Anterior Cervical Pseudarthrosis Treated with Bilateral Posterior Cervical Cages

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BACKGROUND: Pseudarthrosis after anterior cervical discectomy and fusion (ACDF) causes persistent pain and related disability. Posterior revision surgery results in higher healing rates, but is more extensive compared to anterior surgery.

OBJECTIVE: To evaluate minimally disruptive, tissue sparing posterior fusion via bilateral placement of posterior cages between the facet joints as an alternative treatment option.

METHODS: A retrospective, multicenter, medical chart review was performed and included 25 patients with symptomatic pseudarthrosis after ACDF treated with posterior cervical cages, and in select cases, anterior revision. Visual analog scale (VAS) for neck and arm pain, Neck Disability Index (NDI), and perioperative metrics were collected. Fusion at 1 yr was determined via assessment of computed tomography (CT) scan and x-rays.

RESULTS: Mean follow-up was 18 mo. VAS neck and arm scores at last follow-up improved significantly from 7.9 $\pm$ 1.5 to 3.8 $\pm$ 2.3 and 7.24 $\pm$ 2.2 to 3.12 $\pm$ 2.5, respectively. NDI scores decreased from 65.1 $\pm$ 20.3 to 29.1 $\pm$ 17.9 at 18 mo. Fusion at 1 yr was confirmed by CT in all 17 patients with available scans and by x-ray in all 25 patients.

CONCLUSION: Revision of cervical pseudarthrosis after ACDF using a tissue sparing posterior approach to place cages bilaterally between the facet joints is an effective surgical strategy in select cases. Along with positive clinical and radiological outcomes, the procedure is associated with less blood loss, shorter operating times, and briefer hospital stays compared to revision with lateral mass fixation or interspinous wiring.

KEY WORDS: Cervical pseudarthrosis, Minimally disruptive, Posterior cervical fusion, Posterior intervertebral cervical cages, DTRAX cervical cage, Tissue sparing

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Pseudarthrosis is one cause of persistent pain after anterior cervical fusion. While not all pseudarthroses are symptomatic, many studies indicate pseudarthrosis adversely affects clinical outcomes.[1] Surgical repair, when indicated, may be performed with an anterior, posterior, or circumferential approach. The best indication for anterior surgery is to correct kyphosis, graft dislodgment, or to address ventral neurological compression.[2]

Bone healing rates are higher in posterior surgery with reduced revision rate compared to anterior surgery.[3] The posterior approach also eliminates the risk of swallowing dysfunction, recurrent laryngeal nerve injury, and vascular injury.[4]

Although the posterior approach results in consistent fusion results, clinical success is less consistent.[3] Patient recovery after revision using posterior cervical fusion (PCF) is typically more difficult and prolonged compared to anterior surgery. Extensive paraspinal muscle dissection leads to longer surgery time, more bleeding, lengthier hospital stay, and higher complication rate compared to anterior surgery.[5] Persistent pain has been reported in 48% of patients with revision PCF despite a solid arthrodesis.[4] Chronic myofascial pain from surgical dissection may be one factor causing chronic neck pain.

PCF using posterior cervical cages placed between the facet joints has been successfully used to treat patients with cervical radiculopathy secondary to spondylosis and stenosis.[6,7] The surgical technique is tissue sparing and minimally disruptive, minimizing collateral

ABBREVIATIONS: ACDF, anterior cervical discectomy and fusion; **CT,** computed tomography; **NDI,** Neck Disability Index; **PCF,** posterior cervical fusion; **VAS,** visual analog scale

tissue damage associated with other posterior surgical approaches. However, its effectiveness as a revision strategy for pseudarthrosis after anterior cervical discectomy and fusion (ACDF) has not been explored. The objective of this retrospective study is to assess the effectiveness of bilateral posterior cages as a revision strategy for pseudarthrosis after ACDF.

METHODS

A retrospective study was undertaken at 4 centers in the US. The study was deemed exempt from Investigational Review Board (IRB) review under 45CFR46.101 by an independent central IRB (Ethical and Independent Review Services, Corte Madera, California). The central IRB approved that no informed consent was necessary due to the nature of the study being a retrospective chart review with minimal risk to patient safety. Patients with pseudarthrosis after ACDF who were subsequently treated with posterior revision surgery using posterior cervical cages placed between the facet joints were identified. Those with documented patient-reported outcomes at the time of revision surgery and at minimum 1 yr follow-up were included in the study.

Patient medical records were reviewed for demographics, presenting symptoms, comorbidities, clinical risk factors, perioperative metrics, and clinical outcomes. Presenting symptoms included neck pain, radiculopathy, or myelopathy. Potential clinical risk factors for nonunion, as well as perioperative metrics from both index and revision surgery were also collected. Information on index anterior fusion included number of levels fused, fixation hardware used, type of graft, and the level and number of levels not healed. Involvement in workman's compensation or litigation was also recorded.

Duration of revision surgery was from start to end of general anesthesia. Hospital stay was defined from end of surgery to hospital discharge. Blood loss was obtained from anesthesia and operative reports. Surgical complications occurring within 30 d of surgery were noted.

Clinical outcome measures were neurological status, Neck Disability Index (NDI), and visual analog scale (VAS) neck and arm scores. Scores were obtained preoperatively and at a mean of 18 mo postoperatively. Data were assessed for normality using the Shapiro-Wilk test; data were then compared using paired *t*-tests or the Wilcoxon Rank-Sum test. A level of alpha = 0.05 was considered significant. Bias was controlled by review of consecutive cases.

Dynamic x-rays (100%) and computed tomography (CT) scans (68%) were obtained as part of the treating surgeon's standard practice for revision of pseudarthrosis at 1 yr. Films were independently reviewed by both a blinded board-certified musculoskeletal radiologist and an independent spine surgeon who was not the treating physician. Pseudarthrosis was defined using accepted criteria of absence of bridging trabecular bone, or lucency at the intervertebral space (Figures 1 and 2) on CT scan and/or greater than 2 mm of motion between the spinous processes on flexion-extension lateral radiographs.[8,9] Conversely, successful revision arthrodesis was defined as bridging bone through the ventral intervertebral space or posteriorly through the facet or overlying lateral mass and less than 2 mm interspinous movement on dynamic x-rays.

PCF Surgical Technique

This technique has been described previously and is summarized below.[7,10-12] After anesthesia, the patient is positioned prone with the face supported in a donut. Biplanar fluoroscopy was positioned over the neck and adjusted to obtain satisfactory anteroposterior and lateral views. Fluoroscopy was used throughout the procedure to guide instruments. An off-midline incision was made 2 to 3 levels below the target level and carried through the subcutaneous tissue and ligamentum nuchae.

Paraspinal muscles and fascia were dissected off-midline and displaced laterally. An access chisel was inserted through the incision into the target facet and advanced until it abutted the pedicle of the rostral vertebra. A trephine decorticator was then advanced over the chisel to dissect soft tissue off of the lateral lamina and lateral mass and decorticate bone. Decortication was performed using fluoroscopic guidance and direct visualization as needed by removing the access chisel and looking through the hollow trephine decorticator at the lateral mass bone. A guide tube was then placed over the access chisel to maintain facet distraction, provide visualization, and serve as a working channel. The access chisel was then removed and rasps and burrs are inserted through the guide tube to decorticate the facet articular surfaces.

A cervical cage (DTRAX Cervical Cage, Providence Medical Technology, Inc., Walnut Creek, California) was packed with bone graft and inserted through the guide tube into the facet. In patients treated with circumferential surgery, morselized bone was harvested from the vertebral body. Bone graft was then inserted through the guide tube over the lateral mass decortication bed. Instruments were withdrawn, paraspinal muscles and subcutaneous tissues were sequentially closed with sutures, and a sterile dressing was applied. The procedure was then repeated on the contralateral side. Patients were fitted with and instructed to wear a soft collar for 6 wk.

RESULTS

The medical charts of 25 patients were available for review. Median age at the time of index surgery (ACDF) was 56 yr (36-75 range) and 12 (48%) were female (Table 1). Median time to revision surgery was 27 mo (2-230 range) with 2 outliers (2, 230 mo). Mean time of follow-up from revision surgery was 18 mo (range 13-45). All patients presented with neck pain, 32% also had radicular symptoms, and 8% presented with cord symptoms. The number of patients treated for nonunion was as follows: single level (9, 36%), 2-level (6, 24%), 3-level (8, 32%), 4-level (2, 8%; Table 1). Graft material used for PCF was demineralized bone matrix allograft in 10 patients, autograft in 9 patients, and a mix of autograft and allograft in 6 (Table 2). Nine of the 25 revision surgeries required an anterior approach in conjunction with PCF due to kyphosis or ventral neurological compression which could not be adequately treated with PCF solely. Of those 9 patients, cage and plate with local bone were used in 4 patients and structural allograft with plate was used in 5 patients (Table 2). Perioperative metrics for revision surgery were favorable with a hospital stay of 1.4 d, mean operative time of 104 min and estimated blood loss of 88 cc (Table 3).

Patient-reported outcome scores were available for 25 (100%) of the 25 patients at preop and last follow-up with mean of 18 mo. VAS neck scores improved significantly from a mean (SD) baseline score of 7.9 ± 1.5 to 3.8 ± 2.3 at the last follow-up ($P < .01$; Table 4). VAS arm scores improved significantly in a similar fashion decreasing from 7.24 ± 2.2 at baseline to 3.12 ± 2.5 at the

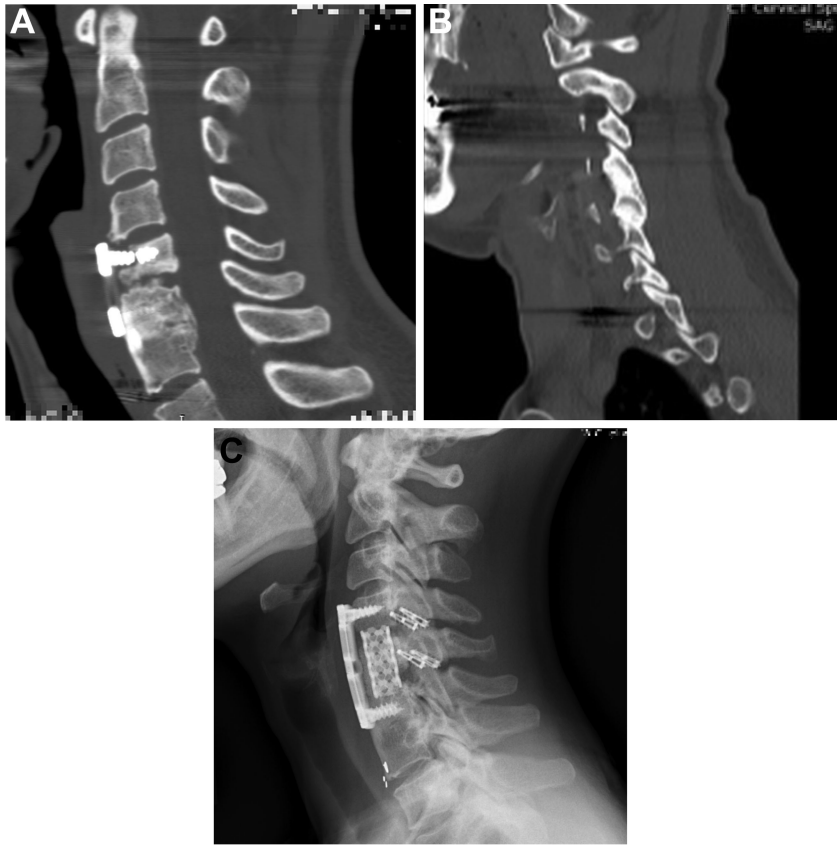

FIGURE 1. *Pre- and postop radiology of a patient with pseudarthrosis at C5-6.* **A**, *Sagittal CT scan indicating screw fracture and nonunion at C5-6 with kyphosis.* **B**, *Sagittal CT scan indicates intervertebral cage at C4-5 and C5-6 with fusion.* **C**, *Lateral cervical spine x-ray indicating successful circumferential fusion.*

last follow up ($P < .01$). Condition-related disability as measured via NDI improved significantly; scores dropped from 65.1 ± 20.3 at baseline to 29.1 ± 17.9 at 18 mo ($P < .01$). VAS neck and arm scores and NDI improved in 80%, 72%, and 80% of patients, respectively, based on a minimum clinically important difference criteria for VAS of at least 3-point improvement and for NDI of at least a 7.5% improvement.[13]

CT scans and lateral flexion and extension x-rays obtained at 1-yr post revision surgery were available for 17 patients; arthrodesis was determined in all 17 patients (100%). Only lateral flexion and extension x-rays were available for 8 patients. Less than 2 mm interspinous movement was observed for 8 (100%) patients, confirming fusion. Of the 16 patients treated with PCF alone, 15 (94%) had fusion of a previous ACDF pseudarthrosis.

Adverse Events

One patient with preoperative radicular symptoms had persistent radicular pain after revision surgery. This patient was subsequently treated 14 mo postrevision with multilevel foraminotomy. Fusion was solid and there was no cage-related complication. There was no clinical improvement after foraminotomy. One patient in this series treated with circumferential surgery for symptomatic spinal cord compression, and pseudarthrosis had a recurrent laryngeal nerve palsy postop; the nerve palsy was not related to PCF. Vocal cord paralysis was successfully treated with a laryngoplasty. One patient experienced a stitch abscess at the posterior cervical wound and was treated with oral antibiotics without sequelae. One patient with multiple medical issues expired at 14 mo postoperatively due to sepsis unrelated to cervical spine surgery. Prior to expiring, the patient was doing well at 1 yr with solid fusion on dynamic x-rays.

DISCUSSION

Pseudarthrosis after ACF associated with poor clinical outcomes can be revised using either an anterior or posterior

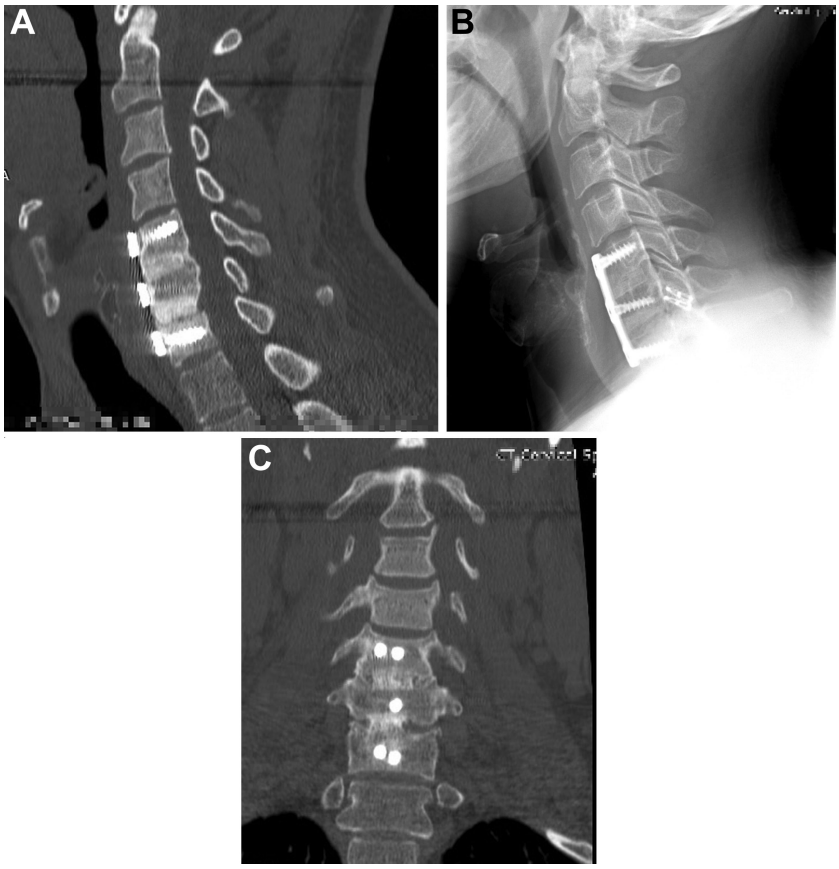

FIGURE 2. *Pre- and postop radiology of a patient with pseudarthrosis at C6-7.* **A**, *Sagittal CT scan indicating a lucency at the bone graft C7 vertebral body interface consistent with nonunion.* **B**, *Lateral cervical spine x-ray with intervertebral cages placed bilaterally at C6-7 facet.* **C**, *Coronal CT scan showing successful fusion at C6-7 after posterior intervertebral cage placement in facets at C6-7.*

approach. PCF has higher healing rates and reduced revision rate compared to anterior surgery.[5] A meta-analysis by McAnany et al[3] of 16 retrospective studies of 497 patients with mean follow-up of 40.6 mo found a higher fusion rate for posterior surgery at 97.1% compared to 86.4% for anterior surgery. Studies included a variety of fixation implants.

All 25 patients in the current study had solid arthrodesis at 1 yr. This is consistent with high healing rates with PCF reported by others using a wide variety of fixation implants including screws, rods, plates, wires, and clamps.[3] Posterior cervical cages to treat pseudarthrosis after ACDF have not been previously reported. Kasliwal et al[14] treated 19 patients with symptomatic cervical pseudarthrosis after ACDF with 1 to 4 mm interfacet bone grafts and reported good results. His study validates the concept of using structural bone allograft under compression to achieve solid arthrodesis. It also shows that there was no negative impact on overall or segmental lordosis. However, it is substantially different from this series, as Kasliwal et al[14] used a standard open surgical approach with supplemental lateral mass fixation. In the current study, an intervertebral cage with teeth locks the facet without the need for supplemental lateral mass fixation and associated soft tissue dissection. Voronov et al[15,16] reported that posterior cages limit cervical segmental motion comparable to a single-level plated ACDF and lateral mass screw and rod construct in cadaveric spine specimens. By the current authors' calculation, supplementation of a single- or 2-level ACDF with posterior cervical cages provides a 6-fold increase in stability compared to ACDF alone.

One limitation of this study is that CT scans are the gold standard for diagnosis of arthrodesis and only 68% of patients had a CT scan at 1 yr. CT scans were not routinely ordered by surgeons participating in this study if the patient was clinically doing

TABLE 1. Baseline Demographics of patients With Pseudarthrosis After ACDF

Characteristics	All patients (25)
Sex	12 female (48%)
Median age at index surgery	56 (36-75 range)
Pseudarthrosis symptom:	
Neck pain	25 (100%)
Radicular symptoms	8 (32%)
Cord symptoms	2 (8%)
Kyphosis	5 (20%)
Worker's compensation	5 (20%)
Time to revision from index ACDF, months, median (range)	27 (2-230)
Anterior cervical plate	25 (100%)
Hardware failure	4 (16%)
Index surgery:	
1 level	9 (36%)
2 level	6 (24%)
3 level	8 (32%)
4 level	2 (8%)
Bone graft:	
Structural allograft	25 (100%)
Iliac crest graft	0 (0%)
Nonunion level:	
C3-4	1 (4%)
C4-5	8 (32%)
C5-6	11 (44%)
C6-7	10 (40%)
C7-T1	2 (8%)
Postop infection (esophageal injury)	1 (4%)
Trauma after index surgery	5 (20%)
Tobacco use	4 (16%)

TABLE 2. Operative Graft Information for Posterior and Circumferential Fusion for Pseudarthrosis

Operative bone graft characteristics for revisions	Patients (25 total)
PCF revisions (25 patients):	
Autograft	9 (36%)
Allograft demineralized bone matrix	10 (40%)
Autograft and allograft	6 (24%)
PCF revisions including anterior fusion construct (9 patients):	
Vertebrectomy with local bone, cage, and plate	4 (16%)
Structural allograft with plate	5 (20%)

well and dynamic x-rays indicated fusion. Another limitation of the study is the potential for metal artifact obscuring intrafacet arthrodesis on CT imaging. In all cases though, bridging bone was observed through the lateral mass sufficiently posterior to the cage such that metal artifact was not a factor. Nine out of 25 patients had combined anterior fusion. This heterogeneous treatment potentially confounds the impact of posterior cages on bony healing.

Sixteen of 25 patients with ACDF pseudarthrosis were treated by PCF revision only. Interestingly, PCF alone resulted in fusion of a previous ACDF pseudarthrosis in 15 of 16 patients (94%). Elder et al[17] first described this same finding in a retrospective series of 22 patients treated with PCF. Twenty-one (91%) fused a previous anterior pseudarthrosis. How a fibrous nonunion through the disc space converts to successful bridging bone with only PCF is unclear and deserves further study.

Anterior approach in conjunction with PCF was performed in 5 patients to address kyphosis from intervertebral bone graft collapse. Independent reports indicate that posterior cervical cages result in minimal to nil effect on segmental kyphosis and overall cervical lordosis is unchanged.[7,18] Still, authors preferred an anterior reconstruction to optimize spinal alignment in those patients with kyphosis or questionable sagittal alignment because posterior cervical cages have the potential to cause or exacerbate kyphosis. One shortcoming of this study is that spinal alignment was not specifically assessed by the reading radiologists. McCormack et al[7] evaluated the impact of posterior cervical cages at 1 level and did not observe a loss of global or segmental lordosis. The anterior approach was used in 4 other patients for ventral cord compression. Posterior cervical cages expand the neural foramen and can resolve radicular symptoms, but authors believe that symptomatic ventral cord compression is best addressed anteriorly.[19,20]

Variable clinical outcomes have been reported despite more predictable fusion rates with PCF. Siambanes and Miz[21] reported on 14 patients treated with posterior wiring and fusion for anterior pseudoarthrosis. Clinical outcome was available in 9 with a mean follow-up of 3.5 yr. Poor clinical result was reported in 78% of patients despite all patients having achieved solid arthrodesis. Kuhn et al[4] published a retrospective review of 33 patients treated with PCF for anterior pseudoarthrosis. Despite solid arthrodesis, mild discomfort was reported in 20% and moderate to severe discomfort in 28%. McAnany et al[3] reported better fusion rates with posterior revision compared to anterior approaches, but clinical results were similar.

Less than optimal outcomes after posterior revision may be due to several factors that include poor patient selection, lack of clarity of the source of pain, and chronic myofascial pain. Acute perioperative morbidity and long-term myofascial issues could be minimized by using the tissue sparing, posterior approach reported herein.

The morbidity of posterior fusion can be measured by length of hospital stay, blood loss, readmission rates, and complications. Blood loss is typically estimated and may be somewhat subjective; length of hospitalization, readmission, and complications are more objective measures of perioperative morbidity. The majority of the published literature on pseudarthrosis after ACDF is comprised of small, retrospective case series. We were

TABLE 3. Comparison of Mean Length of Surgery, Blood Loss, and Hospital Stay in Current study to Published Results

Cohort	Number of patients	Operative time (min), mean(range)	Estimated blood loss (cc), mean (range)	Hospital stay (days)	Adverse events
Current study	25	103.5 (28-282)	87.8 (5-200)	1.4 (0.8-3.4)	2 (8%)[a]
Carreon et al (2006)[5]	93	138.9 (35-356)	282.1 (70-1300)	4.4 (3-8)	7 (8%)[b]
Elder et al (2016)[15]	22	N/A	388 (50-1200)	4 (1-8)	3 (14%)[c]

[a]1 stitch abscess, 1 recurrent laryngeal nerve palsy.
[b]4 wound infections, 3 graft site infections.
[c]1 wound infection, 1 pneumonia, 1 transient C5 nerve root palsy.

TABLE 4. Pain and Disability Clinical Outcomes

Outcome measures	Baseline (n = 25) mean ± SD	Mean 18 mo follow-up (n = 25) Mean ± SD
VAS neck	7.9 ± 1.5	3.8 ± 2.3
VAS arm	7.24 ± 2.2	3.12 ± 2.5
NDI	65.1 ± 20.3	29.1 ± 17.9

able to identify 2 studies that reported length of hospitalization and blood loss (Table 3). The hospital stay for the current case series was 1.4 d, which compares favorably to the 4 d reported by Elder et al[13] and Carreon et al,[5] in which traditional posterior approaches with lateral mass fixation and interspinous wiring was used. Similarly, blood loss in the current study was nearly one-third of that reported by both Elder et al[13] and Carreon et al.[5] Complications in this study were 2% compared to 7% and 3% for Carreon et al[5] and Elder et al,[13] respectively. There were 2 surgical-related complications in the current study: a stitch abscess and recurrent laryngeal nerve palsy in a patient who required anterior approach for symptomatic ventral cord decompression not related to posterior approach.

A retrospective cohort study by Choy et al,[22] of 3401 patients following posterior fusion, found a 30-d readmission rate of 6.2%, of which postoperative infection accounted for 17.06% of readmissions. While the Choy et al[22] study included treatment of a wide spectrum of disorders and not specifically pseudarthrosis after ACDF, readmission rate indicates the perioperative morbidity with standard posterior cervical approaches.

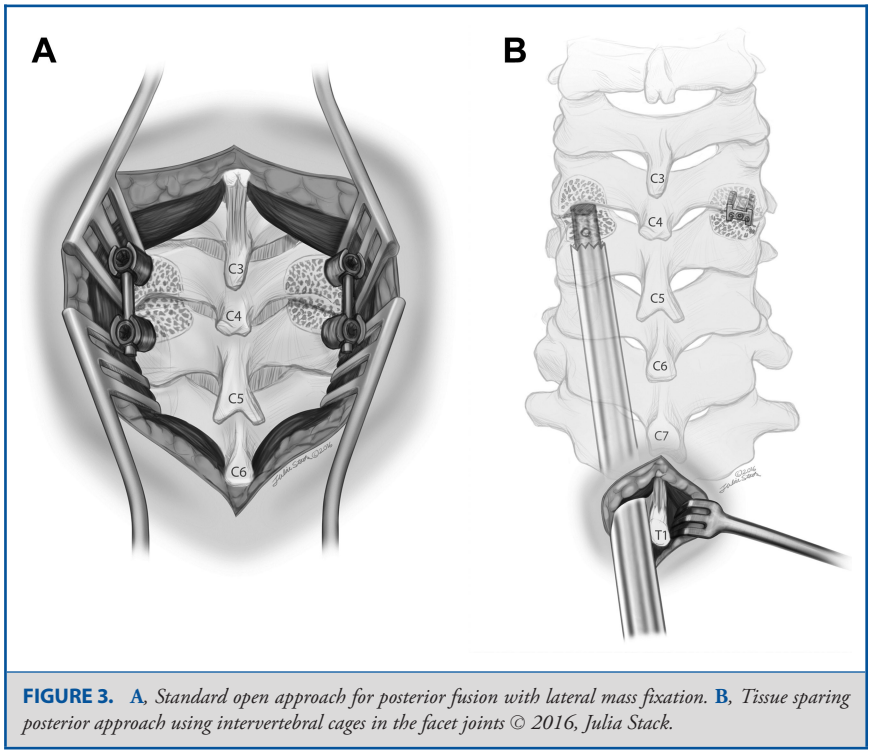

FIGURE 3. A, *Standard open approach for posterior fusion with lateral mass fixation.* B, *Tissue sparing posterior approach using intervertebral cages in the facet joints © 2016, Julia Stack.*

Tissue sparing PCF technique with posterior cervical cages placed bilaterally in the facets results in less soft tissue dissection than standard posterior fusion techniques. A small incision is used to insert an elongated access chisel into the appropriate facet, which confined by facet anatomy, serves as a post extending out through a minimal access skin incision. The surgeon uses the post to apply rotatory decorticators to the medial lamina and rostral and caudal lateral mass. A guide tube inserted after the chisel facilitates rasping of the facet cartilaginous endplates, a task difficult with traditional standard open posterior fusion techniques. Most soft tissue dissection of the medial lamina and spinous process required with lateral mass fixation or interspinous wiring is avoided (Figure 3). If a laminectomy is required, posterior cervical cages can be placed bilaterally into the facets with open surgery, but a laminectomy was not required in this patient series.

Patient-reported outcomes using VAS neck, arm and NDI improved significantly compared to baseline. This lends support for the use of posterior fusion with bilateral posterior cages as a treatment option to relieve symptoms and restore function in select patients with failed ACDF. However, the current case series is small and retrospective. There were no nonoperative controls, an important point because many patients with symptomatic pseudarthrosis become painless and asymptomatic over time. A larger multicenter trial is needed to best define fusion and clinical outcome after revision PCF with posterior cervical cages for pseudarthrosis after ACDF.

CONCLUSION

Revision surgery for pseudarthrosis using bilateral posterior cervical cage in select cases results in positive clinical outcomes and high fusion rates. Perioperative morbidity is reduced compared to standard posterior fusion techniques with interspinous wires and lateral mass screws.

Disclosures

Dr Smith is a Scientific Advisory Board member for Providence Medical Technology, Inc. Dr Gillespy is a teaching consultant for Providence. Dr McCormack has a financial interest in Providence. The other authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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Disclaimer

Some uses of the device described in this publication have not been approved or cleared by the FDA. Dr Smith is a Scientific Advisory Board member for Providence Medical Technology, Inc. Dr Gillespy is a teaching consultant for Providence. Dr McCormack has a financial interest in Providence.