North American Spine Society Journal (NASSJ) 14 (2023) 100223

Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Clinical Studies

# Comparison of revision surgery for pseudarthrosis with or without adjacent segment disease after anterior cervical discectomy and fusion

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ARTICLE INFO

*Keywords:*
Pseudarthrosis
Revision
Cervical
Adjacent segment disease
Posterior cervical decompression and fusion
Patient reported outcomes

ABSTRACT

*Background:* Patients with a pseudarthrosis after anterior cervical discectomy and fusion (ACDF) may have concurrent adjacent segment disease (ASD). Although prior studies have shown posterior cervical decompression and fusion (PCDF) is effective in repairing pseudarthrosis, improvement in patient reported outcomes (PROs) has been marginal. The aim of this study is to evaluate the effectiveness of PCDF in achieving symptom relief in patients with pseudarthrosis after ACDF and whether that is altered by the additional treatment of ASD.

*Methods:* Thirty-two patients with pseudarthrosis were compared with 31 patients with pseudarthrosis and concurrent ASD after ACDF who underwent revision PCDF with a minimum 1-year follow-up. Primary outcomes measures included the neck disability index (NDI), and numerical rating scale (NRS) scores for neck and arm pain. Secondary measures included estimated blood loss (EBL), operating room (OR) time, and length of stay.

FDA device/drug status: Not applicable.

Author disclosures: ***GOS:*** Research Support (Investigator Salary, Staff/Materials): Pfizer (D, Paid directly to institution/employer), TSRH (B, Paid directly to institution/employer), Alan L. & Jacqueline B. Stuart Spine Research (C, Paid directly to institution/employer), Cerapedics (D, Paid directly to institution/employer), Scoliosis Research Society (G, Paid directly to institution/employer), Medtronic (E, Paid directly to institution/employer). ***SDG:*** Royalties: Medtronic (E); Consulting: Medtronic (F), K2M/Stryker (D); Scientific Advisory Board/Other Office: AmericanSpine Registry (none); Research Support (Investigator Salary, Staff/Materials): Pfizer (D, Paid directly to institution/employer), TSRH (B, Paid directly to institution/employer), Alan L. & Jacqueline B. Stuart Spine Research (C, Paid directly to institution/employer), Cerapedics (D, Paid directly to institution/employer), Scoliosis Research Society (E, Paid directly to institution/employer), Medtronic (E, Paid directly to institution/employer). ***MT:*** Research Support (Investigator Salary, Staff/Materials): Pfizer (D, Paid directly to institution/employer), TSRH (B, Paid directly to institution/employer), Alan L. & Jacqueline B. Stuart Spine Research (C, Paid directly to institution/employer), Cerapedics (D, Paid directly to institution/employer), Scoliosis Research Society (E, Paid directly to institution/employer), Medtronic (E, Paid directly to institution/employer). ***JRD II:*** Consulting: Stryker, DePuy, Medtronic (D); Speaking and/or Teaching Arrangements: Stryker, DePuy, Medtronic (D); Research Support (Investigator Salary, Staff/Materials): Pfizer (D, Paid directly to institution/employer), TSRH (B, Paid directly to institution/employer), Alan L. & Jacqueline B. Stuart Spine Research (C, Paid directly to institution/employer), Cerapedics (D, Paid directly to institution/employer), Scoliosis Research Society (E, Paid directly to institution/employer), Medtronic (E, Paid directly to institution/employer). ***CHC III:*** Royalties: Alphatec (D); Consulting: Medtronic (D), Nuvasive (D); Research Support (Investigator Salary, Staff/Materials): Pfizer (D, Paid directly to institution/employer), TSRH (B, Paid directly to institution/employer), Alan L. & Jacqueline B. Stuart Spine Research (C, Paid directly to institution/employer), Cerapedics (D, Paid directly to institution/employer), Scoliosis Research Society (E, Paid directly to institution/employer), Medtronic (D, Paid directly to institution/employer). ***LYC:*** Consulting: National Spine Health Foundation (C), Orthopaedic Research Foundation (B); Scientific Advisory Board/Other Office: University of Louisville Institutional Review Board (NonFinancial), The Spine Journal (NonFinancial), Spine (NonFinancial), Spine Deformity (NonFinancial), American Spine Registry (NonFinancial); Research Support (Investigator Salary, Staff/Materials): Pfizer (D, Paid directly to institution/employer), TSRH (B, Paid directly to institution/employer), Alan L. & Jacqueline B. Stuart Spine Research (C, Paid directly to institution/employer), Cerapedics (D, Paid directly to institution/employer), Scoliosis Research Society (E, Paid directly to institution/employer), Medtronic (D, Paid directly to institution/employer), SDU Faculty Scholarship (E, Paid directly to institution/employer), Johnson & Johnson (E, Paid directly to institution/employer), Cerapedics (F, Paid directly to institution/employer), IRSs Kursus - og rejsepulje (B, Paid directly to institution/employer), TrygFonden (F, Paid directly to institution/employer), Region Syddanmark PhD puljen (E, Paid directly to institution/employer), SLB Forskningsrad (E, Paid directly to institution/employer), Sygeforsikring Donation (F, Paid directly to institution/employer), Sundhedsstyrelsen (F, Paid directly to institution/employer), SLB Forskningsrad Projektstotte (C, Paid directly to institution/employer).

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https://doi.org/10.1016/j.xnsj.2023.100223
Received 4 January 2023; Received in revised form 17 April 2023; Accepted 18 April 2023
Available online 25 April 2023

*Results:* Demographics between cohorts were similar, however there was a significantly higher mean body mass index (BMI) in the group with concurrent ASD (32.23 vs. 27.76, p=.007). Patients with concurrent ASD had more levels fused during PCDF (3.7 vs. 1.9, p<.001), greater EBL (165 cc vs. 106 cc, p=.054), and longer OR time (256 minutes vs. 202 minutes, p<.000). Preoperative PROs for NDI (56.7 vs. 56.5, p=.954), NRS arm pain (5.9 vs. 5.7, p=.758), and NRS neck pain (6.6 vs. 6.8, p=.726) were similar in both cohorts. At 12 months patients with concurrent ASD experienced a slightly greater, but not statistically significant, improvement in PROs (Δ NDI 4.40 vs. -1.44, Δ NRS neck pain 1.17 vs. 0.42, Δ NRS arm pain 1.28 vs. 0.10, p=.107).
*Conclusions:* PCDF is a standard procedure for treatment of pseudarthrosis following ACDF, however improvements in PROs are marginal. Slightly greater improvements were seen in patients whose indication for surgery also included concurrent ASD, rather than a diagnosis of pseudarthrosis alone.

## Introduction

Anterior cervical discectomy and fusion (ACDF) is widely regarded as one of the most effective procedures in spinal surgery [1–4]. Fusion rates are generally high [2,3,5], and even patients with fibrous union may be relatively asymptomatic [6]. Although pseudarthrosis is reported to occur in less than 3% of cases, this still represents a substantial number of patients considering 130,000 ACDFs are performed in the United States each year [4,7].

In 2015, Guppy et al. [8] reported that patients with symptomatic pseudarthroses following ACDF were revised at rates of 0.2%, 2.9%, and 6.5% for 1-level, 2-level, and 3-level ACDFs, respectively [8]. Crawford et al. [6] reported a revision surgery rate of 21% for patients with radiographic pseudarthrosis. While the choice of revision approach is dependent on surgeon preference, posterior cervical decompression and fusion (PCDF) is commonly selected due to its more favorable risk profile [9] and superior rates of fusion [2,3,5,10] to revision ACDF. However, neither the anterior nor the posterior approach has demonstrated superiority regarding improvement in patient reported outcomes (PROs) [3,9,11]. The current literature contains a paucity of data reporting clinical outcomes [9].

For most operative procedures performed on the spine we expect a substantial degree of improvement across PROs. Prior literature on single-level ACDF has reported average rates of improvement of 33.3 in neck disability index (NDI), 4.7 in Visual Analog Scale (VAS) neck pain, and 5.1 in VAS arm pain scores at 4 years [1]. Additionally, the majority of patients on average achieve minimally clinically important differences (MCID) in NDI, VAS neck pain, and VAS arm pain, respectively [12]. However, for revision of pseudarthrosis after ACDF, reported improvement in PROs has been marginal [3,9].

Adjacent segment disease (ASD), defined as new myelopathic or radicular symptoms accompanied by imaging evidence of additional degenerative changes at adjacent levels [13], is another concern after ACDF. Patients with ASD are revised in 5% to 22% of cases [11]. ASD may also occur concurrently with pseudarthrosis, confounding the evaluation of these patients. In contrast to ASD alone, patients with pseudarthrosis and concurrent ASD account for a 2% revision rate after ACDF [14].

The purpose of this study is to evaluate patient reported outcomes after posterior revision for pseudarthrosis after ACDF, and to compare differences in PROs between patients revised with and without extension for concurrent adjacent segment disease.

## Methods

After receiving Institutional Review Board approval, patients who underwent revision PCDF for pseudarthrosis after an ACDF and had complete preoperative and minimum 1-year postoperative data from a single center were retrospectively identified. All cases had symptomatic nonunion identified on computed tomography scans or by >2 mm of motion on flexion-extension radiographs and had persistent neck and recurrent arm pain (Figs. 1 and 2).

Hospital charts and office records were reviewed to collect demographic data, smoking history, surgical data, status of fusion and revision surgeries, postoperative complications, and PROs including NDI (0–100) [15,16], and numeric rating scales (NRS, 0–10) for neck and arm pain [17]. Radiographic outcomes were reviewed using the Picture Archiving and Communication System (PACS, McKesson, Irving, TX). Pseudarthrosis was confirmed during surgery through direct visualization of motion across the facet joints. Patients were stratified into 2 cohorts, patients with pseudarthrosis only and patients with pseudarthosis and concurrent ASD.

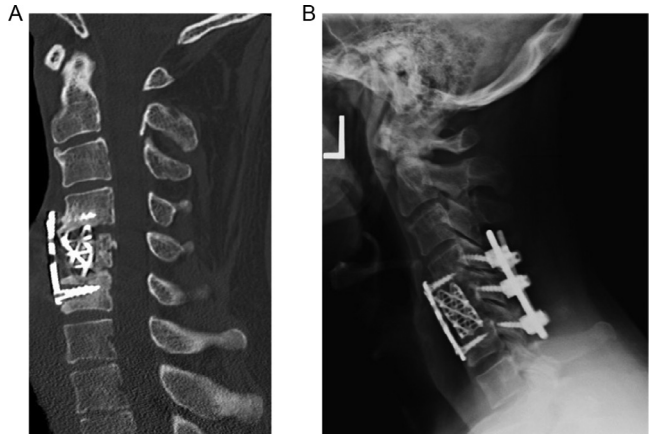


**Fig. 1.** (Left) Preoperative midsagittal CT reconstructions of a patient with a pseudarthrosis at C4-C6 after ACDF without evidence of ASD who underwent revision. (Right) One-year postoperative radiographs of the cervical spine showing posterior instrumentations.

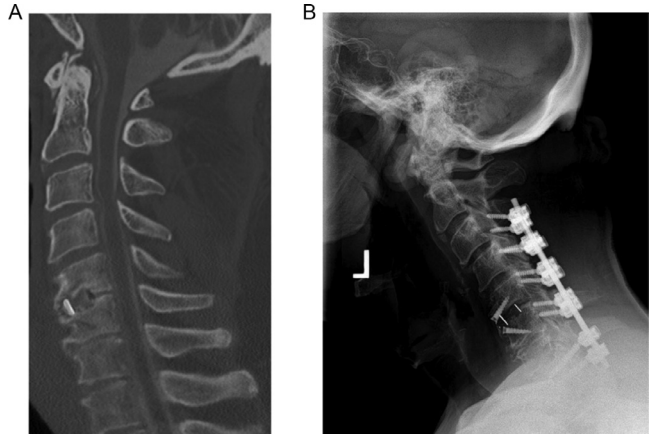


**Fig. 2.** (Left) Preoperative midsagittal CT reconstructions of a patient with pseudarthrosis at C5-C6 and concurrent multilevel adjacent segment disease who underwent revision PCDF with extension. (Right) One-year postoperative radiographs of the cervical spine showing posterior instrumentation.

**Table 1**
Summary of participant and PCDF procedural characteristics.

| N | Pseudarthrosis 32 | Pseudarthrosis+ASD 31 | p value |
|---|---|---|---|
| M:F, N | 9:23 | 11:20 | .457 |
| Age at surgery, years, Mean (SD) | 50.8 (11.2) | 55.1 (8.7) | .097 |
| Smokers, N (%) | 12 (37.5) | 12 (38.7) | .921 |
| BMI, kg/m$^2$, Mean (SD) | 27.8 (6.1) | 32.2 (6.6) | .007 |
| Index ACDF, Mean (SD) | | | |
| No. surgical levels | 1.69 (0.74) | 1.97 (0.84) | .164 |
| Revision PCDF, Mean (SD) | | | |
| No. surgical levels | 1.90 (0.82) | 3.74 (1.03) | .001 |
| ORT, min | 201.8 (35.1) | 255.9 (47.7) | .000 |
| EBL, cc | 106.0 (53.3) | 164.7 (149.0) | .054 |
| LOS, hours | 63.5 (53.4) | 69.6 (38.9) | .631 |

M:F, male:female; ACDF, anterior cervical discectomy and fusion; PCDF, posterior cervical decompression and fusion; EBL, estimated blood loss; ORT, operative time; LOS, hospital length of stay.

All statistical analyses were performed using IBM SPSS v28.0 (Armonk, New York). Differences between groups were analyzed using unpaired *t* tests for normally distributed continuous variables, Mann-Whitney *U* test for non-normally distributed continuous variables and Fisher exact test for categorical variables. Normality of the distribution was assessed using histograms and the Kolmogorov-Smirnov test. PROs were compared using repeated measures analysis of variance (ANCOVA) with baseline PROs as covariates. Binomial regression analyses were performed to evaluate subgroup differences. Statistical significance was defined as $p<.05$.

## Results

Of the 63 identified patients, 32 underwent revision PCDF for pseudarthrosis only and 31 underwent PCDF for pseudarthrosis with concurrent ASD (Table 1). There were 9 males and 23 females in the pseudarthrosis only group and 11 males and 20 females in the pseudarthrosis with ASD group with average ages of 50.8 and 55.1 years, respectively. The proportion of smokers in each group was similar, with 12 in each group. The average number of index ACDF surgical levels were 1.69 (SD 0.74) and 1.97 (SD 0.84) in the pseudarthrosis only and pseudarthrosis with ASD groups, respectively. Average BMI was significantly higher in the pseudarthrosis with ASD group (32.2±6.5) compared with the pseudarthrosis only group (27.7±6.1, p=.007).

The average PCDF operative time for the pseudarthrosis with ASD group was 255.9 minutes (SD 47.7), which was significantly longer than the pseudarthrosis only group (201.8±35.1 minutes, p=.000) (Table 1). Patients in the pseudarthrosis with ASD group also had significantly more levels fused than the pseudarthrosis only group (3.74±1.1 vs. 1.9±0.8 levels, p=.001). However, there was no difference in average estimated blood loss (164.7±149.0 vs. 106.0±53.3 cc) or hospital length of stay (69.6±38.9 vs. 63.5±53.4 hours).

Combined PROs for all patients showed NDI scores of 56.6 (SD 15.3) and 53.8 (SD 19.3), NRS neck pain scores of 6.7 (SD 1.9) and 5.6 (SD 2.2), and NRS arm pain scores of 5.8 (SD 2.4) and 4.6 (SD 2.9) at preoperative and 12 month timepoints, respectively. There was a significant improvement noted in NRS arm pain from preoperatively to 12 months postoperatively (p=.047). While NDI and NRS neck pain scores improved over time, these results were not statistically significant.

PROs comparing patients revised for pseudarthrosis with or without extension for ASD are shown in Table 2. Preoperative PROs were similar for NDI (56.7 vs. 56.5), NRS neck pain (6.61 vs. 6.78), and NRS arm pain scores (5.90 vs. 5.71) for pseudarthrosis with ASD and pseudarthrosis only groups, respectively. PROs were also similar at 12 months postoperatively for NDI (52.3 vs. 57.9), NRS neck pain (5.3 vs. 6.3), and NRS arm pain (4.5 vs. 5.4). Although there was a trend toward greater improvement in all PROs from preoperatively to 12 months postoperatively for patients with pseudarthrosis and ASD, these results did not achieve statistical significance (Δ NDI 4.40 vs. -1.44, Δ NRS neck pain 1.17 vs. 0.42, Δ NRS arm pain 1.28 vs. 0.10).

At 12 months, more patients with pseudarthrosis and ASD exceeded minimally clinically important differences (MCID) compared with patients with pseudarthrosis only for NDI (25.8% vs. 12.5%), NRS neck pain (29.0% vs. 12.5%), and NRS arm pain (25.8% vs. 18.6%) (Table 3). Additionally, fewer patients with pseudarthrosis and ASD reported worsening in PROs compared with patients with pseudarthrosis only (NDI: 35.5% vs. 56.3%, NRS neck pain: 19.4% vs. 31.3%, NRS arm pain: 25.8% vs. 28.1%) (Table 4). Subgroup analyses failed to identify

**Table 2**
Comparison of patient reported outcome measures by cohort.

| N | Pseudarthrosis 32 Mean (SD) | Pseudarthrosis+ASD 31 Mean (SD) | p value |
|---|---|---|---|
| NDI (0–100) | | | |
| Pre-op | 56.50 (16.79) | 56.73 (13.81) | .954 |
| Post-op 12 month | 57.94 (19.89) | 52.33 (18.99) | .257 |
| Δ Pre-op to 12 month Post-op | -1.44 (14.58) | 4.40 (18.66) | .173 |
| NRS neck pain (0–10) | | | |
| Pre-op | 6.78 (1.98) | 6.61 (1.82) | .726 |
| Post-op 12 month | 6.29 (2.24) | 5.34 (2.41) | .122 |
| Δ Pre-op to 12 month Post-op | 0.42 (1.88) | 1.17 (2.82) | .232 |
| NRS arm pain (0–10) | | | |
| Pre-op | 5.71 (2.76) | 5.90 (2.12) | .758 |
| Post-op 12 month | 5.39 (3.04) | 4.48 (3.00) | .251 |
| Δ Pre-op to 12 month Post-op | 0.10 (2.34) | 1.28 (3.10) | .107 |

NDI, neck disability index; NRS, numeric rating scale.

**Table 3**
Number of patients that exceeded minimally clinically important differences (MCID) for each patient reported outcome measure at 12 months.

| N | Pseudarthrosis<br>32<br>N (%) | Pseudarthrosis+ASD<br>31<br>N (%) | p value |
|---|---|---|---|
| NDI | 4 (12.50) | 8 (25.80) | .213 |
| NRS neck pain | 4 (12.50) | 9 (29.03) | .129 |
| NRS arm pain | 6 (18.75) | 8 (25.80) | .556 |

NDI, neck disability index; NRS, numeric rating scale.

**Table 4**
Number of patients whose score worsened for each patient reported outcome measure from preoperatively to postoperatively at 12 months.

| N | Pseudarthrosis<br>32<br>N (%) | Pseudarthrosis+ASD<br>31<br>N (%) | p value |
|---|---|---|---|
| Worse NDI | 18 (56.25) | 11 (35.48) | .098 |
| Worse NRS neck pain | 10 (31.25) | 6 (19.35) | .278 |
| Worse NRS arm pain | 9 (28.13) | 8 (25.81) | .898 |

NDI, neck disability index; NRS, numeric rating scale.

any differences between patients who did or did not clinically improve, and achieved or failed to achieve MCID for each respective PRO.

## Discussion

This is the first study evaluating the effectiveness of PCDF in improving clinical outcomes for patients with pseudoarthrosis after ACDF with or without accompanying ASD. The current study, even with a larger sample size than prior studies [3,9,11], found minimal improvements in NDI, NRS neck, and NRS arm pain scores 12 months after revision of pseudarthrosis. Patients revised for pseudarthrosis with ASD experienced slightly greater improvements in NDI, NRS neck pain, and NRS arm pain at 12 months compared with patients revised solely for pseudarthrosis, although these results were not statistically significant. In this patient population it is difficult to discern whether the etiology of their symptoms stems from pseudarthrosis, ASD, or a combination of both; therefore, they are often revised with extension of the fusion to address both pseudarthrosis and ASD [14].

The poor clinical outcomes observed in the current study are consistent with prior literature, which has shown that although revision PCDF achieves high rates of radiographic fusion [3,9,18], most patients experience minimal improvement in PROs [3,9,11]. In 2016, Kasliwal et al. [19] reported a nonsignificant improvement in NDI scores for patients posteriorly revised using interfacet spacers and lateral mass screws. Additionally, in 2020, Steinhaus et al. [9] reported significant improvements in NDI scores 6 months after revision PCDF, but not at 12 months.

Patient and intraoperative factors both fail to explain the poor clinical outcomes observed in this study. The only preoperative difference between groups was BMI, which was significantly higher in patients with pseudarthrosis with ASD. This result was expected, and concurs with studies by Basques et al. [20], who found significantly greater rates of cervical ASD in patients with BMI $\geq$30 kg/m$^2$, and Jawahar et al. [21], who reported the risk of developing ASD was not affected by age, sex, smoking status, or number of levels at index surgery. The only intraoperative differences between groups were number of operative levels and operative time, which were expectedly greater in patients with pseudarthrosis and ASD. Subgroup analysis also failed to explain these results, and while psychological or psychosocial variables may have played a role [6], the extent of patients who fared poorly is difficult to ascribe to these variables alone.

Given the results of the current study and similar results obtained by prior studies, one might reconsider revision ACDF despite lower rates of fusion and increased risk of injury to the esophagus, trachea, and neurovascular structures [3,5,10]. For patients revised solely for ASD after ACDF, Cao et al. [11] reported significantly greater improvement in NDI and VAS neck pain scores for patients who underwent revision ACDF compared with PDF. However, a 2015 study by McAnany et al. [3] found no differences in clinical improvement between patients revised anteriorly versus posteriorly for pseudarthrosis despite significantly higher rates of fusion success in the posterior group. They posited that residual anterior root compression may have counteracted the expected clinical gains from higher rates of fusion.

The present study is not without limitations. First, the study was a retrospective cohort analysis. Second, the small number of included patients and limited follow-up may affect the generalizability and long-term predictive power of this study. Third, we did not include a comparative group of patients revised via the anterior approach.

In general, over the past 15 years revision of cervical pseudarthrosis has been primarily accomplished through the posterior approach due to higher rates of achieved fusion [2,3,5,10], avoidance of scar tissue, and lower risk of injury to vital structures [5]. However, prior literature has failed to demonstrate significant clinical improvement [3,9], and no studies directly compare patients revised with to patients revised without extension for concurrent ASD. The results of our study show patients who undergo revision PCDF for pseudarthrosis experience minimal clinical benefit, and that patient revised with extension for ASD experience slightly greater, but not statistically significant, improvements in comparison. While it may difficult to refuse surgery to symptomatic patients with radiographic evidence of pseudarthrosis, further research is needed to determine whether the limited clinical benefits obtained from revision outweigh the costs and potential risks to patients.

## Declarations of competing interests

One or more of the authors declare financial or professional relationships on ICMJE-NASSJ disclosure forms.

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