Original Article

# Cervical spondylosis in patients presenting with "severe" myelopathy: Analysis of treatment by multisegmental spinal fixation – A case series


## ABSTRACT

**Background:** Surgical strategy of multisegmental spinal fixation that includes atlantoaxial joint for patients having cervical spondylosis-related symptoms of severe myelopathy is analyzed.

**Objective:** Surgical outcome of patients presenting with "severe" symptoms of cervical myelopathy having multisegmental degenerative cervical spondylosis and treated by multisegmental spinal fixation is analyzed. Atlantoaxial joint was included in the fixation construct in majority of patients. No bone, soft tissue, osteophyte, or disc resection for decompression was done.

**Materials and Methods:** Sixty-four patients having multisegmental cervical spondylosis who presented with symptoms of severe myelopathy were surgically treated during the period from March 2013 to December 2018. On the basis of the concept that instability is the primary cause of spinal degeneration, multisegmental spinal fixation was done in all patients. Atlantoaxial joint was included in the fixation construct in 48 patients. The levels of spinal fixation were determined on the basis of direct observation of facet joints and by manual manipulation and were guided by the presenting clinical features and radiological information. Clinical monitoring was done using Goel clinical grading, modified Japanese Orthopedic Association Score, and visual analog score parameters. Patient satisfaction index assessed the functional and symptomatic improvement.

**Results:** During the follow-up that ranged from 6 to 75 months, all patients improved in their clinical status. Fifty-five (85.9%) patients could walk independently or with mild support.

**Conclusions:** Multisegmental spinal fixation that includes atlantoaxial joint in most patients forms a rational treatment strategy for patients of cervical spondylosis presenting with severe symptoms of myelopathy.


**Keywords:** Atlantoaxial dislocation, cervical spondylosis, decompressive laminectomy, osteophytes, spinal fixation, spinal instability

## INTRODUCTION

Cervical spondylosis is a common ailment worldwide and a cause of wide-ranging clinical symptoms related to spinal dysfunction.[1,2] We recently discussed the role of "only fixation" of the spinal segments as a method of surgical strategy for degenerative spinal disease[3] on the basis of our observation that spinal instability is the nodal point of pathogenesis.[3-7] The role of atlantoaxial instability in pathogenesis of cervical spondylotic disease and the need to include atlantoaxial joint in the fixation construct in selected cases were discussed.[8,9] We describe a series of 64 patients who presented with symptoms of severe cervical myelopathy and were unable to walk unaided when they submitted for surgical treatment. All patients were treated by multiple

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segment spinal fixation that included atlantoaxial joint in a majority of cases.

## MATERIALS AND METHODS

During the period from March 2013 to December 2018, 170 consecutive patients having symptoms related to cervical myelopathy were surgically treated in our neurosurgical departments (two centers). Of these, 64 patients had multisegmental cervical spondylosis and presented with symptoms related to "severe" myelopathy. The surgical treatment of this later subgroup of patients was retrospectively analyzed. All the patients provided written informed consent before surgery, and all clinical tests and surgical procedures were conducted according to the principles of Declaration of Helsinki. As the study is a retrospective analysis of data, and previously published surgical techniques were deployed, ethics committee permission was not deemed necessary. The ages of the patients ranged from 28 to 76 years (average 54.5 years). There were 60 males and 4 females. The presenting clinical features are elaborated in Table 1. Duration of symptoms ranged from 15 days to 20 years (average 16 months). The onset of symptoms was "acute" in seven patients and was probably related to mild or moderate trauma. The preoperative clinical status as assessed on Goel clinical scale, JOA, and visual analog score (VAS) are detailed in Tables 2–4. All patients underwent dynamic (head in neutral, flexed, and extended position) computed tomography (CT) scan and magnetic resonance imaging (MRI). All patients had multisegmental cervical spinal spondylosis-related cord compression. There was no radiologically demonstrable evidence of instability or malalignment in any subaxial spinal segment or spinal component. Clinical presenting features and radiological guides in the form of indenting osteophytes, bulging discs, and ligamentum flavum-related evidence of cord compression guided the level of subaxial facetal instability. Unstable spinal segments were identified and confirmed by the direct observation of the status of facets, their alignment, presence of paraarticular osteophytes, and instability on manual manipulations. Essentially, in the presence of severe neurological deficits, atlantoaxial instability was taken as present, unless radiological evidences of spinal degeneration were limited to only "lower" cervical spine (16 patients). Atlantoaxial instability was assessed by the status of facetal alignment on lateral/sagittal CT scan or MRI imaging with the head in neutral position.[10] Type 1 atlantoaxial facetal instability was when the facet of atlas was dislocated anterior to the facet of axis. Type 2 atlantoaxial facetal instability was when the facet of atlas was dislocated posterior to the facet of axis. In Type 3 atlantoaxial facetal instability, the facets were in alignment, and instability was diagnosed only by the direct manipulation of bones during surgery. There was no abnormal alteration of atlantodental interval or direct odontoid process-related cord compression at the craniocervical junction. Patients with type 1 atlantoaxial instability had odontoid process-related cord compression and an increase in atlantodental interval or had atlantoaxial instability as defined by the conventional radiological parameters. These patients were treated by only atlantoaxial fixation and have not been included in the series. Twenty-two patients had type 2 atlantoaxial facetal instability and 26 patients had type 3 atlantoaxial facetal instability. Patients with types 2 and 3 atlantoaxial instability were classified to have central or axial atlantoaxial instability and underwent atlantoaxial fixation along with subaxial spinal fixation. These patients are included in the study.

All patients were operated in prone position with the head end elevated by 30°. A Gardner–Wells cervical traction was applied after the induction of anesthesia and prior to turning the patient prone for surgery. Traction was used essentially to stabilize the head and keep the face and eyes away from the headrest and avoid direct contact pressure-related injury during the surgery. Atlantoaxial fixation was done by the techniques described by us in 1994 and 2004 and involved

**Table 1: The clinical and radiological features**

| Clinical/radiological feature | Number of patients |
|---|---|
| Sex | |
| Male | 60 |
| Female | 4 |
| Number of levels fixed | |
| Two levels | 5 |
| Three levels | 11 |
| Four levels | 21 |
| Five levels | 18 |
| Six levels | 9 |

**Table 2: Distribution as per Goel clinical grading system**

| Grade | Description | Number of patients (Pre-operative) | Number of patients (Post-operative) |
|---|---|---|---|
| Grade 1 | Independent and normally functioning | - | 18 |
| Grade 2 | Walks on own but needs support/help to carry out routine household activities | - | 26 |
| Grade 3 | Walks with minimal support and requires help to carry out household activities | 34 | 11 |
| Grade 4 | Walks with heavy support and unable to carry out household activities | 18 | 9 |
| Grade 5 | Unable to walk and dependant for all activities | 12 | - |

opening of the joint, denuding of the articular cartilage, and stuffing of bone graft within the joint cavity.[11,12] Plate and screw fixation of the lateral masses of atlas and axis was then done. In the later part of the series, to limit the neck movement restriction disability related to multilevel spinal fixation, a modified form of atlantoaxial stabilization was done in 16 cases. The modified technique involved sharp sectioning of muscles attached to the spinous process of C2 and C2-C3 transarticular fixation. C1 bone or atlantoaxial articulation was not directly involved in the fixation process. Subaxial spinal fixation was done by transarticular method of screw fixation by the technique described by Roy-Camille and Saillant.[13] Whenever the mobility of the facets was excessive and the articular cavity was relatively widely open, facet distraction technique that involved impaction of Goel facet spacer was used for fixation.[14,15] In five patients, facet distraction technique was used in selected levels. The number of spinal levels that were fixated is shown in Table 1. Bone graft was harvested from the iliac crest and was placed over the appropriately prepared recipient bones of the lamina and spinous process by widely drilling the outer cortex. All soft tissues in the region that included interspinous and interlaminar ligaments were resected using sharp instruments. No bone decompression in the form of laminectomy or foraminotomy was done.

## RESULTS

All patients had "significant" clinical improvement that was observed in the "immediate" postoperative period. The improvement was progressive. The average of total duration of hospital stay was 4 days. The follow-up ranged from 6 to 75 months. At follow-up of at least 6 months, 55 patients were able to walk independently or with minimal support. The progress in the clinical scores at maximum follow-up is detailed in Tables 2–5. The first author, at least two coauthors and an external monitor checked the accuracy of the clinical symptoms and neurological findings. The video recordings of both the preoperative and postoperative clinical status were done and were available for independent reviews by personnel not involved in the direct clinical study. In addition, the parameter of Patient Satisfaction Index (PSI), wherein the patient and the family members participated in the clinical interpretation was considered crucial to assess the outcome. The parameters used for this index are mentioned in Table 5. This was based on a series of simple questionnaire for the patient written in his or her own language. PSI assessed the functional and symptomatic recovery. There were no postoperative infective or implant failure-related complications. MRI and CT scan at 6 months after surgery showed the regression of the disc and/or osteophyte-related spinal cord compression in at least one or more spinal level in 39 cases [Figures 1-3] There was no clinical neurological worsening or recurrence of symptoms. There was no increase in size of the osteophyte or any evidence of worsening of neural compression in any case. Bone fusion was identified when the implant construct was intact and in position, and when bone formation could be observed along the articular facets. According to these criteria, bone fusion was successfully achieved in all patients at a minimum follow-up of 6 months. No patient had delayed neurological worsening that warranted the need for any kind of second surgery on the cervical spine. During the period of follow-up, there were no hospital readmissions for any related cervical spine treatment.

**Table 3: The preoperative and postoperative clinical assessment as per JOA scoring system**

| JOA score | Pre-operative (No. of patients) | Post-operative (No. of patients) |
|---|---|---|
| <7 | 39 | 5 |
| 8-12 | 25 | 7 |
| 13-15 | - | 36 |
| 16-17 | - | 16 |

**Table 4: Visual analog scale (0 - no pain, 10 - maximum pain)**

| VAS score | Preoperative | Postoperative | Postoperative (6 months) |
|---|---|---|---|
| Neck pain | 6.4 (4-9) | 1.6 (0-3) | 0.3 (0-1) |

VAS - Visual analog score

## DISCUSSION

In the year 2010, we proposed an alternative hypothesis of pathogenesis of degenerative spinal spondylosis.[4,5] It was proposed that long-term standing human posture and misuse or abuse of muscles results in "vertical" spinal instability that is manifested by listhesis or slipping of superior facet over the inferior facet could be the primary point of initiation

**Table 5: Patient satisfaction index**

| Parameter | Score 0 (not satisfied) | Score 1 (minimally satisfied) | Score 2 (satisfied) | Score 3 (remarkably satisfied) |
|---|---|---|---|---|
| Are you happy with the operation? | - | - | - | 64 |
| Are you relieved of sensory symptoms? | - | - | 8 | 56 |
| Can you make your fist/handgrip better? | - | 1 | 4 | 59 |
| Can you move your shoulders better? | - | 2 | 9 | 53 |
| Can you walk better? | - | - | 9 | 55 |

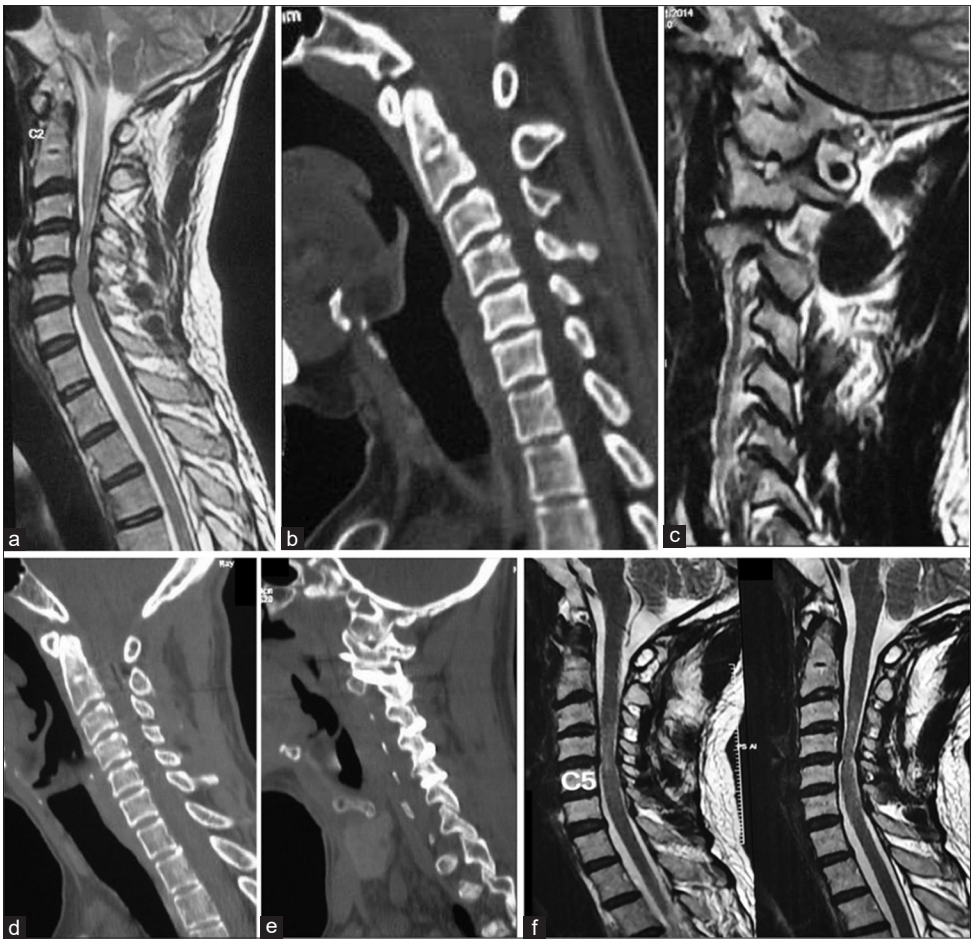


**Figure 1: Images of a 40-year-old male. (a) T2-weighted magnetic resonance imaging showing evidence of multilevel spinal cord compression by osteophytes and buckled ligamentum flavum. (b) Computed tomography scan showing no evidence of atlantoaxial instability. (c) Magnetic resonance imaging cut passing through the facets showing type 2 atlantoaxial facetal instability. (d) Postoperative computed tomography scan. No bone decompression is seen. (e) Computed tomography scan cut passing through the facets showing C1-2, 2-3, 3-4, 4-5, and 5-6 fixation. (f) Postoperative magnetic resonance imaging 6 months after the surgery shows reduction in the extent of neural compression by the osteophytes and bulging ligamentum flavum**

of the entire process of spinal degeneration and all its manifestations.[7] The issues such as old age with limited neck movements, lack of exercise, obesity, and malnutrition have been generally implicated to be the possible cause of development of spinal instability and progress of degenerative disease. In general, vertical spinal instability is usually not focal or at a single spinal level, but it is multisegmental.[7]

Vertical instability or listhesis of superior facet over the inferior facet results in reduction in the intervertebral height. This leads to buckling or infolding of all intervertebral ligaments. Ligmentum flavum buckles and in folds. Similarly, the posterior longitudinal ligaments bulges and infolds and appears initially as a posterior bulge of the disc. In the long run, osteophytes are formed along the posterior longitudinal ligament in proximity of the vertebral bodies. Osteophytes progressively enlarge and protrude into the spinal canal. Disc space reduction is a consequence of vertical spinal instability and reduction in the intervertebral distance. Essentially, our understanding suggests that disc space reduction could be a secondary phenomenon and not a primary degenerative process as has been widely accepted. The entire process leads to reduction in the spinal canal and in the root canal dimensions.[4,5,7]

The validity of the hypothesis is evident by the success of surgical technique of facet distraction by employing Goel facet distraction spacers.[14-16] The aim of the surgery was to achieve reversal of vertical facetal listhesis and arthrodesis of the involved spinal segment. It was identified that the distraction of facets resulted in unbuckling of the ligamentum flavum and posterior longitudinal ligaments. The disc space increased and there was evidence of fresh "water" collection in the disc. The entire process results in an increase in the spinal canal and root canal dimensions.[4,5,17] Remarkable clinical recovery was observed following facet distraction surgery in the immediate postoperative period and on long-term follow-up assessments.[14-16]

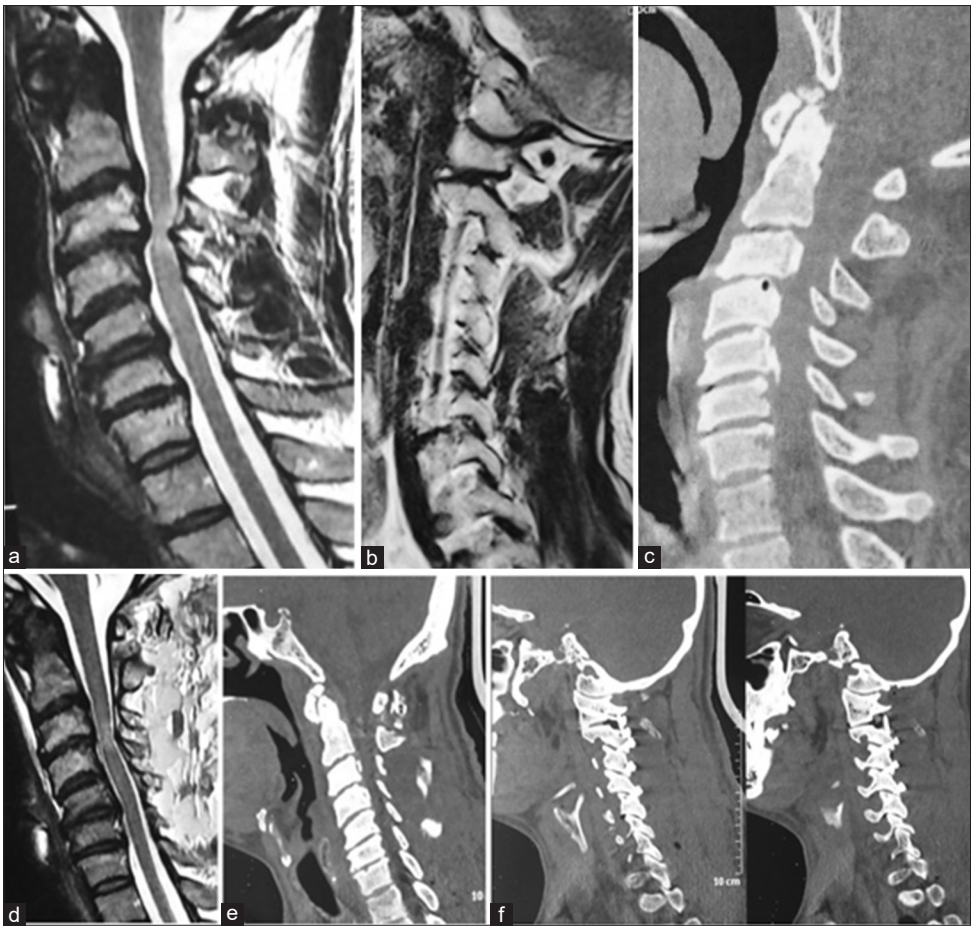


**Figure 2: Images of a 52-year-old male patient. (a) T2-weighted magnetic resonance imaging shows evidence of cervical spondylosis. (b) Magnetic resonance imaging showing type 2 atlantoaxial facetal instability. (c) Computed tomography scan shows normal atlantodental interval. (d) Postoperative Magnetic resonance imaging 12 months after surgery shows reduction in size of osteophytes and related cord compression. (e) Postoperative computed tomography scan. No bone decompression is done. (f) Postoperative computed tomography scan showing C1-2, 2-3, 3-4, and 4-5 fixation**

Lateral location of the facets and their oblique profile makes identification of instability on dynamic imaging difficult or impossible even on modern computer-based imaging. Considering that the cord compression, cord deformation, and cord structural changes are clearly evident on both CT scan and MRI, the entire focus of the surgical treatment has traditionally been on relieving the cord of bone, osteophyte, disc and ligamentous compression. Our further clinical studies identified that it is not cord compression or deformation that is the primary cause of symptoms in degenerative spinal disease, but it is repeated microinjuries related to subtle instability that causes symptoms. The surgery was aimed at "only-fixation" as the treatment. Unstable spinal levels were identified by the direct visualization of the facets on the basis of leads provided by clinical presenting features and radiological imaging. The lateral location and oblique profile of the facetal articulation make radiological identification of instability impossible. It was observed that more than imaging, it was direct visualization of alignment and status of the facets and identification of instability of the facets by direct handling of the bones during the surgery that is crucial to determine the levels of unstable spine.[18,19] We identified that the treatment of single or multilevel spinal degeneration by only fixation resulted in gratifying clinical recovery. It was concluded that transarticular method of screw implantation is a safe, effective, and straightforward surgical procedure for subaxial spinal fixation.[3]

Atlantoaxial joint is the most mobile joint of the body. Its flat and round articular surfaces allow circumferential movements. However, the joint architecture also subjects it to the possibility of instability. "Degeneration" of the atlantoaxial joint has only rarely been identified and reported. Our experience in the field suggests that more the mobility of a joint, higher is the possibility of development of instability. As per this understanding, atlantoaxial joint is the most likely joint to undergo degenerative changes. In our article on the subject,[8,9,20,21] it was identified that atlantoaxial joint instability-related segmental degeneration could be an associated or even a primary factor in the development

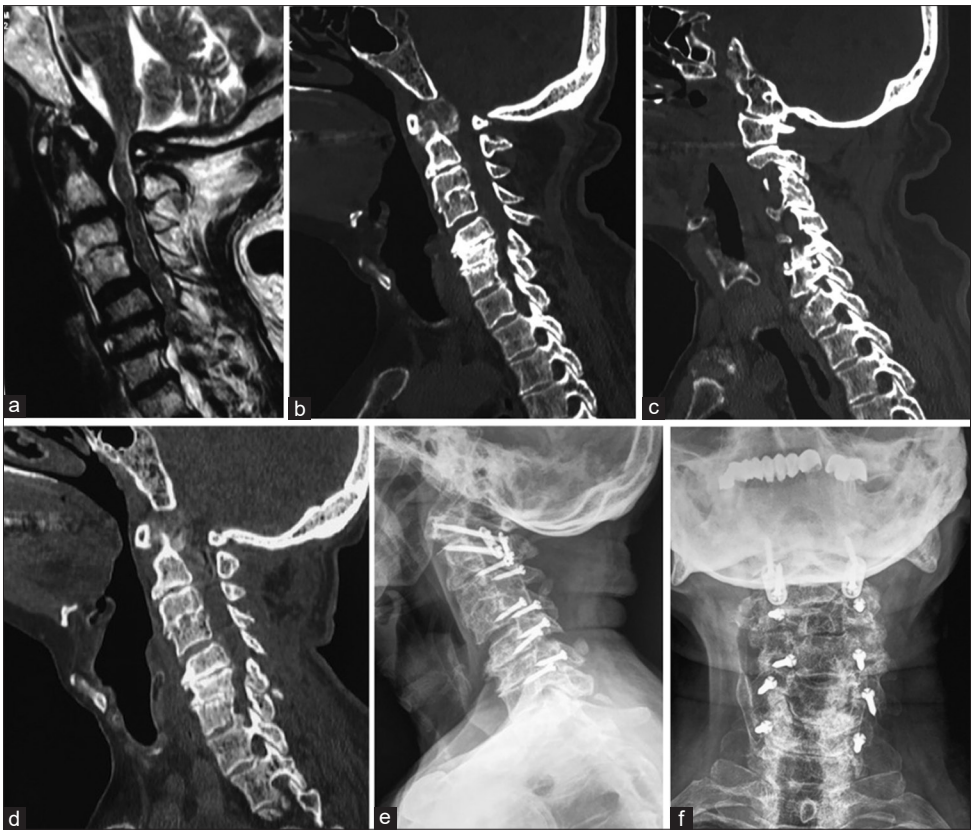


**Figure 3: Images of a 74-year-old male patient. (a) Magnetic resonance imaging showing multilevel spinal degeneration. C3-4 fusion is seen. Osteophytes are seen posterior to odontoid process and in multiple levels in the subaxial cervical spine. (b) Computed tomography scan showing multilevel spinal degeneration, worse being at the C1-2 region. (c) Computed tomography scan showing degenerative changes in the facets. (d) Postoperative computed tomography scan. There is no bone decompression. (e) Postoperative lateral X-ray shows the metal implant and fixation. (f) Anteroposterior view of the X-ray showing the implant**

of multisegmental cervical spinal degeneration. Accordingly, we stressed the need for atlantoaxial stabilization in selected cases with multilevel spinal degeneration.[8,9,21]

Atlantoaxial dislocation is identified on the basis of facetal alignment and on direct observation of instability by manual manipulation of bones during surgery. In Type 1 facetal instability, the odontoid process directly indented into the neural structures. It was observed that in such cases, the multisegmental spinal degenerative changes observed in the subaxial spine were secondary in nature to primary atlantoaxial instability. Atlantoaxial fixation was done in such cases, and there was no need to address the secondary subaxial spine alterations. Such cases were not included in the study, as they form a discrete clinical subgroup. In types 2 and 3 facetal instability, atlantoaxial joint was unstable, but there was no direct compression of the neural structures by odontoid process, and the atlantodental interval was within the normal range. Such instability has been referred to as central or axial atlantoaxial instability.[10] It was observed that central or axial atlantoaxial instability was frequently associated with multilevel spinal degenerative spondylotic disease, particularly when it was associated with severe neurological deficits and myelopathy. In cases with central or axial atlantoaxial instability, it is unclear if atlantoaxial instability is the primary or nodal point of pathogenesis of the entire "degenerative process" that includes the subaxial cervical spine or is one of the components of multilevel spinal instability. Majority of patients underwent atlantoaxial stabilization along with multilevel subaxial stabilization. Subaxial spinal stabilization was done by transarticular fixation technique as described by Roy-Camille and Saillant.[13] In five cases, facet distraction fixation was done, at least in some spinal segments. Facet distraction stabilization was done essentially when the facets were markedly unstable. The articular cartilage was widely denuded, and Goel facet spacer was impacted into the articular cavity. Essentially, the aim of facet distraction-stabilization was to provide a firm fixation and an environment suitable for bone arthrodesis. No bone or soft tissue "decompression" was done either from an anterior or a posterior route. To limit the disability related to multilevel spinal fixation that included atlantoaxial joint, in the later part of the series, an alternative form of atlantoaxial stabilization was done. The technique involved

sharp sectioning of the muscles attached to the C2-spinous process and C2-3 transarticular fixation. The technique blocked the critical anteroposterior movements of the odontoid process orchestrated by the muscles attached to the C2 spinous process and retained the rotatory movements of the atlantoaxial joint essentially executed by the muscles attached to the transverse process of the atlas. Although the exact range of preservation of neck movements by such a technique cannot be confirmed due to heterogeneity of the patient population, the preservation of critical rotatory neck movements does seem to be of significant functional benefit.

Our literature search of cases of cervical spondylosis presenting with severe or very severe symptoms related to myelopathy revealed that although effective and the extent of improvement is substantial, the results of decompressive surgical treatment were only marginally successful, and the patients continued to have "significant" residual neurological deficits.[22-24] Although exact comparison with other clinical reports on the subject is difficult or impossible to make, it appears that the results of our surgical treatment that involved only spinal stabilization were significantly superior to that obtained by surgical treatment that involved decompression of bone and soft tissue elements. In the various reported case series, the bulk of clinical improvement treated by decompressive surgery has been identified 6 months postoperatively; all our patients showed significant clinical symptomatic improvement in the "immediate" postoperative period. At a minimum follow-up of 6 months, we achieved remarkable and gratifying clinical results in 100% patients. Fifty-five (85.9%) patients who were not able to stand or walk unaided could do so by themselves with minimum or no support. All eight patients who had urinary and/or bowel incontinence regained control. Apart from Goel clinical grading scale, validated and universally accepted clinical assessment tools that included the modified Japanese Orthopedic Association scale[25,26] and VAS were used to score the clinical status both before and after the surgery and at follow-up. The parameter of PSI was based on a series of questions that were posed to the patient and to the caretakers. PSI evaluated the major clinical symptoms and related neurological changes after the surgical procedure. The validity of the index as a guide to confirm the degree of surgical success will have to be assessed on further studies and experience. However, it did suggest that the patients were uniformly and "significantly" satisfied with the outcome. Longer duration of disease has also been identified to be a poor prognostic factor for recovery.[22,27-31] The duration of symptoms in our patients ranged from 15 days to 20 years (average 16 months). Despite this long duration of symptoms, the clinical outcome was uniformly satisfactory. The positive clinical outcome provides justification to the proposed concept of surgical treatment. Although the duration of follow-up is relatively short, in none of the treated cases was there a postoperative or delayed neurological worsening. There were no surgery-related complications. During the period of follow-up, no patient needed a reoperation on the cervical spine. Regression in the size of the osteophyte/bulging disc and related cord compression could be clearly appreciated in at least 39 (60.9%) cases. Such regression in the size of disc bulge/osteophyte has not been recorded earlier in the literature. The observation that the osteophytes regressed after segmental spinal fixation suggests that osteophytes are a secondary feature to primary spinal instability. There was no increase in the size of the osteophyte, ligamentum flavum, or disc bulge-related cord indentation in any case. Considering that no patient underwent any bone, soft tissue, disc, or osteophyte resection and still improved in their neurological function suggests the need of reevaluation of "decompression" as a form of widely performed surgical strategy. The indications of inclusion of the atlantoaxial joint in the fixation construct will have to be evaluated by other groups.

Limitation of the study was that no randomized or double-blinded clinical comparison utilizing scientific protocol was done. The study assesses the postoperative and early clinical outcome of patients. Delayed and long-term outcome of the proposed surgical strategy will have to be assessed.

## CONCLUSIONS

Instability of spinal segments is the nodal point of pathogenesis of cervical spondylotic disease. In cases presenting with severe myelopathy, the instability is multisegmental and more often includes atlantoaxial joint. Only stabilization of spinal segments is a rational and effective mode of surgical treatment.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

## REFERENCES


1. Baron EM, Young WF. Cervical spondylotic myelopathy: A brief review of its pathophysiology, clinical course, and diagnosis. Neurosurgery 2007;60:S35-41.
2. Fehlings MG, Tetreault LA, Wilson JR, Skelly AC. Cervical spondylotic myelopathy: Current state of the art and future directions. Spine (Phila Pa 1976) 2013;38:S1-8.
3. Goel A. 'Only fixation' as rationale treatment for spinal canal stenosis. J Craniovertebr Junction Spine 2011;2:55-6.
4. Goel A. Facet distraction spacers for treatment of degenerative disease of the spine: Rationale and an alternative hypothesis of spinal degeneration. J Craniovertebr Junction Spine 2010;1:65-6.
5. Goel A. Facet distraction-arthrodesis technique: Can it revolutionize spinal stabilization methods? J Craniovertebr Junction Spine 2011;2:1-2.
6. Goel A. Is it necessary to resect osteophytes in degenerative spondylotic myelopathy? J Craniovertebr Junction Spine 2013;4:1-2.
7. Goel A. Vertical facetal instability: Is it the point of genesis of spinal spondylotic disease? J Craniovertebr Junction Spine 2015;6:47-8.
8. Goel A. Posterior atlantoaxial 'facetal' instability associated with cervical spondylotic disease. J Craniovertebr Junction Spine 2015;6:51-5.
9. Goel A. Atlantoaxial instability associated with single or multi-level cervical spondylotic myelopathy. J Craniovertebr Junction Spine 2015;6:141-3.
10. Goel A. Goel's classification of atlantoaxial "facetal" dislocation. J Craniovertebr Junction Spine 2014;5:3-8.
11. Goel A, Desai KI, Muzumdar DP. Atlantoaxial fixation using plate and screw method: A report of 160 treated patients. Neurosurgery 2002;51:1351-6.
12. Goel A, Laheri V. Plate and screw fixation for Atlanto-axial subluxation. Acta Neurochir (Wien) 1994;129:47-53.
13. Roy-Camille R, Saillant G. Surgery of the cervical spine 2. Dislocation. Fracture of the articular processes. Nouv Presse Med 1972;1:2484-5.
14. Goel A, Shah A. Facetal distraction as treatment for single- and multilevel cervical spondylotic radiculopathy and myelopathy: A preliminary report. J Neurosurg Spine 2011;14:689-96.
15. Goel A, Shah A, Jadhav M, Nama S. Distraction of facets with intraarticular spacers as treatment for lumbar canal stenosis: Report on a preliminary experience with 21 cases. J Neurosurg Spine 2013;19:672-7.
16. Goel A, Shah A, Patni N, Ramdasi R. Immediate postoperative reversal of disc herniation following facetal distraction-fixation surgery: Report of 4 cases. World Neurosurg 2016;94:339-44.
17. Shah A. Morphometric analysis of the cervical facets and the feasibility, safety, and effectiveness of Goel inter-facet spacer distraction technique. J Craniovertebr Junction Spine 2014;5:9-14.
18. Goel A. Beyond radiological imaging: Direct observation and manual physical evaluation of spinal instability. J Craniovertebr Junction Spine 2017;8:88-90.
19. Goel A, Dharurkar P, Shah A, Gore S, Bakale N, Vaja T, *et al.* Facetal fixation arthrodesis as treatment of cervical radiculopathy. World Neurosurg 2019;121:e875-e881.
20. Goel A, Dhar A, Shah A, Jadhav D, Bakale N, Vaja T. Central or axial atlantoaxial dislocation as a cause of cervical myelopathy: A report of outcome of 5 cases treated by atlantoaxial stabilization. World Neurosurg 2019;121:e908-e916.
21. Goel A. Is atlantoaxial instability the cause of "high" cervical ossified posterior longitudinal ligament? Analysis on the basis of surgical treatment of seven patients. J Craniovertebr Junction Spine 2016;7:20-5.
22. Kopjar B, Bohm PE, Arnold JH, Fehlings MG, Tetreault LA, Arnold PM. Outcomes of surgical decompression in patients with very severe degenerative cervical myelopathy. Spine (Phila Pa 1976) 2018;43:1102-9.
23. Yoon ST, Raich A, Hashimoto RE, Riew KD, Shaffrey CI, Rhee JM, *et al.* Predictive factors affecting outcome after cervical laminoplasty. Spine (Phila Pa 1976) 2013;38:S232-52.
24. Ebersold MJ, Pare MC, Quast LM. Surgical treatment for cervical spondylitic myelopathy. J Neurosurg 1995;82:745-51.
25. Benzel EC, Lancon J, Kesterson L, Hadden T. Cervical laminectomy and dentate ligament section for cervical spondylotic myelopathy. J Spinal Disord 1991;4:286-95.
26. Fujiwara A, Kobayashi N, Saiki K, Kitagawa T, Tamai K, Saotome K. Association of the Japanese orthopaedic association score with the oswestry disability index, Roland-Morris disability questionnaire, and short-form 36. Spine (Phila Pa 1976) 2003;28:1601-7.
27. Takeoka Y, Kaneyama S, Sumi M, Kasahara K, Kanemura A, Takabatake M, *et al.* Postoperative walking ability of non-ambulatory cervical myelopathy patients. Spine (Phila Pa 1976) 2018;43:E927-E934.
28. Haddas R, Lieberman I, Arakal R, Boah A, Belanger T, Ju K. Effect of cervical decompression surgery on gait in adult cervical spondylotic myelopathy patients. Clin Spine Surg 2018;31:435-40.
29. Nouri A, Tetreault L, Zamorano JJ, Dalzell K, Davis AM, Mikulis D, *et al.* Role of magnetic resonance imaging in predicting surgical outcome in patients with cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2015;40:171-8.
30. Nakashima H, Yukawa Y, Ito K, Machino M, Kanbara S, Morita D, *et al.* Prediction of lower limb functional recovery after laminoplasty for cervical myelopathy: Focusing on the 10-s step test. Eur Spine J 2012;21:1389-95.
31. Matsuda Y, Shibata T, Oki S, Kawatani Y, Mashima N, Oishi H, *et al.* Outcomes of surgical treatment for cervical myelopathy in patients more than 75 years of age. Spine (Phila Pa 1976) 1999;24:529-34.