Original Article

C3-4 level cervical spondylotic myelopathy

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Cervical spondylotic myelopathy (CSM) is uncommon at the C3-4 level. Fourteen patients with C3-4 CSM were treated over a period of 3 years. The radiological factors contributing to CSM at the C3-4 level were studied. These factors included the assessment of static and dynamic canal diameters, retrolisthesis, posterior osteophytes and degenerative spinal segmental fusion on plain X-rays; and, the antero-posterior cord compression ratio (APCR) on magnetic resonance imaging (MRI). The clinical status of the patients was assessed by the modified Japanese orthopedic association scale (mJOAS). The mean difference between the static and dynamic canal diameters was statistically significant at C3-4 ($p < 0.01$). The APCR obtained at different levels showed a significant compression at the C3-4 level in comparison to the lower level. There was a correlation between the APCR and the preop mJOAS, $r=0.6$ ($p<0.05$). The mean mJOAS improved from 9.35 to 14.35 at follo-up. The recovery rate calculated using the modified Hirabayashi rate was 66.9%. Degenerative changes at lower cervical segments predispose to increased mobility and spondylotic changes at the C3-4 level. The patients in this study were young as compared to those reported in the international literature.

Key Words: Cervical spondylotic myelopathy, anterior approaches, static and dynamic canal diameter

Introduction

The commonly involved levels in the order of frequency in cervical spondylotic myelopathy (CSM) are C5-6, C6-7, and C4-5.[1,2,3,4,5,6,7] The C3-4 level is infrequently involved in CSM. However, Mihara et al have reported a five times more involvement of the C3-4 level in patients older than 65 years as compared to their younger counterparts.[1,8] This study assesses the radiological factors contributing to the development of CSM at the C3-4 level; the correlation between the clinical status and the radiological compression; the changes in the cervical curvature after surgery; and, the surgical outcome.

Material and Methods

In this prospective study carried out between February 1999 and June 2002, a total of 137 patients of cervical spondylotic myelopathy (CSM) were operated by the anterior approach. A discoidectomy by Cloward's procedure was performed in 73 patients and a corpectomy was done in 64 patients. Of these, 14 patients with the clinical and radiological evidence of C3-4 level CSM were included in the present study. However, 11 of these patients had radiological evidence of spondylotic involvement at the lower levels also.

All the 14 patients had pyramidal signs; 13 had sensory involvement; 5 had posterior column involvement; 3 had distal hand muscle wasting; and, 3 had sphincteric dysfunction. Their age ranged from 24 to 77 years, with a mean age of 50.6 years. There was only one patient above the age of 65 years. All 14 patients were male. The total duration of the symptoms ranged from 1 to 36 months, with the mean duration being 10.64 months. Their preoperative clinical status at admission and at follow-up was assessed by the modified Japanese Orthopedic Association Scale (mJOAS).[9,10] These patients were operated using Cloward's procedure at the level of C3-4. Postoperatively plain lateral radiograph was done in all the patients (Figure 1), (Patient no.8). In one case, an additional discoidectomy without graft was done at the C5-6 level. In two other patients, an additional Cloward's procedure was done at the C4-5 and C5-6 levels, respectively. In addition, the Smith-Robinson's technique was used in one patient at the C6-7 level. There was no perioperative mortality. The surgical outcome was calculated by the method of "modified recovery rate" described by Hirabayashi.[11]

i.e.

$$\frac{\text{Postoperative mJOAS} - \text{Preoperative mJOAS}}{\text{Total score} - \text{Preoperative mJOAS}} \times 100$$

where the total score is the sum of the pre- and postoperative mJOAS

The patients underwent plain lateral radiographs of the cervical spine in the neutral position and in the maximum possible active flexion and extension. A T1- and T2-weighted axial and sagittal MRI of the cervical spine was also performed. The following parameters were noted:

1. Osteophytosis and disc space narrowing.
2. Plain radiographic assessment in neutral position: The static antero-posterior (AP) spinal canal diameter: This was defined as the distance from the mid-point of the posterior margin of

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the vertebral body to the nearest point on the spinolaminar line.

3. Plain radiographic assessment in extension: The dynamic AP spinal canal diameter: This was defined as the distance from the postero-inferior margin of the vertebral body to the antero-superior margin of the lamina of the adjacent lower vertebra on lateral radiographs of the cervical spine in maximum active extension of the neck.
4. Plain radiographic assessment in flexion and extension: Retrolisthesis was defined as the movement of the upper vertebra in the postero-inferior direction in relation to the lower vertebra and was taken as positive if it was equal to or more than 2 mm. Degenerative segmental fusion was defined as the segmental immobility between the vertebrae secondary to degenerative changes as seen on the flexion/extension skiagrams.
5. Assessment on MRI: Antero-posterior cord compression ratio (APCR) [Figure 1]: This was assessed by measuring the percentage ratio of the smallest sagittal and maximum transverse diameter of the cord,[12]

$$\frac{\text{Sagittal diameter (b)}}{\text{Transverse diameter (a)}} \times 100$$

The correlation between APCR and preop mJOAS was studied.

The follow-up period ranged from 1.5 to 39 months (mean 9.57 months). Plain lateral radiographs of the cervical spine in both flexion and extension and neutral positions were carried out. The mJOAS was also assessed at the last follow-up and these were compared with the preoperative status as has already been described.

Figure 1: Postoperative plain lateral radiograph of Patient no.8 showing the bone-graft at the C3-4 level.

Statistical analyses

Mean difference between the static and dynamic A-P spinal diameter was calculated by noting the mean of the static diameter at the two adjacent levels and also by noting the dynamic diameter at the corresponding levels. Then, the dynamic diameter at that level was subtracted from the mean static diameter at the two adjacent levels to obtain the difference between the static and dynamic AP spinal diameter at that level. The mean of this value at the C3-4, C4-5, C5-6, C6-7 levels in all the patients was obtained to provide the mean difference between the static and dynamic AP spinal diameter and was compared statistically using the two sample T test. A p value < 0.05 was considered significant.

The APCR at the C3-4 level was correlated with the APCR at C4-5, C5-6 and C6-7 levels respectively. The APCR at the C3-4 level was also correlated with the preoperative mJOAS. Correlation coefficient(r) was used and a p value < 0.05 was considered significant.

Table 1: Comparison of the static and dynamic cervical spinal canal diameters at various levels.

Sr. No.	C3 Static	C3-4 Dynamic	C4 Static	Mean difference of static diameter at C3 & C4 and diameter at C3-4 (in mm)	C4-5 Dynamic	C5 Static	Mean difference of static diameter at C4 & C5 and diameter at C4-5 (in mm)	C5-6 Dynamic	C6 Static	Mean difference of static diameter at C5 & C6 and diameter at C5-6 (in mm)	C6-7 Dynamic	C7 Static	Mean difference of static diameter at C6 & C7 and diameter at C6-7 (in mm)
1.	13	11	12.5	1.75	11	12	1.25	11.5	13	0.75	12	13.5	1.25
2.	15	15	15.5	0.25	14.5	15	0.75	15	15.5	0.25	15.5	15.5	0
3.	16	14	14	1	13.5	15	1	14.5	15.5	0.75	15	16	0.75
4.	16.5	14.5	15.5	1.5	14.5	15	0.75	14	16	1.5	15.5	16.5	0.75
5.	17	14	15	2	14.5	15	0.5	14	16	1.5	15	15	0.5
6.	16	15.5	16.5	0.75	15	13.5	0	13	14	0.75	14.5	15	0
7.	14.5	13	14.5	1.5	12.5	15.5	2.5	14	15	1.25	13	14.5	1.75
8.	16	15	14.5	0.25	15	14	-0.75	14.5	15	0	14.5	15.5	0.75
9.	16	14	15	1.5	14	14	0.5	14	16	1	15	16.5	1.25
10.	12	10	11.5	1.75	11	12	0.75	11.5	11.5	0.25	12	12	-0.25
11.	13.5	13	14.5	1	14	15	0.75	14.5	15.5	0.75	15	16	0.75
12.	14	12	15	2.5	15	14.5	-0.25	13.5	14	0.75	14	14.5	0.25
13.	13.5	12	17	3.25	16.5	16	0	15	15	0.5	14.5	15.5	0.75
14.	14	12.5	14	1.5	12.5	13.5	1.25	13.5	15	0.75	14.5	14	0
(Mean)	14.79	13.25	14.64	1.46	13.82	14.28	0.64	13.75	14.78	0.76	14.28	14.79	0.60
Std deviation	1.50	1.61	1.42	0.81	1.57	1.2	0.78	1.10	1.28	0.44	1.15	1.15	0.56

The two sample T test was significant at the C3-4 level when compared to the lower levels ($p < 0.01$)

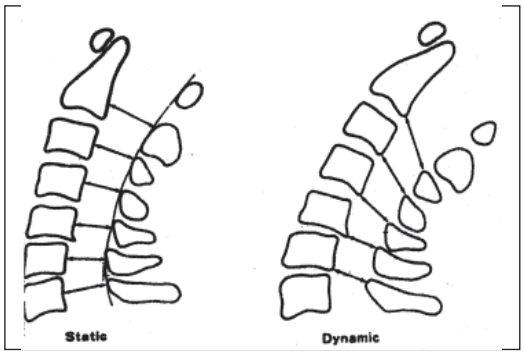

Figure 2: The APCR calculated on MR imaging in Patient no. 8 with significant cord compression at C3-4 was 35.29 (as shown in Table 1)

Results

The plain radiographic findings of the cervical spine are summarized. A reduced disc space was seen at the C3-4 (n=11); C4-5 (n=1); C5-6 (n=6); and C6-7 (n=2) levels . The posterior osteophytes were seen in 8 patients at the C3-4 level; in 6 at the C4-5 level; in 9 at the C5-6 level, and, in 3 at the C6-7 level. On dynamic lateral radiographs, retrolisthesis was present in 6 patients at the C3-4 level and in one at the C4-5 level (Figures 3a and 3b). Both posterior osteophytes and retrolisthesis were present in 5 patients at the C3-4 level and in 1 patient at the C4-5 level.

The mean static canal diameters at the C3, C4, C5, C6, and C7 levels were 14.79, 14.64, 14.28, 14.78 and 14.79, respectively. The mean dynamic canal diameters at the C3-4, C4-5, C5-6 and C6-7 levels were 13.25, 13.82, 13.75 and 14.28, respectively. The dynamic canal diameter was smaller than the static canal diameter at all levels. The mean of the difference between the static and dynamic AP spinal diameter at the C3-4 level was 1.46; at C4-5 was 0.64; at C5-6 was 0.76; and at C6-7 was 0.60. The difference was statistically significant at the C3-4 level in comparison to the lower levels ($p < 0.01$) (Table 1). This indicated an increased mobility and a dynamic canal narrowing at the C3-4 motion segment in comparison to the C4-5, C5-6 and C6-7 motion segments. Six patients had lower cervical degenerative segmental fusion. Three of the patients had ossification of the anterior longitudinal ligament at C4-5, C5-6, C6-7; at C5-6; and, at C3-4, C5-6, C6-7 levels, respectively.

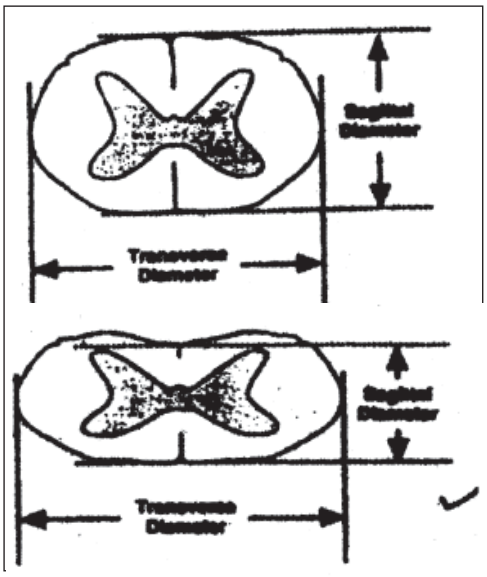

Figure 3: The plain radiograph of cervical spine (a) in flexion and (b) in extension shows retrolisthesis at the C3-4 level with decreased disc spaces at the C5-6 and C6-7 levels and anterior osteophytes at the C5-6 level.

The MRI scans of the patients revealed a significant disc bulge at the C3-4 level in all the patients. A disc bulge was also present at the C4-5 level in 3 patients; at the C5-6 level in 9 patients; and at the C6-7 level in 6 patients. All had T2 signal intensity changes at the C3-4 level only (Figure 2). The APCR was found to be significantly decreased at the C3-4 level than at the lower levels (Table 2). The maximum cord compression was seen at the C3-4 level (Figure 1). In correlating it with the lower levels i.e. C4-5; C5-6 and C6-7, the respective correlation values of r=0.59, r= 0.69 and r= 0.70 were obtained. The APCR of the maximally compressed level i.e. the C3-4 level had a significant correlation with the preoperative mJOAS i.e. a correlation value of r=0.61 ($p<0.05$), as shown in Table 2.

The mean preoperative mJOAS improved from a value of 9.35 to 14.35, at follow-up. There was a significant correlation between the preoperative mJOAS score and APCR ($p<0.05$). Most of the patients improved significantly despite a low APCR. The recovery percentage rate (modified Hirabayashi method) was found to be 66.9% (Table 3). In one patient, however, there was a zero recovery percentage.

Discussion

Cervical spondylosis is an age-related degenerative disorder which starts appearing as early as the third decade and may involve 75-100% of the population by the seventh decade.[1,4] The pathophysiology of this degenerative process has been well described in the literature.[1,2,5,6,7] The degenerative changes include spondyloarthosis, disc degeneration and apophyseal joint osteoarthritis which lead to the progressive narrowing of the cervical canal diameter proceeding to CSM.[1] Various studies have documented that the most common cervical spine levels to be involved are C5-6 and C6-7, followed by C4-5.[4,5,6,7] The C3-4 compression is rarely the cause of CSM.[1] However, Mihara8 in 1998 reported a 5-times higher incidence at this level in patients above the age of 65 years. He reported the C3-4 level to be the cause of CSM in 41% of elderly patients in his series.[1] A similar incidence has been reported by other authors in the elderly population presenting with CSM.[8,15,16] Spondylotic changes in the form of disc protrusion and osteophyte formation start from the C5-6 and C6-7 levels because of maximum motion and stress at these levels.[4,5,6,7] Further degenerative changes lead to the loss of mobility and fusion at these levels. This leads to an increased stress at higher levels

Table 2: The evaluation of the antero-posterior cord compression ratio (APCR) on MR imaging

	Pre op mJOAS	C_{3-4}	C_{4-5}	C_{5-6}	C_{6-7}
(GSH)	10	17.85	43.47	33.33	36
(HLG)	12	35.5	62.5	62.5	62.5
(AS)	8	20.25	23.529	31.25	40
(CLS)	11	40.9	50	47.69	55
(BKD)	15	35.71	50	50	52.91
(NPS)	8	38.43	57.14	46.15	42.85
(RPS)	12	16.66	40	40	33.33
(RPP)	10	35.29	50	60	57.14
(RNS)	11	37.5	66.6	57.14	61.5
(GS)	10	38	41.6	47.82	43.4
(LS)	9	15	46.15	41.6	38.46
(BL)	13	25	42.85	35.29	35.71
(RSG)	2	25.1	50	35.29	46.15
(LV)	5	25.45	35.71	35.71	33.3
Mean		(28.99)	(47.11)	(44.55)	(45.59)
Correlation(r)			0.59	0.69	0.70

Abbreviation used in the table (r) = correlation

A correlation of the APCR at the C3-4 was established with the APCR at the lower levels utilizing correlation coefficient.

A correlation between the APCR at the C3-4 level was also done with the preoperative mJOAS (r=0.61), p value < 0.05.

in order to compensate for the lack of sagittal motion at the lower levels. Once the C4-5 level also loses its mobility due to the degenerative changes, the stress shifts to the C3-4 level for maintaining the cervical alignment and sagittal motion. This explains the increased motion and retrolisthesis seen at the C3-4 and C4-5 levels in elderly patients presenting with CSM while younger patients with CSM have increased posterior osteophytes at the C5-6 and C6-7 levels.8 The average age of the patient in the present series was 50.6 years. This is contrary to that reported in the international literature where C3-4 level CSM was seen in the age group greater than or equal to 65 years.[1,15,17]

The antero-posterior (AP) canal diameter is a good indicator of the existing myelopathy.[18,19] Disc protrusions, posterior

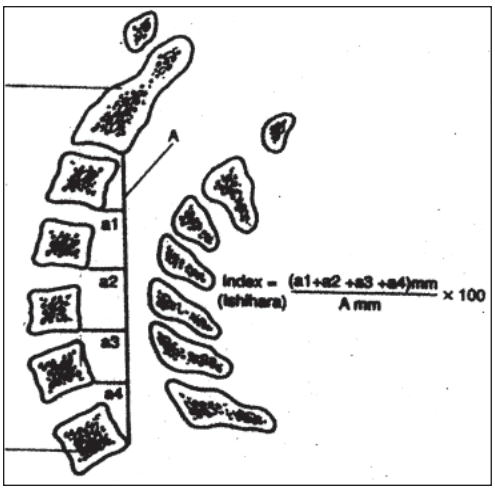

Figure 4: The sagittal T2 MR image depicting the compression at the C3-4 level with cord signal changes at the same level.

Table 3: A comparison of the preoperative mJOAS with the postoperative mJOAS and the recovery rate of patients of CSM with C3-4 involvement, calculated on the basis of modified Hirabayashi method.

Case	Preop mJOAS score	Postop mJOAS score	Recovery Percentage	Average recovery percentage
(GSH)	10	17	100	
(HLG)	12	17	100	
(AS)	8	15	77.7	
(CLS)	11	14	50	
(BKD)	15	16	50	
(NPS)	8	14	66.6	
(RPS)	12	15	60	
(RPP)	10	17	100	66.9
(RNS)	11	11	0	
(GS)	10	16	85.7	
(LS)	9	16	87.5	
(BL)	8	15	77.7	
(RSG)	2	8	40	
(LV)	5	10	41.6	
Mean	9.35	14.35		

osteophytes, infolding of the ligamentum flavum and a redundant annulus fibrosus are the well-known pathogenetic factors implicated in the development of myelopathy.[22,23,24,25] The risk of myelopathy increases when the static AP canal diameter is less than 13 mm.[20,21] The canal stenosis itself does not cause myelopathy but predisposes to an early development of myelopathy.[12] Penning[26] reported a pincer mechanism, whereby the spinal cord was pinched between the postero-inferior margin of the superior vertebral body and the antero-superior margin of the lamina of the inferior vertebra. This gets accentuated during motion. Hence the dynamic canal diameter is an important parameter in the evaluation of CSM. The dynamic canal diameter was significantly reduced at the C3-4 level in comparison to the lower segments in the present study (Table 1).

The reduction in the canal diameter between the static and dynamic measurements is significantly more at the C3-4 level as compared to the lower segments. This dynamic narrowing leads to myelopathy in these patients. This signifies that there was a decreased mobility at the lower cervical levels due to the degenerative changes and consequently an increased motion at the C3-4 level. The presence of posterior osteophytes and retrolisthesis were the major causes of dynamic narrowing at C3-4. Hayashi et al[17] also reported a significant reduction in both the static and dynamic canal diameters in patients with CSM as compared to the normal subjects. They concluded that posterior osteophytes at the C5-6 and C6-7 levels and retrolisthesis at the C3-4 or C 4-5 levels were the major causes of dynamic canal stenosis. Mihara et al[1] also reported the presence of significant segmental mobility at the C3-4 level and relatively less mobility at the lower motion segments.

An evaluation of the APCR revealed a good correlation between the severity of myelopathy and APCR.[14,17] The APCR was significantly reduced at the C3-4 level in the present study in comparison to the C4-5, C5-6 and C6-7 levels (Table 2). The severity of preoperative myelopathy correlated with

APCR. However, the majority of patients in the present series improved significantly irrespective of a low preoperative mJOAS or a low APCR. The recovery rate (RR) value was 66.9% in the present series (Table 3). However, there was one patient whose mJOAS of 11 did not change in the postoperative period Patient 9, (Table 3). The recovery rate signifies that the cervical compression was reversible and not chronic in most patients. This may also be due to the shorter duration of symptoms (average 10.6 months) and the younger age group (mean 50.6 years) seen in the present study. Hayashi et al[17] described an atrophic variety of cord that had a higher prevalence in the elderly patients when compared to their younger counterparts. These elderly patients had a longer duration of symptoms (mean 22 months) and had a poor outcome despite having undergone a spinal decompression.

The Ishihara index is a measure of the lordotic curve of the spine. The lordotic curve has been found to increase with age, especially in the elderly, in order to compensate for the thoracic kyphosis.[27] As the lower cervical segments fuse, the center of lordosis shifts to the C3-4 level. This leads to an increased angulation at the C3-4 level causing a reduction in the sagittal diameter of the spinal canal at this level. Moreover, the spinal cord shortens and its cross-sectional area increases in the extended posture of the neck.[28] Hence, an increased segmental angulation in itself places the cord at a significant risk of myelopathy.

Conclusions

C3-4 is an uncommon level for cervical spondylotic myelopathy. However, in the present series, the age group affected was significantly younger as compared to that reported in the international literature. Despite a low mJOAS, and a low APCR on MRI at the C3-4 level, there was a good recovery after surgery, possibly due to a shorter duration of symptoms and a younger age group. Does cervical spondylosis involve the Indian population at a younger age? The number of cases in the present series is too few and with too short a follow-up to come to a definite conclusion. However, it does suggest the predisposition of younger patients to developing cervical spondylosis. There is a need for a systematic study in the Indian population, both urban and rural, to determine the patterns of involvement of cervical spondylosis.

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