Editorial Commentary | Surgery: Orthopedics

Cervical disc arthroplasty *vs.* anterior cervical discectomy and fusion—what are the outcomes?

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Keywords: Anterior cervical discectomy; fusion; cervical disc arthroplasty (CDA)

Received: 07 December 2023; Accepted: 18 March 2024; Published online: 17 May 2024.

doi: 10.21037/amj-23-242

View this article at: https://dx.doi.org/10.21037/amj-23-242

Introduction

Cervical spondylosis occurs throughout the population and can lead to compression of the spinal cord and exiting nerve roots, resulting in myelopathy, radiculopathy, or combination of the two pathologies. Cervical radiculopathy has a incidence of 80 per 100,000 people (1). Radicular symptoms consist of radiating pain or altered sensation in the dermatome of the affected nerve root as well as muscle weakness in the corresponding myotome of the affected nerve root.

Cervical myelopathy is less common with an incidence of 4 per 100,000 people (1). Myelopathy symptoms include a loss of hand dexterity and coordination, difficulty with balance, in addition to upper extremity motor weakness and sensory disturbances. These symptoms are thought to result from chronic ischemia as well as stretch-related injury to cervical spinal cord.

Diagnosis of cervical radiculopathy and myelopathy are based on history, exam, and imaging studies like upright plain radiographs and supine cross-sectional imaging like magnetic resonance imaging (MRI) or computed tomography (CT) myelogram that demonstrates nerve root or spinal cord compression. Initial treatment for cervical radiculopathy is typically nonoperative, as patients tend to have complete or near-complete resolution of their symptoms. Conversely, the natural history of cervical myelopathy is characterized by a step-wise decline in neurologic function over time and thus there is a limited role for nonoperative management in patients with moderate to severe symptoms.

Patients with anterior-based neural compression with myelopathy or radiculopathy who have failed appropriate nonoperative measures are candidates for anterior cervical surgical decompression. The gold-standard procedure for anterior decompression of disc-space level neural compression is anterior cervical discectomy and fusion (ACDF). However, cervical disc arthroplasty (CDA) is an emerging surgical option that can similarly decompress the neural elements while preserving motion at the instrumented spinal segment. Although both surgeries decompress the canal, there are differences in patient reported, clinical and radiologic outcome measures. Additionally, risks for both perioperative and long-term complications including pseudoarthrosis, reoperation rates, and adjacent segment disease (ASD) should be considered when choosing between these surgical options.

ACDF

First performed in the 1950s, ACDF has become the gold standard treatment for focal, disc-level, anterior-based cervical spine pathology causing radiculopathy or myelopathy. The procedure has excellent radiographic outcomes, improving lordosis with high fusion rates, as well as clinical outcomes. Significant improvement in clinical pain scores, including Neck Disability Index (NDI), Visual Analogue Scale (VAS) neck, VAS arm (2), and Japanese Orthopaedic Association

(JOA) (3) scores has been consistently demonstrated after ACDF in the treatment of myelopathy with improvement in modified JOA (mJOA) scores of up to 3.91 in severe cases (4). Additionally, mental function improvements, as measured by MCS-12 portion of the 12-item Short Form (SF-12) score, have been reported when ACDF was used to treat myelopathy (5).

However, the procedure is not without risk. In the immediate post-operative period, patients can experience dysphagia (32%), hoarseness (14%), C5 palsy (3.6%), wound dehiscence (3.6%), Horner's syndrome (3.6%), and, more rarely, catastrophic injury to the spinal cord and cerebrovasculature (2). Pseudarthrosis has been documented at rates of 4–10% for single level fusion (2,6). When three and four level fusions are attempted, the pseudarthrosis rate has been reported as high as 53% (7). The reoperation rate for ACDF is reported between 14–35% (2) within 2 years, primarily for symptomatic pseudoarthrosis. After a secondary operation to address pseudoarthrosis, a study by Kreitz *et al.* only demonstrated a 69% rate of radiologic fusion (8) on final follow-up. Finally, long-term negative outcomes include adjacent segment degeneration, with 21% of patients undergoing a secondary surgery at the adjacent level within 10 years (6).

CDA

CDA was first introduced in the 1960s as an alternative to ACDF to treat cervical spondylotic radiculopathy or myelopathy. The design philosophy of the CDA is to preserve motion at the instrumented segment, which may reduce the incidence of ASD. Two- and 15-year outcomes studies demonstrate improvement in VAS neck and arm scores, JOA, NDI, SF-12 MCS and SF-12 physical component score (PCS) (9). At 2-year follow-up, 66% of patients had excellent outcomes when treated at one or two levels in the setting of both radiculopathy and myleopathy (9), and in a series of 20 patients at 15-year follow-up, 80% of patients reported excellent outcomes (9) using Odom's criteria in the setting of myelopathy and radiculopathy. Mobility was also maintained with range of motion (ROM) of 9 degrees at the replaced segment (9).

By preserving motion across the instrumented segment, CDA is theorized to reduce stress and strain at adjacent levels thus decreasing rates of ASD. Rates of ASD vary by implant design with groups reporting anywhere from 14% to 64.7% (9,10) determined radiographically by the Kellgren or Miyazaki methods. ASD rates also increase with time, with one study showing 7.3% at mid-term follow-up and 36.0% at long-term follow-up (11). Several studies show a discrepancy in the rates of radiographic *vs.* symptomatic ASD, with a 32.8% incidence of radiographic ASD compared to a 6.3% incidence of symptomatic ASD (12). Despite the variable rates of radiographic and symptomatic ASD, the reoperation rates remain low at 2% (10).

Adjacent-segment ossification is relatively common with rates varying by implant design (10). Studies have suggested rates anywhere from 7.3–69.2%, with Price *et al.* showing a pooled average of 44.6% (13). Despite its high incidence, adjacent-segment ossification does not correspond with worse clinical outcomes (14). Other modes of failure include osteolysis of the vertebral body (50% incidence), typically occurring in the first post-operative year but does not usually necessitate revision surgery (13). Subsidence, vertebral body fractures, metallosis, immune reactions, and implant fractures are also possible but rare (13).

ACDF *vs.* CDA

Numerous head-to-head, prospective studies have compared outcomes between CDA and ACDF when used to treat cervical disk disease resulting in radiculopathy or myelopathy (15-17). Although some studies favor CDA, the cumulative perioperative and early post-operative complication rates are overall comparable. Both ACDF and CDA use the Smith-Robinson approach, which is associated with dysphagia, esophageal injury, recurrent laryngeal nerve palsy, Horner's syndrome, and vertebral artery injury. Dysphagia occurs more frequently with multilevel fusions and longer surgeries (18), but incidence rates appear to be similar between ACDF and CDA cohorts (16). Coric *et al.* (15) reported higher rates of overall clinical success in CDA at 2 years post-op with no significant differences in neurologic exam. Kelly *et al.* (17) found no differences when comparing operation time, blood loss, and duration of hospital stay, however reported statistically higher rates of readmission and re-operation with ACDF. Interestingly, Kelly *et al.* (17) also found higher rates of vertebral artery injury following CDA. However, although vertebral artery injury is a well-documented complication, overall rates were very low in ACDF and CDA: 0.05% *vs.* 0.27%, respectively. Kelly *et al.* concluded that despite these significant differences, ACDF and CDA were overall comparable interventions even in the early post-operative period, and suggested that other studies showing significant differences between the two might be due to bias or a learning curve

for the new CDA technique, and thus concluded no benefit for CDA *vs.* ACDF.

Comparable outcomes between treatment methods persist when assessing mid to long term outcomes. Differences in rates of reoperation, adverse events, and return to work diminish by 1 year post-operatively (15-17,19). No significant differences were found in the development of adjacent-segment ossification (20). Both surgical treatments resulted in significant improvement in terms of patient-reported outcomes (PRO) including the NDI, VAS, and 36-item short form (SF-36). However, CDA trended toward greater improvement in PRO when compared to ACDF, particularly in later follow-up periods (greater than 2 years) (20-22).

In addition to primary outcomes, recovery times and cost should be considered. In the early post-operative period, ACDF may allow earlier return to work due to the early mobility and lack of immobilization necessary for recovery from CDA (19). When considering cost, Qureshi *et al.* (23), found both methods to be cost-effective procedures. However, they concluded that arthroplasty would be a more cost-effective procedure with an implant survival greater than 14 years.

There are theoretical advantages to use of arthroplasty versus ACDF, however the clinical implications are still unclear. Arthroplasty was designed to preserve motion at the level of treatment. Arthroplasty maintains 9.3 degrees of neck flexion-extension and 4.8 degrees of lateral bending (22). This contrasts the less than 1 degree of motion in any plane with an anterior-based fusion. However, the decreased ROM may reduce microtrauma to the spinal cord and be advantageous in treatment of cervical myelopathy with associated cervical instability. Patients with facet arthrosis, severe spondylosis, or disc height loss greater than 50% may be contraindicated to cervical arthroplasty (24). Arthroplasty was found to cause less symptomatic evidence of adjacent segment degeneration (15,22). However, rates of future adjacent segment degeneration may not differ despite radiographic changes (25) (Table S1). Thus, the clinical significance of this finding continues to be studied.

Conclusions

ACDF remains the gold-standard for anterior-based treatment of disc-level pathology resulting in cervical radiculopathy and myelopathy, but CDA shows promising results in head-to-head studies in early- to mid-term follow-up. Patients with ACDF and CDA have similar PROs, but CDA may offer a more prompt return to work. Postoperative complication profiles and reoperation rates are comparable. ASD is a well-established long-term complication of ACDF, and further studies are needed to elucidate whether the early findings of decreased ASD and improved ROM with CDA persist at long-term follow-up.

Future consideration

While there is excellent data in the short-term follow-up (2–5 years) that show excellent results with either surgical approach for cervical disc pathology. However, there is yet to be an abundance of quality evidence reviewing long-term follow-up in regard to patient outcomes and need for secondary surgery as a result to each surgical approach. We believe this data is needed to further elucidate which treatment strategy is superior.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the editorial office, *AME Medical Journal* for the series "Degenerative Spine Disease". The article has undergone external peer review.

Peer Review File: Available at https://amj.amegroups.com/article/view/10.21037/amj-23-242/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://amj.amegroups.com/article/view/10.21037/amj-23-242/coif). The series "Degenerative Spine Disease" was commissioned by the editorial office without any funding or sponsorship. B.A.K. served as the unpaid Guest Editor of the series and serves as a Deputy Editor and editorial board for *Clinical Spine Surgery*. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/amj-23-242
Cite this article as: Torrez T, Dong W, Philippi M, Percin B, Connelly JW, Drain JP, Karamian BA. Cervical disc arthroplasty *vs.* anterior cervical discectomy and fusion—what are the outcomes? AME Med J 2024;9:39.

Supplementary

Table S1 Outline of the studies used: paper type, surgical approach, outcomes, number of patients and follow-up

Paper	Review type	Procedure	Outcome assessed	Number of patients	Follow-up
Charalampidis 2022	Retrospective	ACDF	NDI, VAS, dysphagia, hoarseness, revision	28	2 years
Wang 2016	Retrospective	ACDF	NDI, VAS, mJOA, radiographs	32	5 years
Lambrechts 2023	Retrospective	ACDF	NDI, VAS, SF-12, mJOA, readmisison, revision	374	2 years
Stull 2020	Retrospective	ACDF	NDI, VAS, SF-12	235	1 year
Butterman 2018	Prospective	ACDF	VAS, reoperation, ASD	159	10 years
Bolesta 2000	Prospective	ACDF	Radiographic, pain, neurologic recovery	15	Up to 6 years
Kreitz 2018	Retrospective	ACDF	Revision, neurologic recovery, radiographic	25	>1 year
Pointillart 2018	Prospective	CDA	Odom's, VAS, NDI, SF-12, radiographic	20	15 years
Wahood 2020	Meta analysis	CDA	HO, ASD, reoperation	5,785	<2 years
Hui 2021	Meta analysis	CDA	HO	1,674	1–15 years
Xia 2013	Meta analysis	All spine surgery	ASD	34,716	0.5–20 years
Price 2021	Editorial	CDA and ACDF	ASD, HO, osteolysis, fracture, subsidence	–	–
Hui 2020	Meta analysis	CDA	ASD, HO	3,223	1–5 years
Coric 2011	Prospecitve RCT	CDA and ACDF	NDI, VAS, reoperation	269	5 years
Loidolt 2021	Prospecitve RCT	CDA and ACDF	Adverse events, ASD, radiologic	463	10 years
Kelly 2018	Retrospective	CDA and ACDF	Reoperation, readmission	42,395	1–5 years
Anderson 2013	Review	CDA and ACDF	Dysphagia	–	–
Steinmetz 2008	Prospecitve RCT	CDA and ACDF	Return to work, NDI	1,004	2 years
Rožanković 2017	Prospecitve RCT	CDA and ACDF	NDI, VAS, neurologic status	105	>2 years
Riew 2008	Prospecitve RCT	CDA and ACDF	NDI, SF-36, neurologic status	199	2 years
Radcliff 2016	Prospecitve RCT	CDA and ACDF	NDI, SF-12, reoperation, adverse events	330	5 years
Qureshi 2013	Clinical article	CDA and ACDF	Cost analysis	–	–
Roberts 2018	Editorial	CDA	Pain, neurologic status, ASD	–	–
Verma 2013	Meta analysis	CDA and ACDF	ASD	1,586	2–5 years

ACDF, anterior cervical discectomy and fusion; NDI, Neck Disability Index; VAS, Visual Analogue Scale; mJOA, modified Japanese Orthopaedic Association; SF-12, 12-item short form; ASD, adjacent segment disease; CDA, cervical disc arthroplasty; HO, heterotopic ossification; SF-36, 36-item short form.

https://dx.doi.org/10.21037/amj-23-242