SPINE An International Journal for the study of the spine, Publish Ahead of Print

DOI: 10.1097/BRS.0000000000004129

Multilevel, Percutaneous Posterior Cervical Interfacet Distraction and Fusion for Cervical Spondylotic Radiculopathy: Clinical and Radiographic Outcomes

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The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

No funds were received in support of this work.

Relevant financial activities outside the submitted work: stocks.

ABSTRACT

Study Design. Retrospective review of patients that underwent multilevel posterior cervical interfacet distraction and fusion (PCIDF) using cages for cervical spondylotic radiculopathy (CSR)

Objective. To determine clinical and radiographic outcomes following multilevel PCIDF

Summary of Background Data. Anterior cervical discectomy and fusion has long been the standard of treatment for CSR. Advancements in surgery have employed minimally invasive techniques such as endoscopic discectomy, foraminotomy, and PCIDF. Studies on single-level PCIDF have reported good clinical outcomes, short hospital stays, and rare complications, but its application in multilevel disease is still evolving.

Methods. Patients with CSR and confirmed radiologic evidence of multilevel foraminal stenosis without central canal stenosis were reviewed. Two-year outcomes of multilevel PCIDF included Neck Disability Index (NDI), neck and arm visual analogue scale (VAS), radiographic cervical alignment parameters, evidence of fusion, and incidence of adjacent segment degeneration (ASD) were compared at different time points.

Results. Thirty patients (mean age 54.6±8.3) were included in the study with an average of 3.4+0.8 levels treated. Mean surgical duration and intraoperative blood loss was 143.2+69.7 minutes and 27.7+28.7 mL, respectively, with an average length of stay at 1.8+1.5 days. NDI, VAS-neck and VAS-arm all significantly improved at 2 weeks ($p<0.001$) and was maintained until 2 years postoperatively. A significant decrease in segmental and C2-C7 lordosis, with a corresponding increase in sagittal vertical axis, was observed at 3 months postoperatively ($p<0.001$) but did not deteriorate further on subsequent visits. Successful fusion was achieved in 90% of patients after two years. There was a 13.3% incidence of ASD in the study cohort and one perioperative complication (3.3%).

Conclusion. Our study suggests that multilevel PCIDF is safe and effective for cervical spondylotic radiculopathy caused by foraminal stenosis. However, its potential to cause kyphosis and clinical impact on global sagittal alignment requires further scrutiny and long-term evaluation.

Keywords: spine; cervical; spondylosis; radiculopathy; foraminal stenosis; interfacet; lateral mass; fusion; arthrodesis; posterior; DTRAX; minimally invasive; percutaneous

Level of Evidence: 4

Mini Abstract / Precis:

Percutaneous posterior cervical interfacet distraction and fusion is a safe and effective minimally invasive treatment option for cervical spondylotic radiculopathy. Our clinical and radiographic outcomes suggest that its application can be extended to stand-alone treatment for >2 symptomatic foramina in patients with normal cervical lordosis without central canal stenosis.

Key Points

1. Multilevel percutaneous posterior cervical interfacet distraction and fusion using cages filled with graft material can indirectly decompress symptomatic neural foramina and provide lasting pain relief through eventual arthrodesis.
2. Mean preoperative VAS scores for neck and arm were 4.4+0.9 and 8.4+1.0, respectively and improved to 0.8+0.8 and 0.4+0.6 at 2 years.
3. Mean preoperative NDI score was 65.0+5.3 with an average improvement of 58.0+5.8 points after two years.
4. There was a significant decrease in cervical and segmental lordosis with a corresponding significant increase in C2-C7 sagittal vertical axis from baseline to 3 months ($p<0.001$) with no further significant changes in these parameters up to 2 years; however, longer follow-up is necessary to determine the clinical effect of the kyphosis generated.
5. Successful fusion was seen in 90% of patients and the rate of subclinical adjacent segment degeneration was 13.3% after two years.

Introduction

Sequelae of cervical spondylosis includes neural foramen stenosis causing unilateral or bilateral nerve root impingement. Clinical symptoms of neck and radicular arm pain, paresthesia and weakness may result in significant impairment in activities of daily living and decreased health-related quality of life (HRQOL) [1-4]. Anterior cervical discectomy and fusion (ACDF) has long been regarded as the standard of treatment for cervical spondylotic radiculopathy (CSR) after failure of conservative management [5-8]. Evolving concerns about adjacent segment disease [8-10] have given rise to motion-sparing options and minimally invasive surgical (MIS) techniques, all with comparable outcomes to ACDF [7,11-14]. These options, however, are not always suitable for high-risk patients with multiple comorbidities or for multilevel disease, necessitating technically demanding and lengthy surgeries.

Percutaneous posterior cervical interfacet distraction and fusion (PCIDF) using cervical interfacet spacers (CIS) achieves the goals of spinal surgery and avoids many unwanted complications associated with open anterior or posterior approaches [15,16]. This percutaneous procedure indirectly decompresses symptomatic neural foramina through facet

distraction and arthrodesis [17,18] and has been gaining popularity in this era of minimally invasive surgery. PCIDF has been used as definitive treatment for single-level CSR [18-20], a supplemental procedure to anterior or posterior surgeries [21,22], and as salvage for treating adjacent segment disease [23]. However, there is scarce evidence available on PCIDF as stand-alone treatment for multilevel CSR.

The purpose of this study was to determine the clinical and radiographic outcomes of multilevel PCIDF with a minimum follow-up of two years. Results of multilevel ACDF, arthroplasty, and posterior foraminotomy have proven satisfactory [24-26], and we hypothesize that multilevel PCIDF can yield similar outcomes.

Materials and Methods

This retrospective review included consecutive patients that underwent multilevel PCIDF between 2012 and 2018 at two tertiary sister hospitals. All surgeries were performed by, a single, fellowship-trained, board-certified orthopedic spine surgeon, who was proficient in the procedure. Study approval was obtained from the local Institutional Review Board and Ethics Committee.

Indications for PCIDF using CIS comprised all of the following: (1) debilitating radicular arm pain; (2) progressive decline in neurologic function; (3) failure of non-operative treatment for a minimum of 12 weeks including anti-inflammatory medications, prescribed analgesics, hospital-based physiotherapy, and lifestyle modification; (4) sensorimotor loss correlating with radiographic and magnetic resonance imaging (MRI) findings of >2 levels of foraminal stenosis; and (5) a lordotic cervical alignment on standing preoperative radiographs. Patients were included in this study if they had a minimum follow-up of 2 years with complete clinical and radiologic data. Exclusion criteria included: (1) cervical myelopathy, (2) ossified posterior longitudinal ligament, (3) part of a staged surgery, (4) previous spinal surgery, (5) history of spinal trauma, and (6) spinal infection.

All clinical data was retrieved via electronic hospital and clinic records. Data collected included age, gender, operative variables, length of hospital stay (LOS) and perioperative complications. Operative variables identified were surgical duration, intraoperative estimated blood loss (EBL), and number of levels treated. LOS was defined as the number of days from start of the procedure to discharge from the hospital. Perioperative complications were defined as any unforeseen event arising intra- or postoperatively within 30 days of surgery and requiring medical or surgical intervention. Clinical outcome measures of interest included the Neck disability index (NDI) and visual analogue scale (VAS) for neck and arm pain. NDI scores were collected preoperatively and at 2 weeks, 3 months, and yearly postoperatively. VAS-neck and VAS-arm scores were obtained similarly with an additional score collected 1 day postoperatively.

Pre- and postoperative standing cervical radiographs were accessed using the unified hospitals' Carestream (Onex Corporation, Toronto, Ontario, Canada). Measurements were

performed by two blinded radiologists, and an average of their findings were recorded. These included C2-C7 global cervical angle (GCA), C2-C7 sagittal vertical axis (SVA), and segmental cervical lordosis of treated levels. GCA and segmental lordosis was measured using the Cobb's method and a kyphotic alignment was recorded as a negative value [27]. The C2-7 SVA was defined as the distance of the postero-superior aspect of the C7 vertebral body from the C2 plumb line [27]. Presence of osteophytes, heterotopic ossification, and any decrease in disc height of adjacent levels were noted postoperatively and were considered findings of adjacent segment degeneration (ASD). Successful fusion was defined by at least one of the following: (1) bridging trabecular bone through or adjacent to facets and lateral masses, (2) <2mm translational motion, and/or (3) <2mm motion between spinous processes of all treated levels [19,20,28]. If there was disagreement between radiologists on determining ASD or fusion, a blinded senior orthopedic resident was called to adjudicate.

All statistical analysis was conducted using IBM SPSS Statistics v23.0 (Armonk, NY, USA). Wilcoxon signed-rank tests was used to compare baseline clinical data with those collected at 2 weeks and baseline radiographic data with those at 3 months when the first postoperative radiograph was obtained. Within-patient changes of subsequent follow-ups (i.e. 2 weeks to 2 years for clinical data, 3 months to 2 years for radiographic data) were compared using one-way repeated-measures ANOVA with Greenhouse-Geisser correction. Post hoc tests using Bonferroni correction was utilized to determine significance between different time periods. Statistical significance was set at $p<0.05$ for all analyses conducted.

Surgical technique

The DTRAX system (Providence Medical Technology Inc., Pleasanton, CA) was employed in all surgeries. After general endotracheal anesthesia and prone positioning with shoulders were retracted caudally, two image intensifiers were positioned to obtain dedicated orthogonal anteroposterior and lateral views of the cervical spine. Coronal and sagittal trajectories were planned for each facet joint to be treated and entry points were marked on the posterior neck, utilizing a single incision on each side. Corex percutaneous bone harvester (Acumed, Hillsboro, OR) was utilized to first obtain cancellous iliac crest bone graft, as well as bone marrow aspirate, to be morselized and mixed with Grafton demineralized bone matrix putty (Medtronic/BioHorizons, Minneapolis, MN). The method of implantation and instrumentation done in our surgeries has been previously described by McCormack et al [19]. A soft cervical collar was applied immediately post-operatively for comfort and discontinued after 2 weeks.

RESULTS

A total of 30 patients were evaluated (Table 1), 9 (30%) of whom were female, with a mean age of 54.6+8.3 (33.0-72.0). Majority of patients (46.7%) underwent 3-level PCIDF, 12 patients (40.0%) underwent 2-level surgery, and four patients (13.3%) had 4-level surgery. There were a total of 164 facets instrumented and foramen indirectly decompressed, with the most common level affected being C5C6, which was treated in all patients. Mean overall

surgical duration was 143.2+69.7 minutes, average EBL was 27.7+28.7 mL, and LOS was 1.8+1.5 days.

The mean preoperative VAS-neck and VAS-arm scores were 4.4+0.9 and 8.4+1.0, respectively (Table 2) and improved to 0.8+0.8 and 0.4+0.6 at two years. Average improvement of VAS-arm scores from baseline after two years was 8.8+1.0 in 4-level surgery, 8.2+1.1 in 3-level surgery, and 7.5+0.9 in 2-level surgery. There was a significant decrease in VAS-neck and VAS-arm from baseline to 2 weeks ($p<0.001$). Repeated-measures ANOVA showed an overall decrease in both scores during subsequent follow-ups ($p<0.001$) with post hoc tests revealing continued improvement up to one year postoperatively which was maintained at 2 years. Mean preoperative NDI was 65.0+5.3 with an average improvement of 58.0+5.8 points at 2 years. Five patients (16.7%) had no disability (i.e. NDI score <4) and the remainder of patients had mild disability (i.e. NDI score 5-14) at 2 years. Average 2-year improvement of NDI was 58.3+8.0 points in 4-level PCIDF, 59.9+4.5 points in 3-level PCIDF, and 55.8+3.8 points in 2-level PCIDF. There was a significant decrease in mean NDI from baseline to 2 weeks ($p<0.001$) with a continued significant improvement up to one year postoperatively ($p<0.001$) which was also maintained at 2 years.

There was a significant decrease in cervical and segmental lordosis and a corresponding significant increase in C2-C7 SVA from baseline to 3 months postoperatively ($p<0.001$). However, repeated-measures ANOVA revealed no further significant changes at subsequent follow-ups up to 2 years for GCA ($p=0.200$), segmental lordosis ($p=0.071$), and C2-C7 SVA ($p=0.492$). Overall mean decrease in cervical and segmental lordosis from baseline to 2 years were 8.6+1.1 and 5.6+0.6 degrees, respectively (Table 3) while overall C2-C7 SVA increased on average by 8.6+1.1 mm after two years. Radiographic fusion defined previously was seen at 3 months in 58.3% of patients who had 2-level surgeries (Table 4). Overall, one- and two-year fusion rates were 73.3% and 90.0%, respectively. Our incidence of ASD was 13.3% after 2-years, with majority occurring in 2-level surgeries.

One patient (3.3%) had a medially positioned implant, which manifested clinically as persistence of radiculopathy without improvement in VAS-arm immediately after surgery. Pain resolved after urgent cage repositioning without any residual neurological sequelae. There were no cervical or lumbar wound infections, neurological complications, vascular complications, approach-related adverse events, or unplanned hospital readmissions in the cohort. At one-year follow-up, one patient showed posterior implant migration of a single cage but remained asymptomatic.

There were 6 patients that had available data beyond 2 years with an average follow-up of 55.2+19.1 months. NDI improved an average of 56.7+6.5 points at final follow-up, with a mean reduction in VAS-neck and VAS-arm of 3.8+0.8 and 7.3+1.2 points, respectively. GCA decreased an average of 7.1+3.3 degrees while SVA increased by a mean of 6.9+6.1 mm, but all patients continued to maintain a lordotic alignment at final follow-up. There were 5 patients (16.7%) with evidence of ASD, 4 of whom were already identified at 2 years. All six patients were deemed to have successful arthrodesis of treated levels and did

not have any complications or additional cervical spine surgeries within their follow-up period.

DISCUSSION

PCIDF using CIS is a minimally invasive, tissue-sparing procedure that allows indirect decompression of cervical nerve roots by increasing foraminal height through facet distraction [17-19,29]. Cages filled with fusion material are placed between the facets of the symptomatic levels under radiographic guidance which leads to facet and lateral mass arthrodesis to maintain the decompression and provide stability. Early clinical outcomes of PCIDF in patients with single-level CSR have proven to be satisfactory with rare adverse events [15,16,19,20]. Recently, the application of this procedure has extended to other spinal pathologies. Cheng et al [23] studied PCIDF as treatment for adjacent segment disease with and without laminectomy; they reported improvement in VAS and NDI score, a 96% fusion rate, no significant changes in cervical lordosis, and no device related complications. Kasliwal et al [30] studied symptomatic pseudoarthrosis treated with PCIDF and found high fusion rates and good clinical outcomes. Biomechanical studies have also suggested that PCIDF can augment anterior procedures to improve arthrodesis by increasing stability and limiting cervical segmental motion [31-34]. Kramer et al [21] confirmed this clinically and found that PCIDF was effective in obtaining multilevel circumferential fusion in patients deemed to be at high-risk in developing pseudoarthrosis. Bou Monset et al [35] evaluated PCIDF as supplemental fixation in multilevel laminectomy for cervical spondylotic myelopathy (CSM) and reported excellent patient outcomes and fusion rates.

Few published studies have dealt with the outcomes of PCIDF as stand-alone treatment in multilevel disease [18,36,37]. Traditionally, multilevel CSR or CSM have been treated with anterior cervical decompression and fusion, cervical disc arthroplasty (CDA), posterior cervical decompression and fusion (PCDF) with screw fixation, or posterior cervical foraminotomy. Three to four level ACDF demonstrates substantial improvement in NDI, VAS-neck, and VAS-arm, but revision rates occur in approximately a third of patients due to non-union [25,38]. Multilevel ACCF have yielded similar results with its ACDF equivalent in terms of clinical and radiographic outcomes but suffers from increased blood loss, longer LOS, and a trend towards more complications [39-41]. A systematic review by Joaquim et al [26] revealed that multilevel CDA is as safe and effective as ACDF, with preservation of cervical motion and fewer revisions. Youssef et al [42] showed that myelopathy/CSR treated with PCDF had great improvement in VAS-neck and NDI with a 98.9% fusion rate, 0.8% revision rate, and 7.1% rate of complications. Posterior foraminotomy has also been fairly effective at treating CSR at two to three levels resulting in long-lasting improvement in VAS scores and an increased HRQOL [22,24,43,44]; improvement in its utilization via MIS approaches has yielded similar outcomes [13,43,45]. Our study demonstrates that multilevel PCIDF successfully provided significant improvement in functional outcome and pain up to 2 years (Figure 1), which is in line with those reported for the other aforementioned procedures. We had lower overall EBL, longer surgical durations, and similar LOS when compared to perioperative metrics reported

by Siemienow et al [36] and Smith et al [46]. The improvement in NDI, VAS-neck, and VAS-arm also complements the literature [18,46] regarding the use of CIS at multiple levels.

PCIDF is an MIS procedure that can theoretically mitigate morbidity associated with conventional anterior and posterior approaches. Dysphagia, recurrent laryngeal nerve palsy, and other serious visceral, neurologic, and vascular adverse events inherent to anterior surgery [47] are eliminated in PCIDF. Its percutaneous application avoids persistent axial neck pain, C5 palsy, and surgical site infection common in traditional open PCDF [42,48]. Proper placement of CIS theoretically lowers the risk of dural tears, iatrogenic instability, and transient palsy, which are common in posterior foraminotomy [45], as bone removal and direct handling of nerve roots are avoided. Furthermore, CIS insertion is inherently safe with the superior cervical pedicle acting as a mechanical block preventing over-advancement into the transverse foramen thereby preventing vertebral artery injury [16,18]. Our lone complication of a medial malpositioned implant could have been avoided with a more lateral cage placement, and we had no palsies or infections. Our two-year rate of ASD was 13.3%, but since these occurred in older patients, this may have been progression of mild degeneration that was preoperatively undetectable on imaging modalities. Our overall two-year radiographic fusion rate was 90.0% (Figure 2A-H) due to findings of incomplete arthrodesis in three patients. Nevertheless, we attribute our high fusion rate to meticulous preparation of facet joint and lateral mass fusion beds and the placement of a generous amount of graft material within and behind the CIS.

Cervical sagittal alignment is always a concern in any multilevel posterior surgery as disruption in musculature and bony architecture can potentially cause iatrogenic kyphosis. CIS causes longitudinal distraction of the posterior column and subsequent flexion of the anterior column. This shift in axial load increases compressive forces and theoretically can hasten disc degeneration. There have been reports of mild loss of lordosis after surgery at single- and multiple levels following treatment with PCIDF, but these values were not statistically significant [18,37]. Our results showed a significant decrease in lordosis from baseline to 3 months for both GCA and treated segments with a corresponding significant increase in C2-C7 SVA (Figure 3). From three months onwards, however, these parameters did not further deteriorate, and all patients did not progress into kyphosis after two years. Despite the change in cervical alignment after PCIDF, there were no clinical sequelae as NDI and VAS scores significantly improved from baseline and was maintained at two years postoperatively. The inability of CIS to generate significant kyphosis and impact GCA, even at multiple levels, can be attributed to the correlation of the facet joints with the fulcrum of cervical spinal movement and center of range of motion [18,37].

There are several limitations to our research. Aside from its small sample size and single-surgeon experience, the retrospective nature of the study may have led to selection and information bias. Computed tomography, which is ideal in assessing bony union, was not utilized postoperatively due to financial constraints and a lack of universal health coverage in our developing country; this was mitigated by our radiologic criteria for successful arthrodesis read by blinded radiologists. Changes in cervical alignment were not correlated

with other spinal measurement parameters and it remains unknown whether PCIDF may influence overall sagittal balance. As such, additional studies with long-term follow-up are necessary to further evaluate the effect of this kyphosis-generating procedure on cervical and global spinal alignment.

CONCLUSION

Cervical fusion using CIS is an acceptable MIS treatment option for patients with multilevel CSR without central canal stenosis and kyphosis. Despite a significant decrease in sagittal parameters after surgery, patients did not go into further significant kyphosis and maintained their improvements in NDI and VAS scores up to 2 years. Our results indicate that PCIDF used as initial, stand-alone treatment for CSR due to foraminal stenosis at multiple levels is an effective means of improving clinical outcomes in select groups of patients.

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Figure 1: Line graph showing (A) NDI and (B) VAS scores from baseline to 2 years after PCIDF.

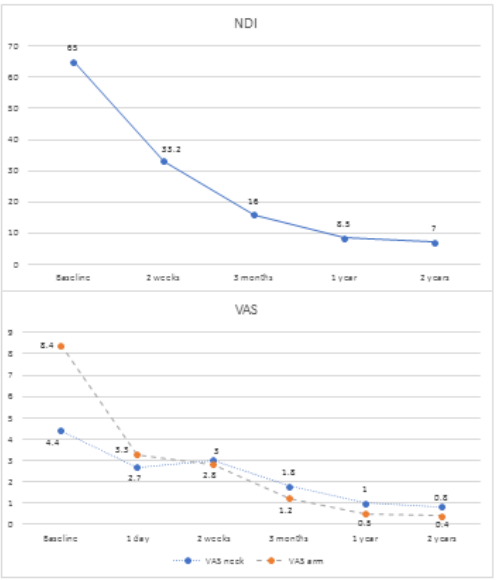

Figure 2: (A-B) A 65-year old male complaining of severe bilateral radicular arm pain who underwent 3-level PCIDF with resolution of symptoms; (C-H) two-year postoperative radiographs showing successful arthrodesis at all treated levels and maintenance of foraminal distraction.

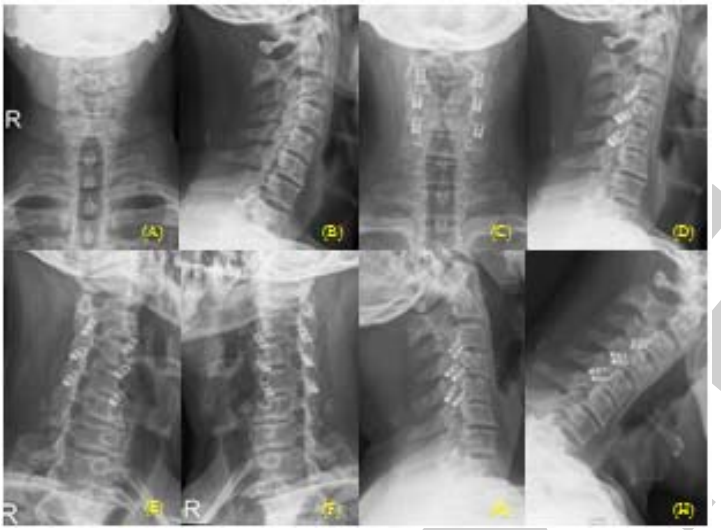

Figure 3: Line graph showing radiographic measurements from baseline to 2 years after PCIDF.