, but also their economic implications. The studies prove that it is difficult to draw a definitive, uniform conclusion regarding adjacent segment degeneration after ACDF surgery.

Most of them find lower rates of ASD in patients after posterior cervical foraminotomy and claim inferiority of ACDF in that matter due to limiting the range of movement in cervical spine, Church et al., (2014), Cho et al., (2014) whereas there are studies that undermine that fact, claiming the possibility that these rates are similar to the natural history of cervical degeneration (Lawrence et al., 2012). The rates of other complications specific to each type of surgical approach appear to be similar, but it is important to note that PCF, by its nature, is free from several implant-related complications as well as those resulting from the anterior approach. Reoperation rates also seem comparable.

Direct comparison between anterior discectomy and fusion and posterior cervical foraminotomy may be difficult as the indications may differ. However, given the prevalence of ACDF, it is possible that in many cases surgeons may benefit from reconsidering PCF as a favourable approach to foraminal nerve root compression. Rising consciousness about PCF being equally effective, can positively affect surgeons, allowing them to broaden the selection of choices for clinical options regarding cervical radiculopathy.

4. CONCLUSIONS

Posterior cervical foraminotomy is a viable choice for approaching a range of patients with cervical radiculopathy. It has been shown to be more cost-effective and at least as effective as anterior cervical discectomy and fusion for cervical radiculopathy with foraminal nerve root compression. Consideration of this approach as an alternative to ACDF during surgical qualification may increase the

success rate of surgical evaluation in some cases of cervical radiculopathy and potentially help to avoid complications associated with cervical motion segment fusion. Although the incidence of ASD appears lower in patients who have undergone PCF, further studies need to address and explore this relationship to draw a definitive conclusion.

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Authors contributions
Conceptualization and design: Karol Leśniewski; Data collection: Karol Leśniewski, Kamil Gibczyński, Piotr Paluch; Check: Karol Leśniewski, Kamil Gibczyński, Karolina Jabłońska, Aleksandra Jeńć-Magoń, Anita Król, Michał Orczyk, Martyna Orzechowska, Piotr Paluch, Jakub Pudźwa, Aleksandra Roztoczyńska; Data analysis and interpretation: Karol Leśniewski, Jakub Pudźwa, Martyna Orzechowska, Aleksandra Jeńć-Magoń; Manuscript rough preparation: Karol Leśniewski, Karolina Jabłońska, Anita Król; Manuscript review and editing: Piotr Paluch, Michał Orczyk, Aleksandra Roztoczyńska

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Conflict of interest
The authors declare that there is no conflict of interests.

Data and materials availability
All data sets collected during this study are available upon reasonable request from the corresponding author.

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