



Review Article

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Anterior Surgical Techniques for Cervical Spondylotic Myelopathy: WFNS Spine Committee Recommendations

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Objective: This study was performed to review the literature and to present the most up-to-date information and recommendations on the indications, complications, and success rate of anterior surgical techniques for cervical spondylotic myelopathy (CSM). The commonly performed anterior surgical procedures are multiple-level anterior cervical discectomy and fusion, anterior cervical corpectomy and fusion and its variants (skip corpectomy and hybrid surgery), and oblique corpectomy without fusion.

Methods: A comprehensive literature search and analysis were performed using MEDLINE (PubMed), the Cochrane Register of Controlled Trials, and the Web of Science for peer-reviewed articles published in English during the last 10 years.

Results: Corpectomy is mandated for ventral compression of fewer than 3 vertebral segments where single-level disc and osteophyte excision is inadequate to decompress the cord. Endoscopic or oblique partial corpectomy improves the sagittal canal diameter by 67% and obviates the need for an additional bone graft procedure.

Conclusion: The indications of anterior surgery in patients with CSM include a straightened or kyphotic spine with a compression level lower than 3. With an appropriate choice of implants and meticulous surgical technique, surgical complications can be seen only rarely. Improvements after anterior surgery for CSM have been reported in 70% to 80% of patients.

Keywords: Cervical spondylosis, Compressive myelopathy, Discectomy, Complications, Outcomes assessment

INTRODUCTION

This study was conducted by the World Federation of Neurosurgical Societies (WFNS) Spine Committee to review the literature, to determine and to recommend most up-to-date information on indications, complications, and success rate of ante-

rior surgical treatments for cervical spondylotic myelopathy (CSM).

Anterior surgeries for CSM offer decompression of the cervical cord by directly addressing the ventral compression of the cervical cord, which is invariably present in these patients. The anteriorly placed pathology consists of prolapsed discs, posteri-

Table 1. Studies on natural history of cervical spondylotic myelopathy (CSM)

Study	No. of patients	Diagnostic methods	Mean age (yr)	Mean duration of symptoms	Outcome
Clarke and Robinson, ¹ 1956	120	Myelography, surgery, autopsy	53	3 yr	<ul style="list-style-type: none"> • 75% Deteriorated in a stepwise fashion • 20% Slow, steady progression of the disease • 5% Developed rapid onset of symptoms and signs, then remained stable for years.
Lees and Turner, ² 1963	Group I (myelopathy): 44 Group II (nonmyelopathy): 51	Radiology, myelography	Group I: 40 Group II: 50	Group I: 5 yr Group II: 6–10 yr	<ul style="list-style-type: none"> • Group I: long periods without new or worsening symptoms. Exacerbations can occur at longer shorter intervals for many years. • Group II: 12 (66%) of 18 improved while wearing collar; 15 (60%) of 25 improved without wearing a collar during or after physiotherapy, osteopathy, manipulation; 3 of 5 improved without treatment; and 2 improved with rest only.
Nurick, ³ 1972	91 Conservative: 37 Laminectomy: 45 Fusion: 7 Combined: 2	Clinical (Nurick grade) and radiology	Conservative: 59 Laminectomy: 53 Fusion: 52	Conservative: 31 mo Laminectomy: 27.2 mo Fusion: 23.1 mo	<ul style="list-style-type: none"> • Both laminectomy and conservative groups had 27 cases in grade I or II at presentation. Eighteen conservative and 24 laminectomy patients remained in this group ($p > 0.05$). • Forty-three patients in grades 1, 2, or 3 aged less than 60 years, and 3 of these deteriorated. Of 32 patients aged 60 years or more 13 deteriorated.
Sadasivan et al., ⁴ 1993	22	Clinical (Nurick grade) X-rays and MRI	50.8	6.3 yr	<p>All cases deteriorated from grade II at presentation:</p> <p>Grade III - 1 Grade IV - 17 Grade V - 4</p>
Nakamura et al., ⁵ 1998	64	Clinical (JOA classification) and radiology	52	> 1 yr	<ul style="list-style-type: none"> • Upper extremity: Improved by > 1 grade in 31 (57%), unchanged in 25 (45%). • Lower extremity: Improved in 35 (57%), unchanged 24 (39%), worse 2 (3%). <p>Younger patients achieved no disability (grade IV) more frequently</p>
Wu et al., ⁶ 2013	14,140	Radiology	N/A	13,461 person year Operated: 4,684.71 Control: 13,461.44	<ul style="list-style-type: none"> • Cervical cord injury was approximately 1.5 times more likely to ensue in CSM patients who were managed without surgery than in those who underwent surgery to treat CSM.

MRI, magnetic resonance imaging; JOA, Japanese Orthopaedic Association; N/A, not available.

or osteophytes arising from the vertebral bodies and thickened or ossified posterior longitudinal ligament.

The commonly performed anterior surgeries are: multiple-level anterior cervical discectomy and fusion (ACDF); anterior cervical corpectomy and fusion (ACCF) and its variants - “skip corpectomy” and “hybrid surgery”; and oblique corpectomy without fusion. Skip corpectomy involves 2 level corpectomy for a 3 level CSM which leaves the intervening body intact. Hybrid surgery involves combining ACCF (1 to 3 levels) with an adjacent ACDF.

METHODS

A comprehensive literature search and analysis was performed with the search words “cervical spondylotic myelopathy,” “ossification of posterior longitudinal ligament,” and “anterior surgery” from MEDLINE (PubMed), Cochrane Register of Controlled Trials, and Web of Science for peer-reviewed articles published in English during the last 10 years. The relevant articles for the purpose of this review were selected by the authors based on 50 patients or more being included in the study and lack of heterogeneity in the pathology for which the anterior surgery was done. This review is not a systematic review or a meta-analysis but an overview of the available relevant literature.

NATURAL HISTORY AND INDICATION FOR TREATMENT

Most of the studies on the natural history of CSM have unequivocally demonstrated that it is a progressive disease with stepwise deterioration observed in most (75%) cases (Table 1).¹⁻⁶

Although the exact duration of conservative management has not been studied, Kadanka et al.⁷ in a randomized control trial to compare conservative and operative treatments of CSM, suggested that conservative management may be continued up to 3 years after diagnosis. In another prospective multicenter review, Sampath et al.⁸ compared 20 operated versus 23 conservatively managed patients with myelopathy with a mean duration of symptoms of 29.8 months and found that those operated had a significant improvement in functional status and overall pain and neurologic symptoms. Patients managed conservatively had a significant worsening of their ability to perform activities of daily living and worsening of neurologic symptoms. Yoshimatsu et al.⁹ concluded in a retrospective comparison that surgically treated patients (n = 32) fared better as compared to conservatively managed cases (n = 69) and 22 cases from the conservative group had to undergo surgical decompression after a mean duration of 32 months.

Table 2. Characteristics of the 9 studies included in the review of ACDF vs. ACCF for treatment of CSM¹⁰

Study	Design	Sample size	Mean age (yr)	Sex, male:female	Mean follow-up (mo)
Oh et al., ¹¹ 2009	RCT	ACCF: 17 ACDF: 14	ACCF: 55.12 ACDF: 52.64	16:15	ACCF: 27.33 ACDF: 24.9
Yu et al., ¹² 2007	RCT	ACCF: 20 ACDF: 20	ACCF: 53.1 ACDF: 52.75	ACCF: 14:6 ACDF: 15:5	N/A
Liu et al., ¹³ 2011	RCS	ACCF: 23 ACDF: 23	ACCF: 54.4 ACDF: 56.5	ACCF: 18:5 ACDF: 16:7	ACCF: 31 ACDF: 29
Park et al., ¹⁴ 2010	RCS	ACCF: 52 ACDF: 45	ACCF: 49.4 ACDF: 49.3	ACCF: 30:22 ACDF: 17:28	ACCF: 23.3 ACDF: 25.7
Wang et al., ¹⁵ 2001	RCS	ACCF: 20 ACDF: 32	ACCF: 51.5 ACDF: N/A	27:25	43.2
Burkhardt et al., ¹⁶ 2013	RCS	ACCF: 38 ACDF: 80	ACCF: 60.3 ACDF: 60.9	ACCF: 25:13 ACDF: 41:39	20.4
Yu et al., ¹⁷ 2012	RCS	ACCF: 48 ACDF: 62	ACCF: 59.3 ACDF: N/A	65:45	32
Jia et al., ¹⁸ 2012	RCS	ACCF: 36 ACDF: 31	ACCF: 48.83 ACDF: 49.12	ACCF: 21:15 ACDF: 17:14	ACCF: 28.96 ACDF: 26.81
Kim et al., ¹⁹ 2012	RCS	ACCF: 16 ACDF: 54	ACCF: 58 ACDF: 56.7	ACCF: 13:3 ACDF: 31:23	ACCF: 20 ACDF: 18.6

ACDF, anterior cervical discectomy and fusion; ACCF, anterior cervical corpectomy and fusion; CSM, cervical spondylotic myelopathy; RCT, randomized controlled trials; RCS, retrospective case series; N/A, not available.

Table 3. Summary of the conclusions of the review of ACCF vs ACDF in <3 level disease¹⁰

Characteristic	Difference	Trials included out of 9 studies
Hospital Stay	No significant difference	3
Bleeding	ACDF has significantly less bleeding than ACCF	4
Operating time	ACDF has significantly shorter time than ACCF	4
JOA score	No significant difference	3
Neck VAS/arm VAS	No significant difference	3
C2–7 Cobb angle	ACCF group had a significantly lower Cobb angle than ACDF	5
Cervical and Fusion ROM	No significant difference	2
Fused segment height	ACCF had significantly lower height than ACDF	5
Fusion rate	No significant difference	6
Graft collapse	ACDF had significantly lower rate than ACDF	2
Adjacent segment degeneration	No significant difference	3
Complications	No significant difference	8

ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical discectomy and fusion; JOA, Japanese Orthopaedic Association; VAS, visual analogue scale; ROM, range of motion.

Table 4. Review of the series on oblique partial corpectomies for treatment of cervical spondylotic myelopathy

Series	No. of Patients	Outcome	Incidence of Horner syndrome	Follow-up (mo)	Sagittal canal diameter
George et al., ²⁰ 1999	101	Improved: 67% Stable: 25% Deteriorated: 8%	57% Temporary, 9% Permanent	37	N/A
Bruneau et al., ²¹ 2007	> 400	Improved: 72% Stable: 28% Deteriorated: none	7% Temporary, 2% Permanent	N/A	N/A
Koç et al., ²² 2004	26	Myelopathy: 77% improvement Radiculopathy: 85% relieved	30.7% Temporary, 7.7% Permanent	12–24	N/A
Rocchi et al., ²³ 2005	48	Improved: 85% Stable: 10% Deteriorated: 4%	29.16% Temporary, 2% Permanent	24	N/A
Chacko et al., ²⁴ 2012	109	Improved: 73%	32.1% Temporary, 8.2% Permanent	30.52 ± 19.71	N/A
Kiris et al., ²⁵ 2007	40	Improved: 62.5% Stable: 25% Deteriorated: 12.5%	25% Temporary, 10% Permanent	59	Mean diameter increased from 5.8 to 13.9 mm
Chacko et al., ²⁶ 2014	153	Improved: 72.8% Stable: 24.4% Deteriorated: 3.2%	21.1% Temporary, 5.9% Permanent	36	N/A
Turel et al., ²⁷ 2013	28	Mean reduction in Nuricks score from 3.39 to 2.11	N/A	36	N/A
Chacko et al., ²⁸ 2007	3*	Improved in all 3	33.3% Temporary, none permanent	36	N/A
Chibbaro et al., ²⁹ 2009	268	Improved: 86.6% Stable: 8% Deteriorated: 5%	5.2% Temporary, 1.1% Permanent	96	Mean diameter increased by 6.5 mm from 9.7 mm (67%)
Salvatore et al., ³⁰ 2011	499	Recovery rate: 87.6%	3% Temporary, 1% Permanent	111	N/A

N/A, not available; OPLL, ossification of the posterior longitudinal ligament; OALL, ossification of anterior longitudinal ligament.

*OPLL with OALL.

ACDF VERSUS ACCF

While it is generally accepted that corpectomies lead to the removal of almost all osteophytes, discs and ossification of the posterior longitudinal ligament pathology that can cause spinal cord compression and may be the ideal procedure, >3 level corpectomies are seldom performed and needed. A review by Huang et al.¹⁰ (Table 2)¹¹⁻¹⁹ of <3 level disease treated with corpectomy vs discectomy showed no significant difference between the 2 in terms of hospital stay, the Japanese Orthopaedic Association (JOA) score, visual analogue scale scores for neck and arm pain, total cervical range of motion (ROM), fusion ROM, fusion rate, adjacent-level ossification and complications (Table 3).²⁰⁻³⁰

ENDOSCOPIC AND PARTIAL CORPECTOMY PROCEDURES

Oblique Partial corpectomy is indicated when only partial removal of the vertebral body that is causing compression is desired and the disc can be left intact. It can thus be used to effectively decompress the spinal cord and root. It has the advantages of avoiding fusion and preserving most of the disc and this could help in preserving motion between vertebral bodies, and also in preventing adjacent segment degeneration. There have been many large series (Table 4) which have demonstrated

the safety of this procedure with preservation of the ROM and improved canal diameter. However, rates of Horner syndrome have been its Achilles heel ranging from 1%–33%. In all large series, the authors have empathized strict selection criteria of excluding all patients with slippage greater than 2 mm between 2 adjacent vertebral bodies on dynamic films and with preoperative listhesis greater than 2 mm between 2 adjacent bodies, even when the degree of slippage does not increase on dynamic films.

There is only one large series of endoscopic corpectomy³¹ comprising of 15 cases with a mean age of 46 years, showing improvement in all cases after endoscopic corpectomy and discectomies.

CSM IN ELDERLY

In a review of all the cases of CSM in elderly (Table 5),³²⁻³⁹ CSM in patients older than 70 years has a unique radiographic appearance, with reduced ROM at lower cervical (C7–T1) levels and high stenosis at C3–4 segments that may manifest a disease localizing to these levels. Electrophysiological studies have shown that in elderly patients with CSM have demonstrated a high incidence (95%) of focal conduction block at the C3–4 level, which was counter-intuitive as the maximum age-related radiological changes were seen at lower cervical levels (C5–7).⁴⁰ Among all the consequences of cord compression, physiologi-

Table 5. Review of all series using anterior approaches for treatment of cervical spondylotic myelopathy in elderly

Series	Design	No. of patients	Definition of elderly	Technique	Follow-up (mo)
Nakashima et al., ³² 2015	Prospective	479	Elderly \geq 65 yr (n = 119); nonelderly < 65 yr (n = 360)	ACDF, discectomy/corpectomy w/ or w/o fusion, laminoplasty, laminectomy w/ or w/o fusion	24
Chen et al., ³³ 2015	Retrospective	136	Elderly \geq 70 yr (n = 58); nonelderly < 70 yr (n = 78)	ACDF, posterior laminectomy+ fusion	39.6
Kanchiku et al., ³⁴ 2014	Retrospective	43	Elderly \geq 75 yr (n = 43)	ACDF, laminoplasty	25
Nagashima et al., ³⁵ 2011	Retrospective	113	Group 1, 36–45 yr (n = 12); group 2, 46–55 yr (n = 22); group 3, 56–65 yr (n = 31); group 4, 76–85 yr (n = 16)	ACDF, laminoplasty	>6
Lu et al., ³⁶ 2008	Retrospective	51	Elderly \geq 70 yr (n = 20); nonelderly < 69 yr (n = 31)	ACDF	35.3
Holly et al., ³⁷ 2008	Retrospective	70	Elderly 75–85 yr (n = 36); nonelderly 30–64 yr (n = 34)	ACDF, laminoplasty, laminectomy+ fusion	24
Matsuda et al., ³⁸ 1999	Retrospective	41	75–81 yr (n = 17); 20–63 yr (n = 24)	ACDF, laminoplasty	N/A
Nagata et al., ³⁹ 1996	Retrospective	173	Elderly \geq 65 yr (n = 50); nonelderly < 65 yr (n = 123)	ACDF, laminoplasty	N/A

ACDF, anterior cervical discectomy and fusion; w/, with; w/o, without; N/A, not available.

cal conduction block plays the most important role in producing potentially curable clinical deficits.⁴¹

POSTOPERATIVE NECK STABILIZATION

A cervical orthosis is used in postoperative cases of CSM in order to relieve muscle spasm and prevent instability. The quantitative assessment of these orthoses was done by Johnson et al.⁴² in which he measured sagittal, rotational and lateral bending using the halo brace, cervicothoracic brace, the Somi brace, Philadelphia collar, and soft collar. While evaluating flexion extension between the occiput and first thoracic vertebrae the halo was most effective followed by the cervicothoracic brace (4%–13% movement allowed), Somi brace and Philadelphia collar (around 30% movement allowed) and lastly soft collar (Around 74% movement allowed). Again, while considering rotation motion only the halo and cervicothoracic brace were effective on controlling motion. Lateral bending was effectively only controlled by a halo brace with a plastic body vest, allowing only 4% of lateral bending.

COMPLICATIONS OF ANTERIOR SURGERIES FOR CSM

Prior to performing surgery, it is always important to have a thorough understanding of not only the surgical anatomy and biomechanics of the cervical spine but also of the unique complications associated with approach and instrumenting the ventral cervical spine. Complication rate of anterior surgeries for CSM varies from 1.6% to 31.3%.^{43,44} Reported complications resulting from anterior surgeries for cervical spine include neuro-

logic and vascular injury, esophageal injury, respiratory distress, implant-related complications, graft dislodgement, adjacent-level disc degeneration, cerebrospinal fluid (CSF) leakage, and infection.

Reported implant-related complication rates associated with anterior cervical plating have varied from 0% to 50% in the literature.^{45,46} Implant-related complications include pseudarthrosis, plate/screw loosening, plate or screw fracture, graft and plate dislodgement, and implant malposition.

Lowery and McDonough⁴⁷ reported a series of 109 patients treated with several different cervical plates with a 35% implant failure rate.

Anterior cervical plates have continually evolved since their earliest application. The addition of an anterior cervical plate appears to lead to earlier fusion and better clinical results in multilevel cases. Nonetheless, the use of anterior cervical implants in the treatment of CSM requires an understanding of their biomechanical benefits and limitations, as well as the unique complications related to the use of them. With the appropriate choice of implants and meticulous surgical technique, the surgical complications should be seen only rarely.

SUCCESS RATES OF ACDF

The success rates of ACDF are summarized in Table 6. The table shows individual case series from a single institution (which report on 50 patients or more) and also the results of 2 meta-analyses.⁴⁸⁻⁵⁴

Improvement was seen in close to 80% of patients. The only study which reports outcomes which are much worse is that by Pumberger et al.⁵³ which reported improvement in only 58.6%

Table 6. Summary of outcomes following ACDF for cervical spondylotic myelopathy

Study	Type of study	No. of patients	Follow-up duration	Outcome
Nirala et al., ⁴⁹ 2004	Retrospective	69	54 mo	Odom criteria – excellent and good – 56/69 (81.2%)
Liu et al., ⁵⁰ 2012	Retrospective	69	26.8 mo	Preop JOA 10.8 improved to follow-up JOA 14.1
Liu et al., ⁵¹ 2012	Retrospective	103	3.6 yr	Preop JOA 10.2 improved to follow-up JOA 14.8
Lin et al., ⁵² 2012	Retrospective	57	24 mo	Preop JOA 9.25 improved to follow-up JOA 13.86 Odom's criteria – excellent and good – 45/57 (79%)
Pumberger et al., ⁵³ 2013	Retrospective	203	15.44 mo	41.4% not improved (98/203 patients were in Nurick grade 1 preoperation)
Wen et al., ⁴⁸ 2015	Meta-analysis (5 studies)	199	N/A	JOA recovery rate – median 62 (range, 56.7–90.8)
Wang et al., ⁵⁴ 2016	Meta-analysis (7 studies)	452	24–87.3 mo; median, 24 mo	Preop JOA median 9.26 (range, 7.5–11.1) improved to follow-up JOA median 13.9 (range, 13.48–14.8)

ACDF, anterior cervical discectomy and fusion; Preop, preoperative; JOA, Japanese Orthopaedic Association; N/A, not available.

of patients. But it should be noted that a large percentage of their patients were in Nurick grade 1 prior to surgery (that is, patients who do not complain of gait impairment but have signs of pyramidal tract involvement such as exaggerated deep tendon reflexes). It is unlikely that the signs of pyramidal tract involvement will reverse completely in a large number of patients (that is, improvement to Nurick grade 0). When JOA was used, the improvement in mean JOA scores ranged from around 3 to 5 points. JOA recovery rates have ranged from 56.7 to 90.8.

Most of the studies are also limited by their short follow-up duration that is less than 3 years.

SUCCESS RATES OF ACCF AND ITS VARIANTS

The success rates of ACCF and its variants (“skip corpectomy” and “hybrid surgery”) are considered together as the number of reports for the latter is few. Table 7 summarizes the outcomes with this form of anterior surgery.^{48,51,52,54-58} Again there

are individual case series (reporting on 50 patients or more) and 2 meta-analyses. The largest individual case series had 352 patients all operated by one surgeon.⁵⁸

Improvement was seen in 69.8% to 82% of patients with one series showing that 35.8% of patients achieved a follow-up Nurick grade of 0 or 1 (“cure”). Sarkar and Rajshekhar⁵⁸ reported that the mean Nurick grade improved from 3.2 to 1.9. When JOA was used, the improvement in mean JOA score ranged from nearly 4 to 5. This seems to be slightly higher than that reported with ACDF. JOA recovery rates have been around 60% to 65% but one report had a recovery rate of over 140%.

Although the follow-up duration was generally short (2 to 3 years), there were a few studies that reported outcomes at 4.5 years or longer.^{55,57,58} These studies are discussed separately below.

Outcomes in hybrid surgery were noted in 2 reports.^{51,56} The mean JOA score improvement was 2.6 and 5. There was only one study reporting outcomes in skip corpectomy and mean JOA scores improved by around 4.5 and nearly 70% of patients

Table 7. Summary of outcomes of ACCF for cervical spondylotic myelopathy

Study	Type of study (ACCF unless otherwise mentioned)	No. of patients	Mean follow-up duration	Improved	Worse	Functional grade change
Emery et al., ⁵⁵ 1998	Retrospective	55	4.5 yr	82%*	6%	N/A
Guo et al., ⁵⁶ 2011	Retrospective (hybrid)	53	37.3 mo	N/A	N/A	JOA preoperative mean 8.1 improved to follow-up mean 13.1
Gao et al., ⁵⁷ 2012	Retrospective	145 (158 patients lost to follow-up)	8.5 yr	73.8%	22.8%	Mean JOA improvement was 3.8 ± 1.3 JOA recovery rate was 62.5%.
Lin et al., ⁵² 2012	Retrospective (skip corpectomy)	63	24 mo	69.8% (Excellent and good outcome, Odom criteria)	N/A	JOA preoperative mean 8.86 improved to follow-up mean 13.27
Liu et al., ⁵¹ 2012	Retrospective	87	3.6 yr	N/A	N/A	JOA preoperative mean 10.7 improved to follow-up mean 14.5
Liu et al., ⁵¹ 2012	Retrospective (hybrid)	96	3.6 yr	N/A	N/A	JOA preoperative mean 11.3 improved to follow-up mean 13.9
Sarkar and Rajshekhar, ⁵⁸ 2017	Retrospective	352 (130 patients lost to follow-up)	57.1 mo	72.4% (35.8% “cured”)	3.5%	Mean Nurick grade improved from preoperative 3.2 ± 0.1 to follow-up 1.9 ± 0.1
Wen et al., ⁴⁸ 2015	Meta-analysis (5 studies)	185	N/A	N/A	N/A	JOA recovery rate median 60.1 (range, 54.2–143.6)
Wang et al., ⁵⁴ 2016	Meta-analysis (7 studies)	452	Median 24 mo (range, 26.4–94.3 mo)	N/A	N/A	JOA preoperative median 9.18 (range, 7.4–11.4) and follow-up median 13.6 (range, 13–14.5)

ACCF, anterior cervical corpectomy and fusion; N/A, not available; JOA, Japanese Orthopaedic Association.

*Improvement rates for both ACDF and ACCF were reported together and not separately.

showed improvement by Odom criteria.⁵²

SUCCESS RATES OF OBLIQUE CORPECTOMY WITHOUT FUSION

Oblique corpectomy was suggested by George et al.⁵⁹ in 1993 as an alternative to ACCF in elderly patients in whom the involved segments were already fused due to disc desiccation and collapse. The major publications on oblique corpectomy for CSM have come from George's group²⁹ and by Chacko et al.²⁴ (Table 8). A review of all publications on oblique corpectomy by Tykocki et al.⁶⁰ included publications where this surgery has been used in patients with varied pathologies and presentations such as those with radiculopathy, spinal cord tumors etc. The total number of patients reported in this review is approximately 800. The authors estimated that the improvement rate following oblique corpectomy for those with CSM or ossification of the posterior longitudinal ligament was over 70%.⁶⁰

ACDF VERSUS ACCF

Table 9 shows the conclusions of 2 individual comparative studies and 4 meta-analyses comparing the outcomes of ACDF and ACCF.^{48,54,61-64} ACDF was generally associated with less intraoperative blood loss and less operative complications than ACCF. One meta-analysis reported that rates for postoperative dysphagia, hoarseness, graft extrusion, infection, epidural hematoma, and CSF leak were the same for both ACDF and ACCF. Some series reported better lordosis of the cervical spine and fusion rates for the grafts at follow-up. However, the functional outcomes, using Odom's criteria, JOA, Neck Disability Index (NDI) were universally reported to be the same.

LONG-TERM OUTCOMES

One major deficiency in most reports on outcomes of anterior surgery for CSM has been the short duration of follow-up.

Table 8. Summary of outcomes in oblique corpectomy for cervical spondylotic myelopathy (CSM)

Study	Type of study	No. of patients	Mean follow-up duration	Functional improvement
Chibbaro et al., ²⁹ 2009	Retrospective	268	96 mo	86.6% improved; 5% worse
Chacko et al., ²⁴ 2012	Retrospective	109	30.5 mo	Nurick grade improved from preoperative mean of 3.6 to follow-up mean of 2.5 JOA improved from preoperative mean of 11.4 to follow-up mean of 14.2
Tykocki et al., ⁶⁰ 2018*	Review	N/A	N/A	> 70% for CSM/OPLL

N/A, not available; JOA, Japanese Orthopaedic Association; OPLL, ossification of the posterior longitudinal ligament.

*Review included patients with radiculopathy, tumors etc.

Table 9. Outcomes in ACDF versus ACCF for cervical spondylotic myelopathy (CSM)

Study	Type of study	No. of patients	Conclusions
Han et al., ⁶¹ 2013	Systematic review and meta-analysis (15 studies, non-RCT)	1,372	ACDF better lordosis and less complications and blood loss; Odom's criteria, JOA, VAS, NDI equal, surgery time same
Wen et al., ⁴⁸ 2015	Meta-analysis (15 studies, non-RCT)	1,368	Same outcome; ACDF has less blood loss and complications
Lau et al., ⁶² 2015	Retrospective	55	ACDF less blood loss and complications (not significant); Other outcomes same
Liu et al., ⁶³ 2015	Meta-analysis (hybrid vs. ACCF) (5 controlled trials)	356	Both hybrid surgery and ACCF give the same functional outcomes but blood loss and complications were less with hybrid surgery and fusion rate was better
Wang et al., ⁵⁴ 2016	Meta-analysis (8 studies, retrospective)	878	ACDF better for complications, blood loss, lordosis and fusion rate; hospital stay, surgery time, JOA, NDI, dysphagia, hoarseness, graft extrusion, infection, pseudoarthrosis were same
Li et al., ⁶⁴ 2017	Retrospective (4 level CSM)	70	Same outcome; ACDF better lordosis, less complication

ACDF, anterior cervical discectomy and fusion; ACCF, anterior cervical corpectomy and fusion; RCT, randomized controlled trials; JOA, Japanese Orthopaedic Association scores; VAS, visual analogue scale; NDI, Neck Disability Index.

Thus, it is difficult to determine whether the benefits of surgery are seen at a longer follow-up. It is encouraging to note that those studies that have reported long-term outcomes at > 4 years after surgery, have reported that over 70% of patients have improved.^{55,57,58} A follow-up of > 4 years involving more than 50 patients has been reported by few authors.^{55,57,58} Emery et al.⁵⁵ reported that 82% of patients had improved at a mean follow-up of 4.5 years after an ACDF or ACCF. Long-term results for ACCF were not separately reported. Gao et al.⁵⁷ published a large series of 145 patients with an impressive mean follow-up of 8.5 years. They reported 73.8% of their patients had improved. One level ACCF was performed in 133 patients and only 12 had undergone 2 level ACCF. Moreover, 52% of their patients were lost to follow-up. Sarkar and Rajshekhhar⁵⁸ reported the largest single surgeon series of 352 patients who had all undergone un-instrumented ACCF and followed up for 1 year or more. Most of their patients (60.8%) had undergone 2 level ACCF. They reported that 72.4% of their patients had improved at last follow-up (mean, 57.1 months). They also noted that the improvement rates for patients followed up for different durations (> 5 years, 5–10 years and > 10 years) were similar. They also had lost 27% of their patients (complete cohort of 482 patients who had undergone ACCF) to follow-up. Chibbaro et al.²⁹ reported the long-term outcome (mean follow-up, 96 months) in 268 patients following oblique corpectomy.

Only few studies have studied the durability or sustainability of improvement after surgery. In other words, do patients who improve soon after surgery continue to maintain their improvement at further follow-up. In one such study, Sarkar and Rajshekhhar,⁵⁸ analyzed serial follow-up outcomes in 175 patients who reported initial improvement (> 1 Nurick grade improvement) at 1 year after ACCF. At 5 and 10 years after surgery, 90.5% and 76.3% of patients who reported improvement at 1 year, continue to maintain their improvement. Thus, the outcomes after ACCF are durable in vast majority of patients. There is, however, attrition in the improvement rate with time but the rate of attrition is very slow.

OUTCOMES IN SPECIAL GROUPS

Success rates of anterior surgery in special groups such as those in poor functional grades and in the elderly (> 65 or 70 years of age) is infrequently reported. Rajshekhhar and Kumar⁶⁵ reported good outcomes in 72 poor grade patients (Nurick grades 4 and 5) with CSM, following ACCF. Improvement of one Nurick grade or more was noted in 76% of patients at a

mean follow-up of 36.3 months. A “cure” (follow-up Nurick grade of 0 or 1) was noted in 23.9% of patients. Thus, it appears that good functional outcome can be expected in a large number of patients in poor grades following anterior decompressive surgery. The outcomes of anterior decompressive surgery seem to be worse than that in younger patients.^{33,66} Age has been shown to be a predictor of poor functional outcome following decompressive surgery for CSM in some but not all series.¹¹

WFNS SPINE COMMITTEE RECOMMENDATIONS

1. Surgical Indications for Treatment of CSM

- In patients with CSM, the indications for surgery include persistent or recurrent radiculopathy nonresponsive to conservative treatment (3 years); progressive neurological deficit; static neurological deficit with severe radicular pain when associated with confirmatory imaging (computed tomography, magnetic resonance imaging) and clinical-radiological correlation.
- The indications of anterior surgery for patients with CSM include straightened spine or kyphotic spine with a compression level below 3.

2. Comparison of Anterior Surgical Techniques for CSM

- There are many options for anterior decompression such as ACDF, ACCF, oblique corpectomy, skip corpectomy and hybrid surgery.
- A corpectomy is a good option for a ventral compression of less than 3 vertebral segments where a single-level disc and osteophyte excision are inadequate to decompress the cord in patients with CSM. In cases with a kyphotic deformity of the cervical spine, corpectomy can restore the normal lordotic curvature alignment.
- In cases of a multisegment disease with contiguous multisegment thecal compression, alternate segment discectomy/osteophyte removal while keeping the body of the intervening vertebra intact is biomechanically more stable than a complete corpectomy with contiguous segment discectomy.

3. Endoscopic and Partial Corpectomy Procedures

- An oblique partial corpectomy can improve the sagittal canal diameter substantially. However, this procedure may be difficult to perform in cases with bilateral radiculopathy. If there is significant instability, oblique corpectomy should not be chosen.
- The incidence of the Horner syndrome due to unilateral

disruption of the sympathetic chain has been decreased to less than 5% by some modifications in surgical technique.

4. CSM in Elderly

- In the elderly age groups with bony ankylosis due to osteophytes at C5–6–7, CSM may manifest at higher levels where motion segments are preserved, especially the C3–4 level and also at lower levels such as the C7–T1 level.

5. Complications of Anterior Surgeries for CSM

- Reported complications resulting from anterior surgeries for CSM are quite variable. Approach-related complications (dysphagia, dysphonia, esophageal injury, respiratory distress etc.) are more often than neurologic, and implant-related complications. With the appropriate choice of implants and meticulous surgical technique, the surgical complications should be seen only rarely.

6. Success Rate of Anterior Surgeries for CSM

- Improvement after anterior surgery for CSM has been reported in 70% to 80% of patients. JOA recovery rates are around 60% to 70%.
- There is no significant difference in success rates with ACDF, ACCF, and oblique corpectomy.
- ACDF is generally associated with less intraoperative blood loss and less operative complications than ACCF. The functional outcomes, using Odom criteria, JOA, NDI are reported to be the same.

CONCLUSION

In patients with CSM, the indications for surgery include persistent or recurrent radiculopathy nonresponsive to conservative treatment, progressive neurological deficit, static neurological deficit with severe radicular pain when associated with confirmatory imaging and clinical-radiological correlation. Complication rate of anterior surgeries for CSM varies from 1.6% to 31.3%. Improvement after anterior surgery for CSM has been reported in 70% to 80% of patients. JOA recovery rates are around 60% to 70%. These outcomes are also seen in long-term follow-up studies and appear to be durable. The success rates appear to be similar for the different forms of anterior surgery.

CONFLICT OF INTEREST

The authors have nothing to disclose.

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