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EXPERIMENTAL RESEARCH - SPINE

Anterior cervical discectomy and fusion versus posterior cervical foraminotomy in the treatment of brachialgia: the Leeds spinal unit experience (2008–2013)

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Abstract
Background The surgical management of cervical brachialgia utilising anterior cervical discectomy and fusion (ACDF) or posterior cervical foraminotomy (PCF) is a controversial area in spinal surgery. Previous studies are limited by utilisation of non-validated outcome measures and, importantly, absence of pre-operative analysis to ensure both groups are matched. The authors aimed to compare the effectiveness of ACDF and PCF using validated outcome measures. To our knowledge, it is the first study in the literature to do this.
Methods The authors conducted a 5-year retrospective review (2008–2013) of outcomes following both the above procedures and also compared the effectiveness of both techniques. Patients with myelopathy and large central discs were excluded. The main outcome variables measured were the neck disability index (NDI) and visual analogue scores (VAS) for neck and arm pain pre-operatively and again at 2-year follow-up. The Wilcoxon signed-rank test and Student *t*-tests were used to test differences.
Results A total of 150 ACDFs and 51 PCFs were performed for brachialgia. There was no differences in the pre-operative NDI, VAS neck and arm scores between both groups ($p>0.05$). As expected, both ACDF and PCF delivered statistically significant improvement in NDI, VAS-neck and VAS-arm scores. The degree of improvement of NDI, VAS-neck and VAS-arm were the same between both groups of patients ($p>0.05$) with a trend favouring the PCF group. In the ACDF group, two (1.3 %) patients needed repeat ACDF due to adjacent segment disease. One patient (0.7 %) needed further decompression via a foraminotomy. In the PCF group one (2.0 %) patient needed ACDF due to persistent brachialgia.
Conclusions We found both interventions delivered similar improvements in the VAS and NDI scores in patients. Both techniques may be appropriately utilised when treating a patient with cervical brachialgia.

Keywords Anterior cervical discectomy and fusion · Posterior cervical foraminotomy · Spine · Neck disability index · Visual analogue scale · Outcomes · Complications · Recurrence · Re-do surgery · Instrumentation

Introduction

Cervical radiculopathy (from degenerative conditions) is common amongst middle-aged to elderly individuals. It occurs secondary to disc prolapse or foraminal compression due to spondylotic arthropathy [17]. In the majority of patients, symptoms resolve without surgical intervention [12]. However, surgical interventions are employed if conservative management fails. Recent randomised control trials have demonstrated that surgery improves short-term disability secondary to pain in comparison to conservative management [6, 16]. The surgical management of cervical radiculopathy is a controversial area of spine surgery. Traditionally, posterior approaches were preferred [7]; however, in recent years anterior approaches are increasingly being favoured as a result of ease of exposure, bilateral decompression, wider access of disc space and, importantly, less patient discomfort [12]. However, the long-term outcomes due to risk of adjacent segment disease, pseudoarthrosis, graft subsidence and kyphosis remain a concern [2, 10, 12]. These risks are not present with posterior

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cervical foraminotomy (PCF), which can provide better access to laterally positioned discs and is often less technically challenging. Furthermore, PCF avoids the risks of a hoarse voice and dysphagia. PCF may also allow loose disc fragments to be removed. Finally, with a posterior approach the patient also avoids the risks of damage to vital structures, i.e. trachea, oesophagus, sympathetic chain, internal carotid artery, vertebral artery and recurrent laryngeal nerve [11]. However, despite these advantages, the indication for PCF is limited only to patients with isolated nerve root entrapment without cord compression and large central disc.

Only three retrospective and two prospective studies have compared outcomes between anterior cervical discectomy and fusion (ACDF) and PCF (Table 2). These retrospective studies did not utilise validated outcome measures, there is no statistical analysis and pre-operative baseline assessment was not performed to ensure both groups were matched. The prospective studies, on the other hand, were limited by the absence of a randomisation process, power calculation and failure to utilise validated outcome measures. Taking the above shortcomings into account, the authors aimed to compare the effectiveness of both surgical interventions in the treatment of cervical radiculopathy using statistically validated outcome measures and ensure both groups were matched pre-operatively. To our knowledge, this is the first study in the literature utilising such validated outcome measures.

Methods

The authors conducted a 5-year retrospective review (2008–2013) of outcomes following both the above surgeries and also compared the effectiveness of both techniques in treating cervical radiculopathy. The diagnosis of cervical radiculopathy was made by history, examination and magnetic resonance imaging (MRI). The NHS national research ethics committee was informed of our study and informed us that formal ethics approval is not necessary due to its retrospective nature and the fact that the study does not influence patient care. Only patients who had provided written informed consent for the study and aged 18 and above were included. Patients with myelopathy and those who have had previous surgery were excluded. The choice of surgery was based on individual surgeon's preference regardless of the source of compression (disc or foraminal narrowing secondary to spondylosis). To minimise selection bias, images were reviewed by an external independent experienced spine surgeon to confirm that both techniques can be utilised in treating all cases.

In our institution, all patients who underwent ACDF had a standard discectomy via a right-sided Smith-Robinson approach with removal of foraminal osteophytes. Disc space was then replaced with PEEK Solis™ Stryker cage packed with Vitoss™ and supplemented with a Stryker Aviator™ plate. Patients who underwent PCF had a standard midline posterior approach up to ligamentum nuchae. Beyond this, only unilateral subperiosteal exposure of the joint at the side affected was performed. Nerve was decompressed by removing up to 50 % of the medial half of the joint.

The main outcome variables measured were neck disability index (NDI) and visual analogue scores (VAS) for neck and arm pain. These scores were obtained pre-operatively and again at 2-year follow-up. Other variables assessed included amount of blood loss, operative time, length of hospital stay, re-operation rates and complications. Wilcoxon signed-rank test and Student *t*-test were used to test differences in outcomes between the two groups. Statistical analysis was performed using SPSS Statistics 22 (IBM SPSS, Chicago, IL, USA) software.

Results

Between 2008 and 2013, a total of 150 ACDFs and 51 PCFs were performed for brachialgia. Characteristics of patients in each group are displayed below (Table 1). Twenty-six (17.3 %) and 13 (25.5 %) ACDF and PCF patients were lost to follow-up respectively. Median follow-up for the ACDF and PCF groups were 24 months (range 23–26 months) and 25 month (range, 21–26 months) respectively. There was no differences in the pre-operative NDI, VAS-neck and VAS-arm scores between both groups ($p>0.05$) (Table 1). In the ACDF group, 111 patients' (74 %) compression was secondary to postero-lateral disc protrusion, with the remaining due to foraminal stenosis secondary to spondylosis. In the PCF group, 18 patients' (35.5 %) compression was secondary to foraminal stenosis, with the remaining due to postero-lateral disc protrusion .

ACDF resulted in statistically significant improvement in NDI ($p=0.016$), VAS-neck ($p=0.003$) and VAS-arm ($p=0.000$). Similar improved outcomes were also seen in the PCF group with NDI ($p=0.008$), VAS-neck ($p=0.003$) and VAS-arm ($p=0.000$). At 2-year follow-up, the degree of improvement of NDI, VAS-neck and VAS-arm were all no different between the two groups of patients ($p>0.05$), although there was a non-significant trend favouring the PCF group (Figs. 1 and 2).

There was no statistically significant difference in the NDI and VAS scores in either operative group between those with nerve compression secondary to degenerative disc disease and those with foraminal stenosis. However, there is a trend suggesting that ACDF may be more effective in compression related to disc and PCF may be more effective in foraminal pathology at 2-year follow-up. The amount of blood loss and length of operation was the same in both groups ($p>0.05$).

Table 1 Pre-operative characteristics of both the anterior cervical discectomy (*ACDF*) and posterior cervical foraminotomy (*PCF*) groups of patients

	ACDF	PCF	*p* value
n	150	51	
Age (median)	48	50	0.234
Male/female	61/89	34/17	0.151
Median stay (days)	1.0±3.2 (0–36)	1.0±6.5 (0–35)	0.182
Median follow-up (months)	24.0±1.4 (23–26)	25.0±1.2 (21–26)	0.891
Pre-op VAS-neck	7.1±3.1 (0–10)	8.0±1.5 (4–10)	0.244
Pre-op VAS-arm	7.2±2.4 (1–10)	7.3±1.9 (3–10)	0.687
Pre-op NDI (%)	45.7±17.4 (12–74)	49.5±14.5 (22–81)	0.360

In the ACDF group, two (1.3 %) patients needed adjacent level ACDF due adjacent segment disease. One patient (0.7 %) needed further decompression via a foraminotomy. Four (2.7 %) and seven (4.7 %) patients had hoarse voice or dysphagia respectively, all of which improved on follow-up. One (0.7 %) patient had a simple wound infection, needing only oral antibiotics. In the PCF group, one (2.0 %) patient had a deep wound infection needing surgery for washout. One (2.0 %) patient needed an ACDF due to persistent brachialgia.

Discussion

As expected, both ACDF and PCF resulted in statistically significant improvement in NDI, VAS-neck and VAS-arm scores. We found that both interventions delivered similar improvement in the aforementioned scores in patients, with a trend favouring PCF. The widely held belief that PCF worsens neck pain was not true in our series; on the contrary, patients reported statistically significant improvement in neck pain on follow-up.

As reported above, we found PCF an effective modality in treating cervical radiculopathy. Several studies have demonstrated that in more than 90 % of cases, PCF achieved good outcomes [5, 8, 9, 13, 18, 19]. However, the biggest flaw from previous studies was that no validated outcome measures were used to demonstrate this. This is the first study to prove the effectiveness of PCF using validated outcome measures.

Few studies have directly compared outcomes between ACDF and PCF (Table 2) [9, 13, 15, 19, 20]. Tumalan et al. [19] showed that both anterior and posterior approaches have comparable clinical efficacy. However, PCF was more cost-effective and also allowed patients to make a quicker return to unrestricted activity [17]. Interestingly, there was no difference in patient outcome in those patients who had PCF secondary to disc disease versus those secondary to spondylotic arthropathy. The above study did not use validated outcome measures or pre-operative analysis to ensure both groups were matched.

Onimus et al. [15] compared 14 patients who had ACDF to 14 PCF. All 28 patients had soft postero-lateral disc protrusions. Both groups demonstrated similar outcomes statistically at 30 and 36 months follow-up respectively. Again, non-

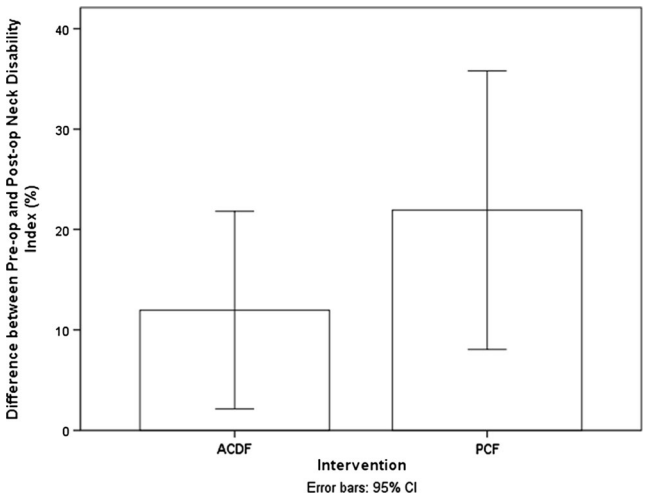

Fig. 1 Mean difference between pre-operative and post-operative neck disability index scores (%) across both groups

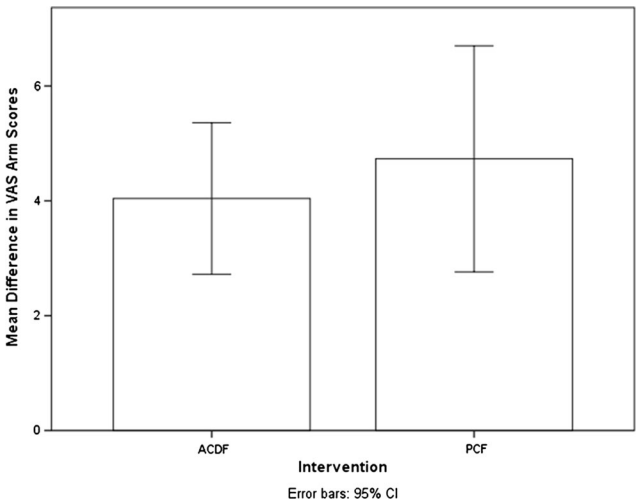

Fig. 2 Mean difference between pre-operative and post-operative visual analogue scores across both groups

Table 2 Summary of previous studies undertaken to compare anterior cervical discectomy and fusion (*ACDF*) with posterior cervical foraminotomy (*PCF*)

Study	Type	Outcome	Criticism
Tumalan et al. 2010 [19]	Retrospective (n=21 each arm)	Comparable efficacy (blood loss, operating time, analgesic use). PCF more cost effective. Quicker return to work	Non-validated outcome measure. No pre-op analysis to ensure groups are matched
Onimus et al. 1995 [15]	Retrospective (n=15 each arm)	ACDF — 8 excellent, 7 good; PCF — 7 excellent, 8 good	Non-validated outcome measure. Non-statistical. No pre-op analysis to ensure matching
Herkowitz et al. 1990 [9]	Prospective (ACDF —28; PCF —16)	ACDF, 95 % excellent/good; PCF, 75 % excellent/good. Higher proportion excellent in the PCF group	Cohort study. Non-randomised. No power calculation. Non-validated outcome measure. No pre-op analysis to ensure groups are matched
Wirth et al. 2000 [20]	Prospective (3 arms — ACD, ACDF and PCF; n=14 each arm)	PCF — complete/partial relief in all patients. Complete /partial relief in 96 % of ACDF patients	Cohort study. Non-randomised. No power calculation. Non-validated outcome measure. No pre-op analysis to ensure groups are matched
Korinth et al. 2006 [13]	Retrospective (ACDF —124; PCF —168 patients)	Excellent/good in ACDF (93.6 %); PCF (85.1 %) (p<0.05)	Non-validated outcome measure. No pre-op analysis to ensure groups are matched

validated outcome measures were utilised in the analysis. Pre-operative analysis was not performed to ensure both groups were matched. Herkowitz et al. [9] also compared outcomes between ACDF and PCF in patients with antero-lateral disc protrusions. Good and excellent results were obtained in 95 % of patients who had ACDF; however, good and excellent results were found in only 75 % of PCF patients. This difference was not statistically different. Their results have to be interpreted with caution as the study was not statistically based, included a small number of patients (n=33), utilised non-validated outcome measure and pre-operative baseline analysis was not performed to ensure both groups were matched.

Wirth et al. [20] conducted a prospective trial comparing PCF and anterior cervical discectomy with and without fusion. All the patients recruited had radiculopathy secondary to postero-lateral disc protrusion. The study found that the proportion of patients with pain improvement (complete or partial relief), requirement for analgesia and length of hospital stay was similar across all three groups. The only significant difference was the longer anaesthetic time in the PCF and ACDF fusion groups in comparison to those patients who had an anterior approach without fusion. In the PCF group, the authors found that a significant proportion of this time was spent in patient positioning as opposed to prolonged operating time. This study has several limitations. Again, non-validated outcome measures were used to measure the effectiveness of the intervention. The number of patients recruited in each trial arm was small with no evidence that a power analysis was performed to demonstrate numbers needed to determine the most effective treatment modality. The mean duration of symptoms for the PCF, ACD and ACD with the fusion group was 5.5, 7.3 and 4.0 weeks respectively. It is difficult to draw too many conclusions from this study as it is difficult to extrapolate these findings to patients who are refractory to conservative management for 6–8 weeks. Lastly, the entire patient cohort analysed had a disc protrusion and this study did not include those who had foraminal stenosis.

At 2 months follow-up, Wirth et al. [20] found that in their group of patients, all the patients who had PCF reported either partial or complete relief of radicular pain compared to 96 % of patients in the ACDF group. Nevertheless this difference was not statistically significant, although there was a trend favouring PCF. In spite of this being a prospective study, it was not performed with the benefit of power analysis and, like our study, this difference has been limited by type 2 error due to the small number of patients. Onimus et al. [15] also found similar outcomes in their small group of patients (n=28) with a trend favouring PCF with 57 % of patients reporting excellent or good results as oppose to 50 % in the ACDF group.

Trends favouring PCF were not reported in the study by Herkowitz et al. [9] In their study group, 95 % of patients in the ACDF group reported excellent/good results in comparison to 75 % in the PCF group. The difference was not tested statistically and again non-validated outcome measures were used. Korinth et al. [13] also found that the patients who had ACDF had better outcomes (excellent and good) based on Odom's criteria compared to PCF. Interestingly the proportion of patients who reported excellent outcomes was higher in the PCF group. The authors also found complications in the ACDF group to be significantly higher.

One of the most commonly cited complications of PCF is post-operative neck pain. Our findings, however, suggest that neck pain overall does improve significantly at follow-up.

Jeganathan et al. [12] in their series of 162 patients who had PCF also found that 47 % of patients reported improvement in neck pain. However, the authors did not report the proportion of patients whose neck pain worsened or remained unchanged. Bydon et al. [1] published a series of 151 patients who had PCF; 92.5 % of patients reported an improvement of neck pain. We would recommend that the traditionally held view that PCF worsens neck pain needs to re-evaluated in the light of the findings of modern retrospective studies.

In terms of risk of instability and the need for instrumentation, no patients in the PCF group required to have posterior instrumented fixation. In the literature, there is certainly no evidence that there is increased risk of instability from PCF [12]. The likely explanation for this being that, despite disrupting parts of the facets (less than one-third of the facet joint), the integrity of the disc space remains intact. The risk of kyphosis is also minimal in the PCF patients. Only one patient out of 169 in the Jeganathan et al. [12] series of PCF patients needed to have posterior fixation after a median follow-up of 84 months (range, 60–145 months). Furthermore, 18.5 % of patients in their series did demonstrate loss of cervical lordosis. However, this was merely a trend towards increased kyphosis and was not statistically significant. Their series also identified a subset of patients who are at increased risk—those above the age of 60, previous posterior surgery and, lastly, those with lordosis less than 10° pre-operatively. Extrapolation of knowledge from cadaveric biomechanical studies may help to reduce this risk further by ensuring that during PCF less than 50 % of the facet is removed [14, 21].

ACDF has an effect on adjacent segment motion. In our series, adjacent-level ACDF was performed in two patients in the ACDF group and this consequence needs to be taken into account during the decision-making process. A recent study by Cho et al. [2] demonstrated that in PCF the range of motion in the adjacent segments is preserved, however this certainly was not the case in the ACDF patients. The increased range of motion at the adjacent levels has been postulated as the cause of adjacent segment disease in patients who had ACDF. The increased risk of adjacent segment disease needing further ACDF is well documented in the literature [3]. Wirth et al. [20] also noted that patients who underwent ACDF are at increased risk of further surgery at adjacent levels.

Both ACDF and PCF were effective in treating patients regardless of the source of the compression, i.e. degenerative disc disease or foraminal stenosis. However, in our study there was a trend favouring ACDF in being more effective in treating disc disease and PCF being more effective in treating foraminal pathology. This may represent a type 2 error. Nevertheless, there are several series demonstrating effectiveness of both ACDF and PCF in treating radiculopathy regardless of the source of the compression. Wirth et al. [20] reported 77 % of patients with PCF had complete relief of symptoms in comparison to 76 % of patients in the ACDF group in treating patients with radiculopathy secondary to cervical disc disease.

Other complications that do not favour ACDF are the risk of dysphagia and a hoarse voice. In our cohort of patients, these symptoms resolved. In the series reported by Tumalan et al. [19], of 19 patients who had ACDF, two developed transient recurrent laryngeal nerve palsy. Permanent complications can occur along with other risks, such as injury to the oesophagus, sympathetic chain, carotid artery and recurrent laryngeal nerve; however, these risks are rare [11].

Both techniques are effective in achieving adequate decompression of nerve roots as index level re-operation rates were low in our series with only one patient in each intervention needing further surgery. Only 2 out of 162 cases in the Jeganathan et al. [12] series required further ACDF due to disc disease. In a larger series by Clarke et al. [4], of 303 patients who had PCF, the risk after 5 and 10 years was 3.2 and 5 % respectively. Wirth et al. [20] found 4 out of 22 (18 %) patients needed repeat surgery at that level in the PCF group compared to 2 out of 25 (8 %) in the ACDF group. However, the reason cited was due to recurrent disc disease at that level. None of these authors report whether the disc was soft or hard. In our study, the PCF patient who needed ACDF had a soft disc.

We demonstrated that both ACDF and PCF is appropriate to be utilised, based on surgeon and patient preference; however, there are several limitations to our study. Firstly, the follow-up period for our study is relatively short and only through a longer follow-up of 5 and 10 years can risks such as further surgery at index and adjacent level be seen. Importantly, our study is also limited by type 2 errors due to insufficient number of patients to demonstrate difference. This is because of lack of patients who have had pre-operative and post-operative NDI and VAS scores recorded. Importantly, due to the retrospective nature of the study and absence of randomisation, our study is subject to selection bias, whereby patients with disc pathology are more likely to be treated with ACDF. Certainly we noted a slightly larger proportion of patients with disc pathology in the ACDF group. We attempted to reduce this by having an external independent spine surgeon to review our images to ensure that patients that are included in the study are suitable for both interventions. Furthermore, being retrospective, we did not have 2-year follow-up data on 26 (17.3 %) and 13 (25.5 %) ACDF and PCF patients respectively. This differential lost to follow-up can itself add bias to our analysis. Finally, due to the retrospective nature of our study, important variables such as psychiatric history, smoking status and body-mass index (BMI) were not recorded and therefore not controlled for in our analysis. Despite the above limitations, our study is the first known study to have utilised validated outcome measures to directly compare the effectiveness of ACDF and PCF. Certainly there is a research gap in this area that needs to be filled with better quality studies.

Conclusions

Based on our retrospective analysis, at 2-year follow-up, PCF is as effective as ACDF in reducing neck disability and VAS pain scores. The literature comparing these two techniques is poor and a prospective randomised study is required.

Conflicts of interest None.

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