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ORIGINAL ARTICLE

Surgical approach to cervical spondylotic myelopathy on the basis of radiological patterns of compression: prospective analysis of 129 cases

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Abstract This is a prospective analysis of 129 patients operated for cervical spondylotic myelopathy (CSM). Paucity of prospective data on surgical management of CSM, especially multilevel CSM (MCM), makes surgical decision making difficult. The objectives of the study were (1) to identify radiological patterns of cord compression (POC), and (2) to propose a surgical protocol based on POC and determine its efficacy. Average follow-up period was 2.8 years. Following POCs were identified: POC I: one or two levels of anterior cord compression. POC II: one or two levels of anterior and posterior compression. POC III: three levels of anterior compression. POC III variant: similar to POC III, associated with significant medical morbidity. POC IV: three or more levels of anterior compression in a developmentally narrow canal or with multiple posterior compressions. POC IV variant: similar to POC IV with one or two levels, being more significant than the others. POC V: three or more levels of compression in a kyphotic spine. Anterior decompression and reconstruction was chosen for POC I, II and III. Posterior decompression was chosen in POC III variant because they had more incidences of preoperative morbidity, in spite of being radiologically similar to POC III. Posterior surgery was also performed for POC IV and IV variant. For POC IV variant a targeted anterior decompression was considered after posterior decompression. The difference in the mJOA score before and after surgery for patients in each POC group was statistically significant. Anterior surgery in MCM had better result (mJOA = 15.9) versus posterior surgery (mJOA = 14.96), the difference being statistically significant. No major graft-related complications occurred in multilevel groups. The better surgical outcome of anterior surgery in MCM may make a significant difference in surgical outcome in younger and fitter patients like those of POC III whose expectations out of surgery are more. Judicious choice of anterior or posterior approach should be made after individualizing each case.

Keywords Cervical spondylotic myelopathy · Anterior surgical approach · Laminectomy

Abbreviations

CSM	Cervical spondylotic myelopathy
MCM	Multilevel cervical myelopathy
POC	Pattern of compression
ACDF	Anterior cervical discectomy and fusion
ACCF	Anterior cervical corpectomy and fusion

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Introduction

Formulation of a surgical protocol in cervical spondylotic myelopathy (CSM) has been adversely influenced by the diversity in clinical and radiological presentation. This is evident from the lack of prospective data that help to assign a specific surgical procedure to a group of patients with identifiable similarities in clinico-radiological attributes.

Surgical management has been divided into two schools of thought. Posterior decompression procedures are effective and have been rigidly applied to all cases with satisfying results. Anterior decompression has grown in popularity due to improvement in technology that allows direct decompression and reconstruction of the cervical spine with complication rate now comparable to posterior surgery. Inability to assign superiority of one procedure over the other creates a dilemma in choosing an ideal procedure for an individual patient.

Combining the advantages of these two procedures, to arrive at a rational surgical protocol is the need of the hour. The purpose of this study was to identify clinical and radiological patterns of compression (POC) and to formulate a treatment strategy based on these patterns.

Material and methods

Study design

A total of 181 consecutive patients of CSM were operated in a single spine unit between 2000 and 2006 and followed up prospectively for an average period of 2.8 years. Patients were informed that they would be a part of the prospective study. Their consent was obtained along with the operative consent taken before surgery.

Inclusion criteria

All patients diagnosed with cervical myelopathy due to degenerative cervical spondylosis were included in this study. Diagnosis of myelopathy was clinical with a corroborative MRI. Patients with coexistent radiculopathy ($n = 9$, 6.9%) (POC I, $n = 6$; POC II, $n = 1$; POC III, $n = 1$; POC IV, $n = 1$) on clinical examination were subjected to electrophysiological studies.

Exclusion criteria

1. Patients suffering from associated neurological disorders like Parkinson's disease ($n = 2$) and hemiplegia ($n = 6$), as these conditions confounded with the neurological evaluation of the patient.
2. Patients suffering from acute deterioration in neurology following trauma over a spondylotic canal ($n = 4$).
3. Patients suffering from myelopathy due to ossified posterior longitudinal ligament ($n = 3$).

Fifteen patients were lost to follow up (including one postoperative death). Twenty-two patients have not yet completed 2 years. A total of 129 patients, aged 26–80 years (average 49 years) were evaluated in this prospective study with an average follow-up period of 2.8 years. Male to female ratio was 5.4:1 with 109 males and 20 females.

Clinical evaluation and imaging studies

Various clinical and radiological parameters were assessed preoperatively (Table 1). A modified JOA (mJOA) score was used (Table 2) for quantifying the severity of myelopathy [11]. Modification was made because the use of chopsticks, forks or spoons for eating is uncommon in this population. The Nurick disability index (DI) was also modified to include hand dysfunction in cervical myelopathy patients (Table 3) [5]. Radiological assessment included antero-posterior and lateral cervical spine radiographs in sitting position and an MRI. Flexion–extension views were obtained only where instability was suspected. Many referred patients ($n = 96$) had already been investigated with an MRI. For economic reasons, these patients were not subjected to repeat scans. The aim was to identify

Table 1 Preoperative clinical and radiological parameters

Clinical parameters	Radiological parameters
1. Age at surgery	1. Pavlov's ratio
2. Duration of myelopathy	≤0.8 considered as developmentally narrow canal
3. Modified JOA score (mJOA)	2. Compression ratio
4. Modified Nurick's disability index (DI)	≤0.4 considered as significant compression
5. Coexisting medical co-morbidities (ASA grades 1 to 5)	3. Number of levels of involvement
	MCM: 3 or more levels involvement
	4. Signal intensity change on T1 and T2 weighted MRI (T1/T2 = N/N or N/H or L/H) [23]
	5. Spinal column alignment on lateral extension cervical radiograph
	6. Assessment of instability on flexion–extension lateral cervical radiographs

ASA American Society of Anesthesiologists, *MCM* multilevel cervical myelopathy, *N* normal intensity, *H* hyperintense signal, *L* hypointense signal

Table 2 Modified Japanese Orthopedic Association score for assessment of myelopathy

Upper extremity function		Lower extremity function		Sensations		Bladder function	
0	• Unable to feed oneself with a spoon or by using fingers • Inability to hold a pen • Total inability to carry out finer hand function like buttoning shirt/blouse, attaching watch strap	0	Unable to walk by any means	Upper limb		0	Retention
				0	Apparent sensory loss		
				1	Minimal sensory loss		
				2	Normal		
1	• Able to feed oneself with a spoon but not with hands • Able to hold pen but unable to write	1	Unable to walk without a cane or other support on the level	Lower limb		1	Severe disturbance • inadequate evacuation of the bladder • straining • dribbling of urine
				0	Apparent sensory loss		
				1	Minimal sensory loss		
				2	Normal		
2	• Clumsiness while eating food with hands • Able to write, but with great difficulty • Difficulty in buttoning/ unbuttoning shirt/blouse, attaching watch strap	2	Able to walk independently on the level but needs support on stair	Trunk		2	Mild disturbance • Frequency • Hesitancy
				0	Apparent sensory loss		
				1	Minimal sensory loss		
				2	Normal		
3	• Change in handwriting due to clumsiness • Slightly clumsy in buttoning shirt/blouse, attaching watch strap	3	Slightly clumsy in walking			3	Normal
4	Normal	4	Normal				

Total score = 17

Table 3 Modified Nurick's grades (DI)

Excellent
0 Normal with no clinical signs of myelopathy
1 Sub clinical myelopathy but no difficulty in walking/no difficulty in working with hands
Good
2 Slight difficulty walking but that does not prevent full time employment and manages most activities/ adequate hand grip strength and coordination
2a Patient performing previous occupational activity
2b Patient has modified occupation due to reason other than myelopathy
Fair
3 Difficulty in walking that prevents full time employment or the ability to do all housework but is not so severe as to require someone else's help to walk/inadequate hand grip strength and coordination
Poor
4 Severely restricted activity, ability to walk only with someone else's help or with the aid of a frame. Unable to use hand for any activity
5 Chair bound or bedridden

radiological POC, which were evident on good resolution MR images without the need for standardization.

Radiological patterns of compression

Criteria for defining significant anterior or posterior cord compression were as follows:

Significant anterior cord compression (Fig. 1):

1. Effacement of anterior CSF buffer on T2 sagittal and axial image.
2. Evidence of anterior compression of cord substance on T1 sagittal and axial images.
3. Cord ratio of ≤ 0.4 as measured on T2 images at the level of the disc space.

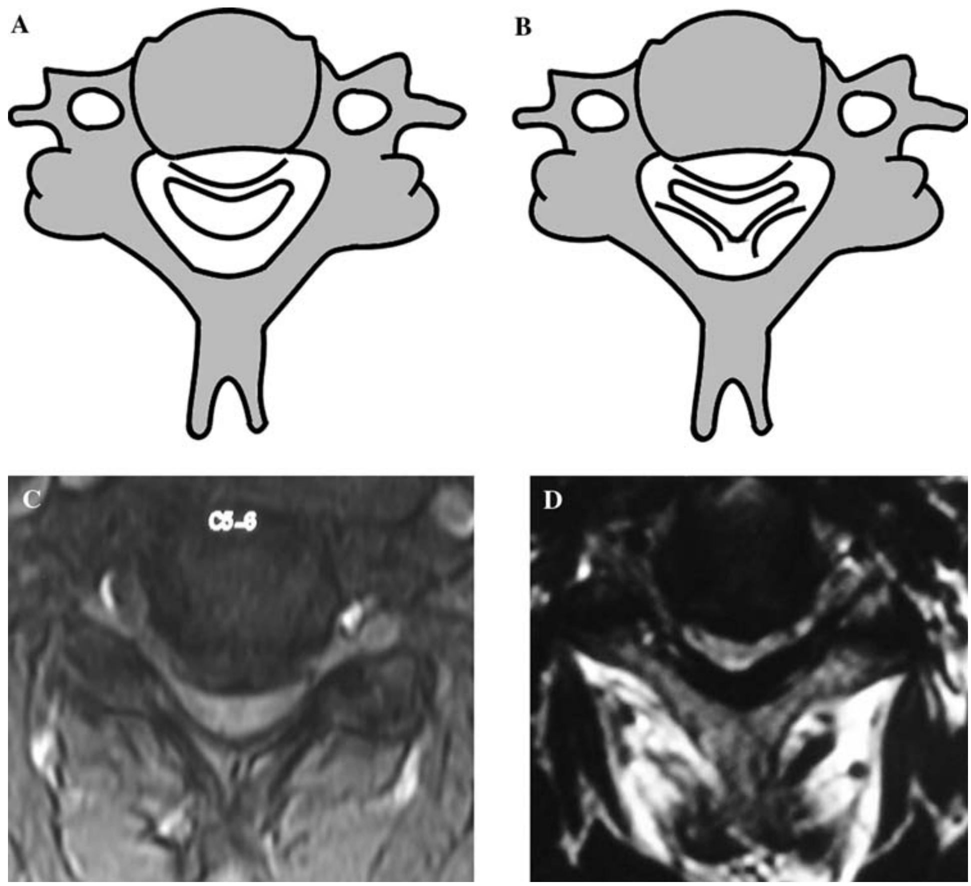

Fig. 1 **a**, **c** Anterior cord compression: cord indentation from anterior aspect with maintained posterior smooth contour of the cord. **b**, **d** posterior cord compression: cord indentation causing distortion of posterior smooth, rounded contour (V shaped)

4. Posterior smooth contour of the cord maintained.
5. Signal intensity change at affected level/levels.

Significant posterior cord compression (Fig. 1):

1. Effacement of posterior CSF buffer on T2 sagittal and axial images.
2. Evidence of posterior compression of cord substance on T1 sagittal or axial images.
3. Cord ratio of $\leq$0.4 on T2 axial image.
4. Posterior smooth, rounded contour distorted (V shaped).
5. Signal intensity changes at affected level/levels.

Following POC were identified (Fig. 2):

- POC I ($n = 79$): patients with significant one or two levels of anterior cord compression in a developmentally normal or narrow canal (Pavlov ratio $\leq$ 0.8).
- POC II ($n = 5$): both significant anterior and posterior cord compression at one or two levels irrespective of the canal size. We labeled such a compression as "pincer cord".
- POC III ($n = 20$): three levels of anterior cord compression in a developmentally normal canal with the American Society of Anesthesiologists (ASA) grade 1 or 2.
- POC III variant ($n = 10$) (POC III-v): similar to POC III with associated significant medical problems. (ASA grade > 2).
- POC IV ($n = 11$): three or more levels of significant anterior and posterior cord compression ("beaded cord"), or three or more levels of only anterior cord compression in a developmentally narrow canal. The spinal alignment was lordotic or neutral on lateral radiographs.
- POC IV variant ($n = 4$) (POC IV-v): similar to POC IV but out of the multiple sites of anterior compression; one or two levels showed compression ratio significantly lower than the other levels. These levels frequently had localized focal signal intensity change.
- POC V ($n = 0$): three or more levels of compression in a rigidly kyphotic cervical spine.

Inter observer reliability

Two independent observers, who were qualified orthopedic surgeons, were explained the POC by both senior authors (MB and VL). Ten random MRI scans (except for POC IV-v and POC II which had less than ten patients) from each POC group were assessed and POC were recorded and

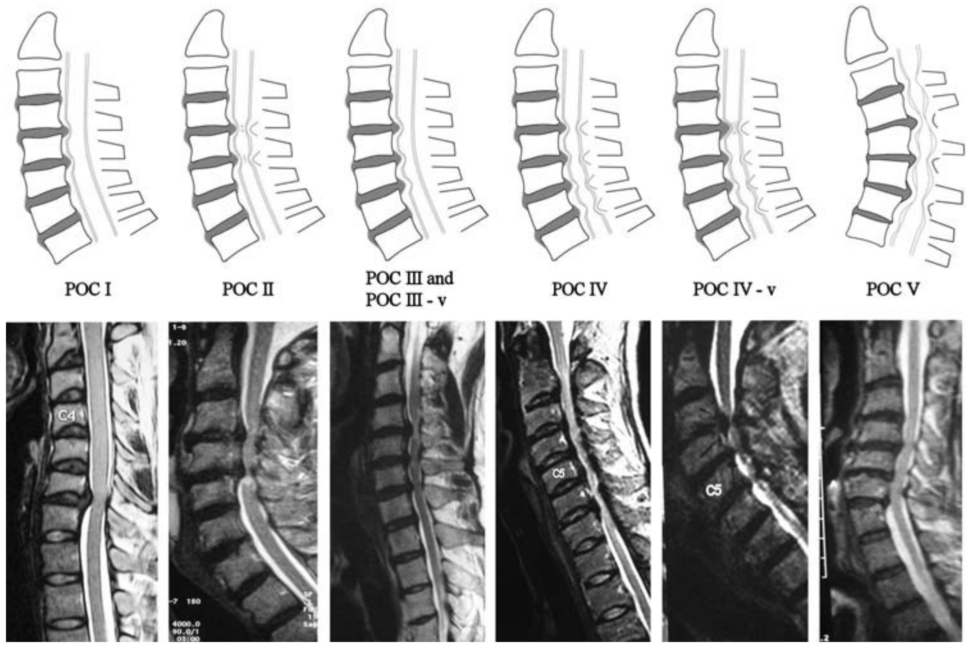

Fig. 2 Radiological patterns of compression (*POC*): diagrammatic and radiological (Sagittal T2 MRI) examples of various POC. *POC I* C6-7 disc herniation causing anterior cord compression, *POC II* C3-4 and C4-5 anterior and posterior cord compression, *POC III* and *POC III-v* C4-5 C5-6 C6-7 significant anterior cord compression, *POC IV* multiple levels of anterior and posterior cord compression, *POC IV-v* multiple levels of cord compression with C3-4 being more significant and severe compared to others, *POC V* multi-level cord compression in a kyphotically aligned canal

matched with the observations of a senior author (MB) (Table 4). Since POC III-v is similar radiologically to POC III patients and a separate category for identifying this group was not created. POC II was over diagnosed by both observers. CSF effacement (T2 image) with the maintenance of smooth posterior cord contour was the cause of the error. Also Observer 2 misidentified one case of POC IV-v, grouping it as POC IV. Reliability statistics (Cronbach's α) showed that there was no significant inter observer variation in indentifying these groups ($\alpha > 0.7$).

Table 4 Inter-observer variability in identifying various radiological patterns of compression (POC)

POC	Author (MB)	Observer 1	Observer 2
I	10	9	9
II	5	6	6
III or III-v	10	10	10
IV	10	10	11
IV-v	4	4	3
Reliability data	MB and Observer 1	$\alpha = 0.992$	
	MB and Observer 2	$\alpha = 0.992$	
	Observer 1 and Observer 2	$\alpha = 1$	

α = Cronbach's alpha

Formulation of the surgical protocol

Senior authors (MB and VL) formulated the surgical protocol based on retrospective analysis of cases operated by them between 1995 and 2000 (unpublished data). As data were inadequate, these patients were not included in this study. Research and review articles published in literature were also considered while formulating the protocol [14, 16–18, 20, 25, 26]. The surgical approach was decided on the basis of radiological POC (Fig. 3). All surgeries were performed by a single surgeon (MB).

The surgical protocol was as follows. POC I and POC II patients underwent anterior decompression. POC II patients who had suboptimal neurological recovery (JOA $\leq$ 14 or DI $\geq$ 3 at 3 months) underwent a second stage posterior decompression (Fig. 3). POC III patients with minimal or no preoperative morbidity (ASA grade $\leq$ 2) underwent anterior decompressive surgery with instrumentation. POC III-v with ASA grade > 2 underwent posterior decompression. POC IV and POC IV-v patients underwent posterior decompression. POC IV-v patients who had suboptimal neurological recovery were considered for a targeted anterior decompression at one or two levels as demonstrated by a MR scan (Fig. 3). This study does not have any case belonging to POC V. The proposed management was anterior decompression with reconstruction.

The anterior cervical discectomy or corpectomy or combination of the two, were used for anterior decompression. The iliac crest ($n = 101$) or cages ($n = 5$) were used for reconstruction. Discectomy up to two levels were not instrumented. In the remaining cases anterior cervical plate was used. Posterior decompression included laminectomy (Fig. 4).

The presence of associated radiculopathy did not influence this surgical strategy. The problem of radiculopathy was addressed through the same approach decided for the myelopathy, by performing a foraminotomy (anterior or posterior).

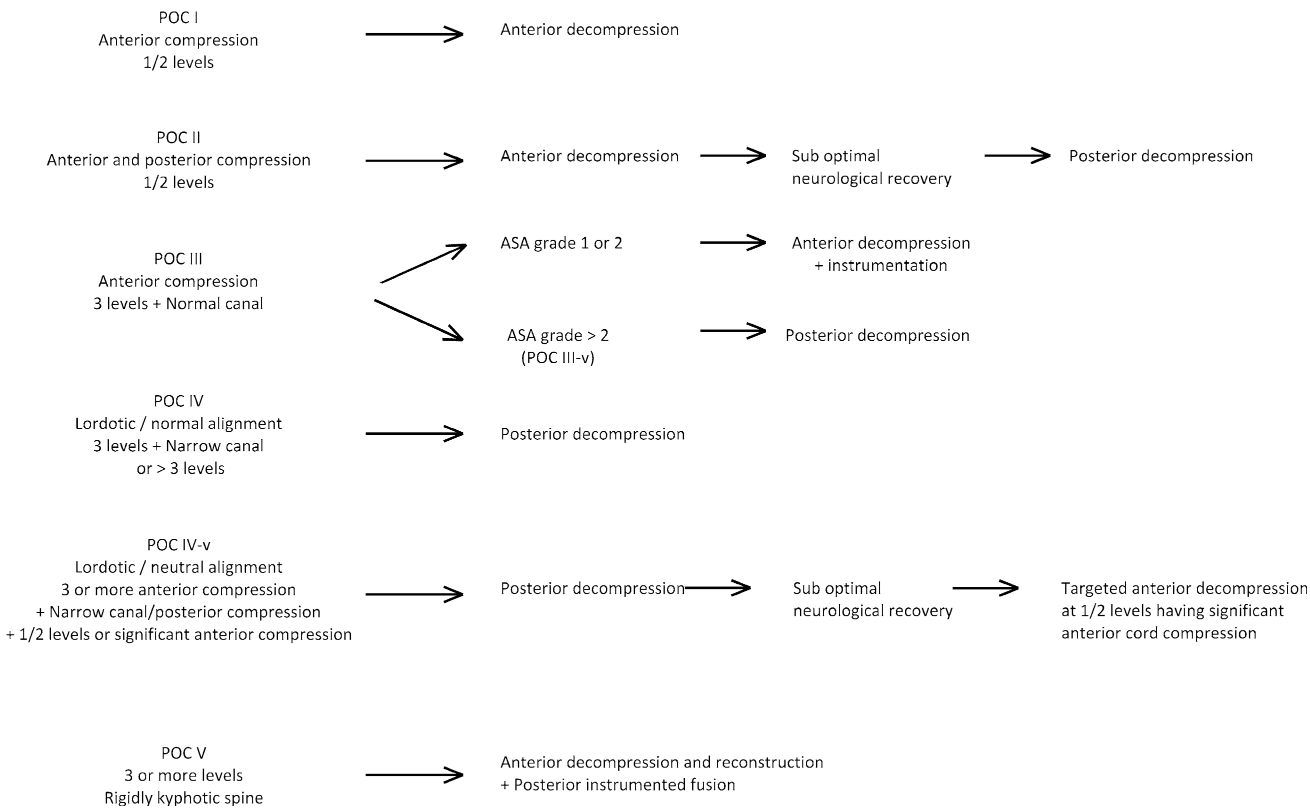

Fig. 3 Surgical protocol. Anterior decompression: ACDF, ACCF, graft–autograft iliac crest. Posterior decompression: laminectomy. Suboptimal neurological recovery—JOA $\leq$ 14 or DI $\geq$ 3 at 3 months. Second-stage surgery in POC II and POC IV-v was performed after compression of cord was proved on MRI imaging

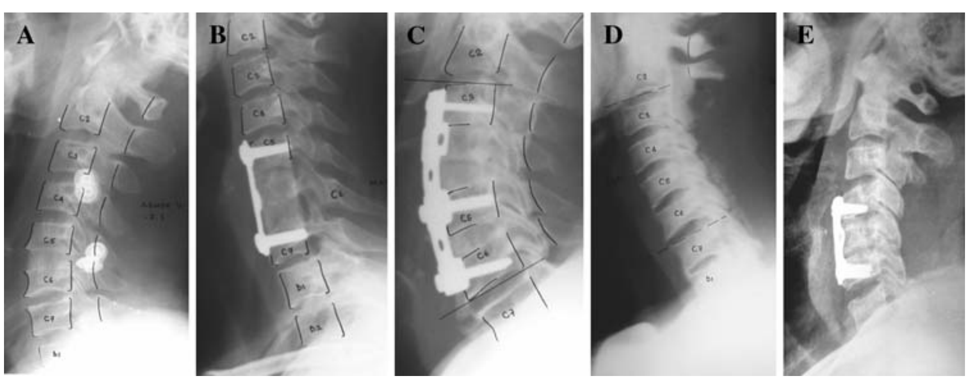

Fig. 4 Postoperative lateral radiographs of various POCs. **a** C5-6 anterior cervical discectomy and fusion (POC I). **b** C6 corpectomy and instrumented fusion using iliac crest autograft (POC II). **c** C4 corpectomy and C5-6 discectomy and instrumented fusion (POC III). **d** Laminectomy with uninstrumented fusion (POC IV). **e** Laminectomy and second stage targeted C5 corpectomy with instrumented fusion (POC IV-v)

Evaluation of surgical outcome

Patients were examined at three monthly intervals for 1 year, six monthly for the second year and on a yearly basis thereafter. A single surgeon, who was blinded to the purpose of the study, independently evaluated each patient and their radiographs. The average duration of follow-up was 2.8 years (2–5 years).

Cervical spine radiographs were obtained at each follow-up. Patients who had doubtful fusion on plain radiographs underwent flexion–extension radiographs with or without supplemental CT scan evaluation.

Postoperative outcome was evaluated using the mJOA score (Table 2). Recovery rate (RR) was calculated by the Hirabayashi's method.

$$\text{Recovery rate} = \frac{(\text{post operative mJOA score} - \text{preoperative mJOA})}{(17 - \text{pre operative mJOA})} \times 100$$

Postoperative disability assessment was performed using a modification of the Nurick's DI (Table 3). Outcome was graded as excellent, good, fair and poor on the basis of the DI. Many patients voluntarily changed their occupation or chose a retired lifestyle in spite of having a good neurological recovery (grade 2b). They were labeled to have a good rather than a fair result.

At each follow-up visit patients were specifically asked for any swallowing difficulties or change in voice. Swallowing difficulties were classified as painful swallowing (odynophagia) and difficulty in swallowing solid or liquid food or both. Patients who reported dysphonia underwent indirect laryngoscopy to detect vocal cord paralysis.

Statistical analysis

Statistical analysis was carried out using Fisher's exact test for dichotomous variables and Mann–Whitney *U* test for continuous variables. Nonparametric ANOVA and Dunn multiple comparisons test were used for nonparametric data. P value < 0.05 was considered significant.

Results

Study sample characteristics

Tables 5 and 6 show the preoperative clinical and radiological characteristics of all patients. Majority of the

Table 5 Preoperative clinical characteristics of the cohort classified according to the POC

POC	Overall	I	II	III	III-v	IV	IV-v
Number of patients (*N*)	129	79	5	20	10	11	4
Age at surgery (years) (mean ± SD)	49.29 ± 11.44	46.35 ± 10.31	55.20 ± 6.42	50.15 ± 12.16	51.90 ± 7.46	57.36 ± 14.07	67.00 ± 6.00
Duration of myelopathy (mo) (mean ± SD)	5.12 ± 5.71	4.63 ± 5.51	15.30 ± 9.86	4.93 ± 6.28	5.30 ± 2.91	4.46 ± 1.86	4.50 ± 1.73
Pre op mJOA (mean ± SD)	10.40 ± 3.33	10.75 ± 3.44	6.60 ± 4.28	11.25 ± 2.25	10.30 ± 2.16	9.73 ± 3.00	6.25 ± 2.63
Medical co-morbidities							
ASA 1, *n* (%)	79 (61)	61 (77)	3 (60)	12 (60)	0 (0)	3 (27)	0 (0)
ASA 2, *n* (%)	33 (25)	14 (17)	1 (20)	8 (40)	0 (0)	6 (54)	4 (100)
ASA 3, *n* (%)	15 (11)	3 (4)	1 (20)	0 (0)	9 (90)	2 (18)	0 (0)
ASA 4, *n* (%)	2 (1)	1 (1)	0 (0)	0 (0)	1 (10)	0 (0)	0 (0)

Table 6 Preoperative radiological characteristics of the cohort classified according to the POC

POC	Overall	I	II	III	III-v	IV	IV-v
Number of patients with Pavlov's ratio less than 0.8, *n* (%)	57 (44.2)	43 (54.4)	1 (20.0)	0 (0.0)	0 (0.0)	10 (90.9)	3 (75.0)
Number of patients with Compression ratio less than 0.4, *n* (%)	106 (82.2)	61 (77.2)	2 (40.0)	19 (95.0)	9 (90.0)	11 (100.0)	4 (100.0)
Number of levels (mean ± SD)	2.07 ± 0.90	1.47 ± 0.50	2.00 ± 0.00	3.00 ± 0.00	3.00 ± 0.00	3.27 ± 0.47	3.75 ± 0.50
One level, *n* (%)	42 (32)	42 (53)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Two levels, *n* (%)	42 (32)	37 (46)	5 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Three levels, *n* (%)	39 (30)	0 (0)	0 (0)	20 (100)	10 (100)	8 (72)	1 (25)
Four levels, *n* (%)	6 (4)	0 (0)	0 (0)	0 (0)	0 (0)	3 (27)	3 (75)
Signal intensity change (T1/T2)							
N/N, *n* (%)	10 (8)	8 (10)	0 (0)	2 (10)	0 (0)	0 (0)	0 (0)
N/H, *n* (%)	118 (91)	70 (88)	5 (100)	18 (90)	10 (100)	11 (100)	4 (100)
L/H, *n* (%)	1 (0.7)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

N normal intensity, *H* hyperintense signal, *L* low intensity signal patients belonged to the POC I group. Multilevel CSM (MCM) comprised of 35% ($n = 45$) of the study group.

Overall surgical outcome

The average mJOA score was 10.40 ± 3.33 (2–16) before surgery and 15.76 ± 1.45 (10–17) after surgery. Postoperative mJOA was significantly better than the preoperative mJOA (*P* value < 0.05). The mean gain in mJOA was 5.36 (±3.28). Of the 129 patients, 53 patients achieved normality with a mJOA of 17, 32 patients achieved near normality with a score of 16, 19 patients had a score of 15, 25 patients had a score of 14. The average RR was 80.10 ± 26.38 (−67 to 100%).

Analysis of the postoperative mJOA with respect to the POC is shown in Table 7. For each group the postoperative mJOA was statistically better than the preoperative JOA score ($P < 0.05$). The variation of the average RRs between the surgical groups was found to be statistically insignificant using the nonparametric ANOVA ($P = 0.074$) as well as Dunn's test. Variation in the postoperative mJOA was not significant using the Dunn's multiple comparison tests though significant variation was found using the nonparametric ANOVA. This discrepancy is probably because some of the POC (e.g. II and IV-v had small sample size). Though statistically insignificant, a slightly better RR and postoperative mJOA was seen in POC I and III.

Surgical outcome in multilevel cervical myelopathy

POC III (MCM anterior surgery group) versus POC III-v, IV and IV-v (MCM posterior surgery group)

The RR and postoperative mJOA were statistically better in the former group (*P* value = 0.029 and 0.007, respectively, Mann–Whitney test) (Table 8). These groups were matched for preoperative variables known to affect the surgical outcome. All the preoperative variables were statistically comparable except for the number of levels of involvement where anterior surgery had statistically lower number of levels (3) than posterior surgery group (3.24).

POC III versus POC III-v

These groups were radiologically comparable, and the only difference was the higher incidence of medical problems in POC III-v. Anterior surgery for POC III had higher post-op mJOA (15.9) and better RR (81%) than those observed following posterior surgery in POC III-v, though this was not statistically significant (*P* value = 0.596 for post-op mJOA and 0.490 for RR) (Table 8).

Table 7 Surgical outcome (means with SD)

POC	*N*	Follow-up (mo)	Post-operative mJOA	Recovery rate (%)
I	79	34.76 ± 10.60	16.01 ± 1.41	82.44 ± 28.49
II	5	43.20 ± 13.01	15.20 ± 1.10	70.09 ± 39.86
III	20	30.45 ± 8.46	15.90 ± 1.59	81.93 ± 24.99
III-v	10	26.00 ± 10.54	15.10 ± 0.88	70.72 ± 13.68
IV	11	31.64 ± 7.15	14.91 ± 1.38	73.44 ± 16.75
IV-v	4	30.50 ± 3.79	14.75 ± 1.89	78.89 ± 14.88
Overall	129	33.34 ± 10.38	15.76 ± 1.45	80.10 ± 26.38
Dunn's test			NS	NS
Nonparametric ANOVA				
P value			0.0024 (S)	0.074 (NS)

Table 8 Surgical outcome-comparisons between the anterior and posterior surgery groups in multilevel cervical myelopathy (MCM)

	POC III (MCM anterior surgery group)	POC III-v, IV, IV-v (MCM posterior surgery group)	POC III-v
Number of patients	20	25	10
Number of levels	3.00 ± 0.00	3.24 ± 0.44	3 ± 0.0
Duration of myelopathy (months)	4.93 ± 6.28	4.80 ± 2.27	5.3 ± 2.91
Preoperative mJOA	11.25 ± 2.25	9.40 ± 2.90	10.3 ± 2.16
Age at surgery (years)	50.15 ± 12.16	56.72 ± 11.64	51.9 ± 7.46
Follow-up (months)	30.45 ± 8.46	30.16 ± 6.05	28.4 ± 5.48
Post-operative mJOA	15.90 ± 1.59	14.96 ± 1.24	15.1 ± 0.88
Recovery rate (%)	81.93 ± 24.99	73.22 ± 14.93	70.72 ± 13.68

Evaluation of disability

Overall excellent to good results were obtained in 86% ($n = 111$) of patients, who could return to full time employment or original level of activity after surgery. Out of these, nine (8%) patients had voluntarily chosen a less active lifestyle (occupation) in spite having a good neurological recovery. In the multilevel group (POC III, III-v, IV, IV-v), excellent to good results were significantly lower than the nonmultilevel group (POC I and II). Within the multilevel group patients undergoing anterior surgery (MCM anterior surgery group) had 80% excellent to good outcome compared to 72% for patients treated by posterior surgery (MCM posterior surgery group) though this was not statistically significant. A similar outcome was observed while comparing disability rates between POC III and POC III-v groups (Table 9).

Complications

Mean operative time for MCM anterior surgery and MCM posterior surgery groups was 3.2 and 1.5 h with the average blood loss being 520 and 342 ml, respectively. No major graft-related complications were observed in the multilevel group (Tables 10, 11).

Table 9 Comparisons of postoperative DI scores between various surgical groups

	Nonmultilevel group	Multilevel group	Total
Excellent to good	77 (91.67)	34 (75.56)	111 (86.05)
Fair to poor	7 (8.33)	11 (24.44)	18 (13.95)
Total	84 (100)	45 (100)	129 (100)
Fisher Exact test, P value = 0.0165 (significant)			

	MCM Anterior surgery group	MCM posterior surgery group	Total
Excellent to good	16 (80)	18 (72)	34 (75.6)
Fair to poor	4 (20)	7 (28)	11 (24.4)
Total	20 (100)	25 (100)	45 (100)
Fisher Exact test, P value = 0.729 (not significant)			

	POC III	POC III-v	Total
Excellent to good	16 (80)	7 (70)	23 (76.7)
Fair to poor	4 (20)	3 (30)	7 (23.3)
Total	20 (100)	10 (100)	30 (100)
Fisher Exact test, P value = 0.657 (not significant)			

Nonmultilevel group = POC I, POC II; multilevel group = POC III, III-v, IV, IV-v; MCM anterior surgery group = POC III; MCM posterior surgery group = POC III-v, IV, IV-v

Difficulty in deglutition and abnormal phonation was the most common complication observed in the anterior surgery group (Table 11). Odynophagia was a frequent problem with 50% of the patients complaining of pain or discomfort on swallowing. Fortunately these symptoms were limited to the early postoperative period.

Dysphagia was seen in 30% of patients but it was difficult to differentiate odynophagia from true dysphagia. However, severe dysphagia was not a frequent occurrence

Table 10 Complications

	Nonmultilevel group	Multilevel group
Anterior surgery		
Neurodeterioration		
Irreversible	1	0
Transient	0	0
Implant failure (screw back out)	0	0
Malpositioned implant	0	1
R Laryngeal nerve palsy (permanent)	0	1
Bed sore	1	0
Graft site pain	1	4
Adjacent segment degeneration (symptomatic)	3	1
Pseudoarthrosis (graft subsidence)	2	0
Posterior surgery		
C5 radiculopathy	–	1
Deltoid paresis (transient)	–	1
Post laminectomy kyphosis	–	0
Post-op death (Myocardial Infarction)	–	1
Late neurological deterioration	–	0

Table 11 Incidence of dysphagia and dysphonia following anterior surgery in one or two-level disease (POC I/II: $n = 84$) and multilevel disease (POC III: $n = 20$)

	0–1 month n (%)	1–3 months n (%)	>3 months n (%)
Odynophagia			
POC I/II	42 (50)	1 (1.2)	0 (0)
POC III	9 (45)	0 (0)	0 (0)
Overall	51 (49)	1 (0.9)	0 (0)
Dysphagia			
POC I/II	22 (26)	0 (0)	0 (0)
POC III	9 (45)	2 (10)	1 (5)
Overall	31 (30)	2 (1.9)	1 (0.9)
Dysphonia			
POC I/II	32 (38)	8 (0.9)	0 (0)
POC III	6 (30)	2 (10)	1 (5)
Overall	38 (36.5)	10 (9.6)	1 (0.9)

in the early postoperative period. Symptoms such as coughing out of swallowed food, sensation of food getting stuck in the throat, preferential spitting out of collected saliva which all indicated severe dysphagia, were seen in only three patients (POC I: $n = 2$ and POC III: $n = 1$). One of these patients developed aspiration pneumonia which responded to intravenous antibiotics. After 1 month of surgery no patient complained of severe dysphagia, but a few patients ($n = 2$) had persistent minor discomfort on swallowing solid foods.

Dysphonia was also a common complication in the early postoperative period. Out of the 38 patients who reported dysphonia, 15 patients had unilateral vocal cord paralysis secondary to recurrent laryngeal nerve palsy. Most nerve palsies resolved over a 3-month period with only one patient with permanent nerve damage and persistent dysphonia.

Symptomatic adjacent segment degeneration was defined as new onset radicular or myelopathic symptoms referable to an adjacent degenerated level. Three patients from POC I and II and one patient from POC III had radicular symptoms correlating with a degenerated adjacent segment and were treated conservatively. No patient was reoperated for a symptomatic adjacent degeneration.

Discussion

Management of CSM, especially MCM, has been a topic of controversy. Until 1960s, posterior decompressive surgery was considered the gold standard for MCM. Since the advent of anterior procedures such as corpectomies with fusion for multilevel disease, there has been a considerable debate regarding a superior procedure for these kinds of patients.

A few comparative studies, evaluating the outcome of anterior versus posterior surgery in MCM, exist in literature. From these studies, the following conclusions can be drawn: (1) clinical outcome of anterior and posterior surgery in MCM is comparable [4, 11, 21, 29], (2) complications are more frequent with anterior surgery [4, 21, 26, 29] and (3) axial pain is a significant problem in the laminoplasty group [21, 26].

However, accurate interpretation of these outcomes is difficult due to several drawbacks and limitations of these studies. (1) All are retrospective analyses, (2) some have included two level disease in the multilevel group [21, 26, 29], (3) many studies have not used implants for multilevel anterior surgery which probably might be the reason for the high rate of graft-related complications observed in these studies [21, 26, 29], (4) anterior and posterior surgery groups are unmatched with respect to preoperative clinical and radiological characteristics [11], (5) small sample size [4, 21] and (6) short duration of follow-up [4, 29].

Irwin et al. [12] studied the relationships between surgeon specific factors and surgical approach to CSM. Higher variation was found with respect to the choice of surgical approach (anterior, posterior or combined) among surgeons treating patients with MCM. Even indications for fusion and instrumentation varied. The authors concluded that this may reflect the lack of consensus in literature regarding preferred approaches to this problem [12].

Over the years, anterior decompressive surgery for MCM has grown in popularity due to technological advancement and lowered complication rates [22, 25]. Combining the advantages of anterior and posterior decompressive procedures, to arrive at a rational surgical protocol, probably is the need of the hour. Based on this surmise we developed a surgical protocol and decided to test it. Following is the analysis of surgical outcomes of various patterns of radiological compression described in this study.

The differentiation between anterior, posterior or combined compression is sometimes difficult as suggested by the results of the interobserver study. In our study confusion arose in diagnosing patterns POC II and IV-v. Experience in reading degenerative cervical spine MRI can influence the interpretation of patterns. Although difficult, strict adherence to the criteria laid down for each pattern may help in identifying the side of compression.

POC I

There is little doubt that in cases of CSM involving one or two levels, an anterior cervical approach is the preferred choice [5, 8, 14, 18, 20]. Most studies have demonstrated excellent to good results in this group of patients [2, 6, 30]. In our study this group had 96% excellent to good outcome with most patients achieving normal to near normal postoperative mJOA score. Two instances of pseudoarthrosis were found in this group (both patients had uninstrumented two-level ACDF) although these patients were asymptomatic and had excellent postoperative outcome (Tables 10, 11).

POC II

Since the disc and ligamentum flavum are at the same level, if both protrude in the spinal canal, there is a likelihood of significant cord compression [17]. This situation also predisposes to the pincer phenomenon causing dynamic compression during extension of the spine. This was probably reflected in the very low preoperative mJOA scores (6.4) observed in this group. A few authors have suggested anterior decompressive surgery followed by a posterior decompression if necessary at a second stage for such patients [17]. Controlled distraction of disc space may reduce the invagination of ligamentum flavum into the canal [14, 20], avoiding a second stage posterior decompressive procedure. This probably was the reason why, out of the five patients in this group, three patients had an excellent neurological recovery following anterior surgery. Out of the two patients who had a suboptimal recovery (mJOA = 14), one patient refused further surgery and accepted his dysfunction while the other did not have a neurological recovery in spite of undergoing a second stage laminectomy. The poor outcome in the latter patient was probably because of a long duration of preoperative severe cord dysfunction (more than 2 years). However, the limited number of patients in this rare POC makes it difficult to draw conclusions from this outcome.

POC III

Traditionally the number of levels of compression for patients undergoing multilevel anterior decompression has been limited to three levels.[5, 8, 17, 19, 20] Graft and instrumentation related complications have been shown to be unacceptably high for anterior decompressive surgery involving more than three levels [9, 16, 24, 25]. A study by Naderi et al. [16] demonstrated a high rate of fusion (97.72%) and 86% incidence of neurological improvement in patients undergoing multilevel ACCF (anterior cervical corpectomy and fusion) though the patients undergoing one or two levels of ACCF had statistically better clinical outcome than the patients undergoing three level ACCF. Hilibrand et al. [9] reported a successful clinical outcome in more than 85% of patients undergoing instrumented ACCF for MCM with a low incidence of complications.

Papadopoulos et al. [19] reported a high rate of fusion and excellent to good outcome in 83% of patient treated with three-level instrumented ACDF. The best argument against posterior surgery in this group of patients who are relatively younger and medically less morbid is the high incidence of post surgery instability, recurrence of myelopathy and axial pain [13, 15].

In our study the results of three-level multilevel anterior surgery for POC III (post-op mJOA = 15.9 ± 1.59) were comparable with anterior surgery in POC I (post-op mJOA = 16.01 ± 1.41) with the RR being more than 80% in both the groups. A total of 80% of the patients had an excellent to good clinical outcome with 100% fusion rate, which is comparable with the existing literature [9, 16]. Most of the complications were minor and reversible (Tables 10, 11). Although problems of dysphagia and dysphonia were common in the early postoperative period (<1 m) persistence of severe disabling symptoms was rare. Our results disagree with many prospective studies [1] that have reported a high rate of persistent dysphagia and dysphonia following anterior surgery. We feel that the low incidence of complications was probably because (1) we limited our levels of anterior decompression to not more than three levels, (2) patients undergoing this procedure were relatively younger and medically fit, (3) corpectomy was avoided wherever possible and (4) anterior instrumentation was used in all patients.

POC III-v

We chose a posterior approach to decompress this group which, in spite of being radiologically similar to POC III, had more incidence of preoperative co-morbidity. Various authors have suggested avoiding extensive anterior decompressive surgery in MCM patients with significant medical co-morbidities to reduce the incidence of complications [5, 10, 20]. Since ours is a developing country, sufficient infrastructure (anesthetic and surgical) to deal with complications associated with prolonged anterior decompressive surgery is not readily available. The outcome (RR, mJOA, DI) in this group was inferior to that of patients in POC III, though this did not reach statistical significance. There were no complications observed in this group. Thus we feel that posterior approach should be the preferred surgery in MCM patients who have significant medical co-morbidities.

POC IV

This group underwent laminectomy considering the high rate of complications associated with three-level corpectomy. Moreover, some authors have suggested that in patients with multiple levels of anterior compression associated with a developmentally narrow canal or multiple posterior cord compressions, anterior surgery may increase the risk of injury to the spinal cord because the dura and the spinal cord are pressed against the posterior longitudinal ligament in a stenotic canal [14]. Also following anterior surgery if segments adjacent to the fusion develop degenerative changes it might compromise the cord if the canal is stenotic to start with [14]. These along with the problems associated with long segment anterior reconstruction were the rationale behind choosing posterior surgery for this group.

Although laminectomy diminishes intrinsic spinal stability [28], the extent of their effect on stability is often exaggerated. Studies have shown good results if strict criteria, such as avoiding significant facetectomy, are followed [3, 7]. Moreover the patients in this group usually are older (approximately one decade older than those undergoing anterior surgery in our study), in whom due to the degenerative changes, the spinal column has significantly more intrinsic stability than the cervical spine in a younger patient [17, 27]. None of the patients undergoing laminectomy in our study developed late neurological deterioration or post laminectomy kyphosis though the duration of follow-up for these cases is relatively short (2.5 years). Recovery rate observed in this group (73%) was comparable to that in the existing literature [3, 7].

POC IV-v

In POC IV-v, the authors feel that myelopathic symptoms in a severely stenotic MCM patient may be due one or two levels of extremely severe compression. Posterior decompression may be satisfying; however, if the recovery is suboptimal a targeted anterior decompression to decompress the maximum stenotic segment may prove beneficial. We are not aware of any study elucidating this surgical rationale.

There were only four patients in POC IV-v out of which two patients underwent instrumented anterior decompressive surgery following a laminectomy. Though the neurological outcome in this group (RR = 79% post-op mJOA = 14.75) was comparable with the other POCs, the small sample size of this group made it difficult to draw statistical conclusions.

Overall surgical outcome

The RR did not vary significantly among the POCs, though seemingly POC I and III had better RRs. Anterior surgery in MCM (POC III) achieved a significantly higher post-operative mJOA (15.9) as compared to one grade less (14.9) in the posterior surgery group (POC III-v, IV, IV-v) though this discrepancy may have occurred due to the fact that the former group had lesser number of levels of cord compression and therefore tended to do better. Between POC III and POC III-v, in which all confounding variables including levels of cord compression were matched, anterior surgery for POC III again fared slightly better (15.9) than posterior surgery for POC III-v (15.1), though this was not of statistical significance. Many studies have reported better surgical outcome of anterior surgery in MCM over posterior surgery even if it did not reach statistical significance [4, 12, 26].

We postulate that the better surgical outcome of anterior surgery, though statistically insignificant, may make a significant difference in surgical outcome in younger and fitter patients like those of POC III whose expectations out of surgery are more. Whereas in the POC III-v and IV where the patients have co-morbid factors and lead mostly a sedentary lifestyle a one grade less neurological recovery might not make a significant difference in the surgical outcome. This was probably reflected in the comparable DI scores observed between these groups. One would expect the MCM posterior surgery group, with significantly lower post-op mJOA than the MCM anterior surgery group, to score poorly on the DI scale. But contrary to the expectation this group tended to have comparable DI scores with the MCM anterior surgery group. This was probably because the MCM posterior surgery group, a relatively older and more morbid population, had a sedentary life to start with. Surgery restored enough function in them so that they could go back to their pre-operative functional status.

The limitation of this study is that it is a short follow-up. Whether these patients actually maintain their gain in JOA for a longer duration remains to be determined. Whether adjacent segment degeneration poses a significant problem for those patients who are reconstructed anteriorly is also not clear. Our series has a small sample size for the multilevel group and therefore statistically results of the multilevel group might not be an accurate estimate. We wish to emphasize that the conclusion drawn from the results of POC II and POC IV-v should be interpreted with caution as the number of patient in these groups is quite small.

We feel that anterior surgery where indicated can give the best possible outcome which is especially important in a younger and fitter patient whose life expectancy is comparatively more than the morbid group. Physicians who use both the anterior and posterior approach in management of CSM are capable of providing optimal care because each patient's case must be individualized.

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