

Anterior Deformity Correction in Cervical Spondylotic Myelopathy

¹Anil Pande, ²Daniel Rajesh Babbu, ³Siddhartha Ghosh

ABSTRACT

Deformity in the cervical spine is ascribed to congenital, degenerative, traumatic, infective, neoplastic, iatrogenic causes. The deformity can be in the sagittal and coronal plane and is an important factor in the generation of symptoms in cervical spondylotic myelopathy (CSM). Better understanding of the etiopathogenesis, imaging and improving instrumentation allows for the tackling of these deformities. Correction requires to be tailored to each patient and may require anterior, posterior or combined approaches.

Keywords: Cervical, Spondylotic myelopathy, Deformity correction.

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INTRODUCTION

Cervical spondylosis as a distinct clinical entity was described rather late in 1952 by Brain and Northfield⁵ as degenerative changes of the spine, nerve roots and the spinal cord causing canal and foraminal compromise leading to myelopathy and radiculopathy. This is the most prevalent cause of acquired myelopathy in adults and is definitively the most common cause of myelopathy in the elderly.^{2,28,41}

Deformity in the cervical spine is ascribed to congenital, degenerative, traumatic, infective, neoplastic, iatrogenic causes.^{3,4,21,22} The deformity can be in the sagittal and coronal plane and is an important factor in the generation of symptoms.^{20,32} Treatment protocols in the dorsal and lumbosacral deformities are well-established. The treatment of cervical deformity is evolving. Cervical spondylotic myelopathy is very common and is tackled by neurosurgeons by anterior microdiscectomy and corpectomy depending on whether the pressure is opposite the disk space or the body. Posterior approaches have their indications which include deformity correction. The spine has complex natural curves which develop to reach the adult configuration and these are

very important from the point of biomechanics.^{8,28,30,39} Each curve in turn affects the global sagittal balance.^{15,24,28,33,37} The importance of the normal curves of the spinal column is often not appreciated and even in asymptomatic and normal individuals the radiology can be alarming at times. The spinal curvature between C2 and C7 has the widest range of 'normal' as compared with any other region of the spine as reported by Kuntz et al.²⁴ As populations age the problems due to loss of the sagittal and coronal balance become more evident and large number of patients with cervical spondylotic changes present with deformity which by itself is an important factor causing myelopathy and the spinal kyphosis is reported to be an independent cause of demyelination and neuronal loss in the spinal cord.^{20,32,38,40}

The anterior strategies^{3,4,13,36,41} in tackling the deformities of the cervical spine have been gaining in popularity and are currently favored over the posterior ones^{9,10,19} due to the adage that the anterior problem needs to be tackled from anterior and a corridor that allows for a single stage decompression and correction of deformity and stabilization is indeed ideal. The pioneering efforts of Bohler (1964) Smith Robinson, Cloward, Caspar⁶ and the use of the operating microscope dedicated microinstruments and better spinal implants and electrophysiological intraoperative monitoring have made this corridor a safe and reliable route for accessing a wide spectrum of pathology.

The biomechanics of cervical spondylotic spine with both static and dynamic factors is implicated in the complex march of degeneration.^{1,2,4,39} Congenital and acquired canal stenosis, disk degeneration, abnormal mobility and instability, pincer mechanism of penning are the various factors causing damage in cervical spondylitic myelopathy but deformity is the most under recognized factor.

The Dubousset's 'conus of economy' theory states that body adapts to changes in balance in order to regulate the center of gravity over as narrow a perimeter as possible. As with other parts of the spine the disability of the neck increases with progressive cervical standing sagittal malalignment.^{30,33}

METHODS OF MEASURING THE SAGITTAL BALANCE

The patients who present with clinical features of cervical spondylotic myelopathy are evaluated initially with plain X-rays of the cervical spine in the standing position pre-

^{1,2}Senior Consultant, ³Director

¹⁻³Department of Neurosciences, Apollo Speciality Hospitals Chennai, Tamil Nadu, India

Corresponding Author: Anil Pande, Senior Consultant Department of Neurosciences, Apollo Speciality Hospitals Chennai, Tamil Nadu, India, e-mail: profpande@yahoo.com

ferably to know the true cervical alignment. The different methods commonly used are the straight-line method, posterior tangent method or the regional Cobb's angle method.⁷ Effective lordosis: is currently the method of choice in the analysis of sagittal spinal canal alignment in cervical spondylotic myelopathy. The effective lordosis of the spinal canal is calculated by drawing a line from the dorsalcaudal aspect of the C-2 vertebral body to the dorsalcaudal aspect of the C-7 vertebral body. Gwinn et al¹⁸ elaborate that the effective lordosis measurement method provides a simple and reliable means of determining clinically significant lordosis because it accounts for both overall alignment of the cervical spine as well as impinging structures ventral to the spinal cord. They propose that this method should be considered for use in the treatment of patients with CSM.

WHY CORRECT THE DEFORMITY IN CERVICAL SPONDYLOTIC MYELOPATHY?

Cervical and thoracic kyphotic deformity increases spinal cord intramedullary pressure (IMP) and Winestone et al,⁴⁰ in a recent cadaveric study found that laminar decompression reduced change in intramedullary pressure (Δ IMP) by approximately 15 and 25%, while correction of the kyphotic deformity returned change in IMP (Δ IMP) to zero. They explain the etiogenesis and the pathophysiology of myelopathy in kyphotic deformity and the reason for failure of laminectomy alone in cervical and thoracic kyphotic deformities with myelopathy. This cadaveric study emphasizes the need for correction of deformity during operative treatment of kyphotic deformity.

Goel and Shah¹⁶ found that features characteristically associated with basilar invagination such as a short neck, exaggerated neck lordosis, torticollis, cervical spondylotic changes and fusions are potentially reversible after decompression and stabilization of the craniovertebral junction.

The effects of these deformities causing mechanical trauma leading to spondylotic myelopathy, or the reduction and fusion of kyphotic sagittal alignment have not been consistently documented. Uchida et al²³ determined the effects of kyphotic sagittal alignment of the cervical spine in terms of neurological morbidity and outcome after 2 types of surgical intervention and found that kyphotic deformity and mechanical stress in the cervical spine plays an important role in neurological dysfunction. They concluded that in a select group of patients with kyphotic deformity $\geq 10^\circ$, adequate correction of local sagittal alignment may help to maximize the chance of neurological improvement.

Glassman et al¹⁵ point out that the sagittal spinal alignment in deformity as measured by use of C7 plumb line is more related to disability than the coronal deformity and the severity of symptoms increases with progressive sagittal

malalignment. Thus, sagittal deformity causes disability and correction leads to better outcome. Smith et al³³ reported on the spontaneous improvement of cervical alignment after correction of global sagittal balance following pedicle subtraction osteotomy. Sagittal spinopelvic malalignment according to them is a significant cause of pain and disability in patients with adult spinal deformity. Surgical correction of spinopelvic malalignment can result in compensatory changes in spinal alignment outside of the fused spinal segments. These, compensatory changes are termed reciprocal changes. Adults with positive sagittal spinopelvic malalignment compensate with abnormally increased cervical lordosis in an effort to maintain horizontal gaze. Surgical correction of sagittal malalignment results in improvement of the abnormal cervical hyperlordosis through reciprocal changes.

Any procedure which will permit further kyphotic deformity, such as laminectomy, is contraindicated and Kaptain et al²¹ found that kyphosis may develop in up to 21% of patients who have undergone laminectomy for CSM. Progression of the deformity appears to be more than twice as likely if preoperative radiological studies demonstrate a straight spine. Houten and Cooper¹⁹ suggest that multilevel laminectomy and instrumentation with lateral mass plates is associated with minimal morbidity, provides excellent decompression of the spinal cord (as visualized on MRI), produces immediate stability of the cervical spine, prevents kyphotic deformity, and precludes further development of spondylosis at fused levels. Neurological outcome is equal or superior to multilevel anterior procedures and prevents spinal deformity associated with laminoplasty or noninstrumented laminectomy.

PREOPERATIVE ASSESSMENT

The patients with cervical spondylotic myelopathy after a detailed clinical and radiological workup⁸ are positioned on the operating position to evaluate the flexibility of the neck and curve and safety of the positioning. Many elderly patients do not rest on the head ring due to excessive stiffness and calcification of ligaments especially patients with DISH.

SURGERY FOR ANTERIOR DEFORMITY CORRECTION

Muthukumar²⁶ in a comprehensive review of management of spondylotic myelopathy stresses on the importance of proper clinical and radiological evaluation prior to the surgical procedure. The biomechanics, static and dynamic factors involved should all be addressed before surgery and instrumentation. The approach whether anterior, posterior or combined¹¹⁻¹⁴ needs to be decided with thorough evaluation of clinical, radiological and medical factors, i.e. co morbidity assessment and control. Diabetes is an important variable affecting prognosis.



PROCEDURE

The patient is positioned supine with head resting on a head ring or fixed in a 3 pin fixator. Skeletal tong traction is also occasionally used. A sand bag under the shoulder is placed to recreate the normal lordosis, the endotracheal tube is taken straight and backwards and the cuff is periodically decuffed. The neck and iliac graft site are prepped and prepared. Motor and sensory evoked potential monitoring is routinely used. Standard vertical and horizontal neck incisions are made as necessary and the subaxial spine is accessed using blunt dissection keeping the trachea and esophagus in midline and carotid sheath laterally to reach the anterior aspect of vertebral bodies. The self-retaining Clowards retractor or the more flexible Langenbeck retractors are used to gently retract the soft-tissues to reach the anterior surface of vertebral bodies, the radiographs are reviewed and a C-Arm image is taken to confirm the level. Microscope is brought into use and after removing the anterior osteophytes and calcification discectomy is done vertebra spreader or postretraction is done to distract the disk space and complete discectomy is done with the removal of osteophytes using curettes or a high speed drill. Associated OPLL may require a extension of the operative field and conversion into a corpectomy. Adequate gardening and preparation of the disk space is done and the C-Arm images are studied to decide on the correction strategy for the deformity. Fixed deformities will require a corpectomy and fusion. Use of differential sizes of grafts, spacers or cages is done to recreate normal lordosis. The precontoured modern plates with variable or fixed screws are used. The upper and lower body screws are tightened and then the middle body is pulled toward the plate by tightening the

middle screws. The curve is recreated and maintained. Check C-Arm images are taken to confirm the implant and restoration of the curve.

ANTERIOR POSTERIOR OR CIRCUMFERENTIAL

The optimal surgical decompression strategy for CSM has not been defined and Ghogawala et al¹⁴ in a survey of a group of spine surgeons concerning the surgical approach to CSM in a cohort of patients found that 51% recommended ventral surgery, 38% dorsal surgery, and 11% a combined approach showing significant variation.

Steinmetzs et al^{34,35} indicate that depending on flexibility of the deformity and the presence or absence of facet ankylosis, a dorsal, ventral, or combined approach may be used. All approaches are unique in their ability to correct a deformity and in their associated complications.

Benzel et al³⁶ described a anterior deformity correction technique where a precontoured plate is used to correct deformity by pulling the middle body by differential tightening of screws (Figs 1 to 4). Most of the deformities in CSM are flexible and after doing decompression and adequate gardening and recontouring of bodies the multisegmental sagittal balance of these cervical spines can be restored and maintained using modern anterior instrumentation. Fixed deformity, osteoporosis, long segment involvement, coexisting OPLL are relative contraindications.

Epstein et al¹⁰ found that the success of a posterior procedure like laminectomy was dictated by the preservation of cervical lordosis and in patients with major dorsally located abnormalities, such as hyperlordosis, shingling and arthrosis with hypertrophy of the yellow ligaments, posterior-decompression was essential.

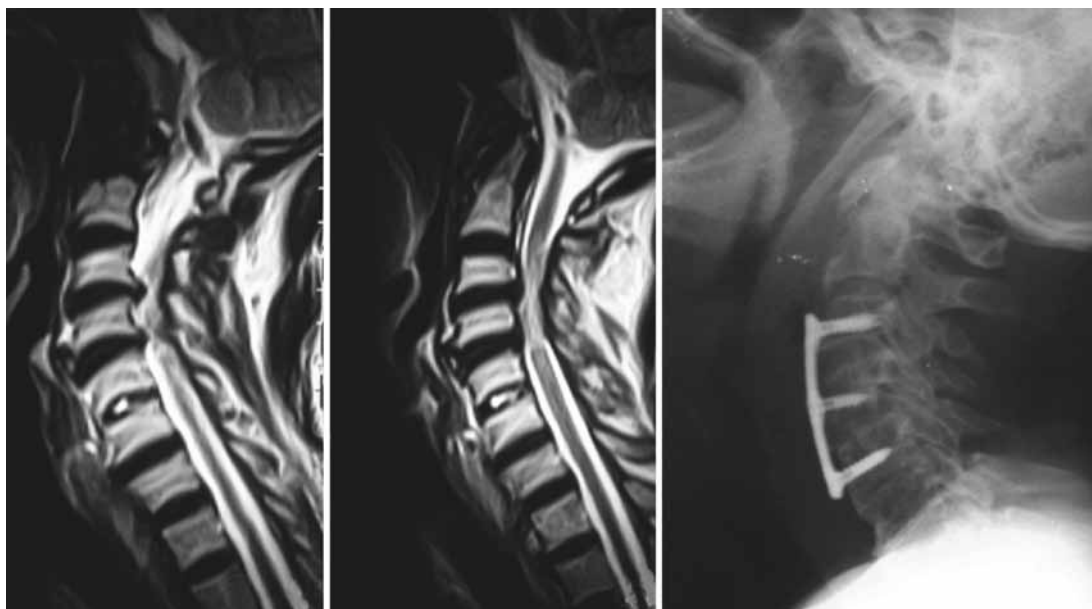
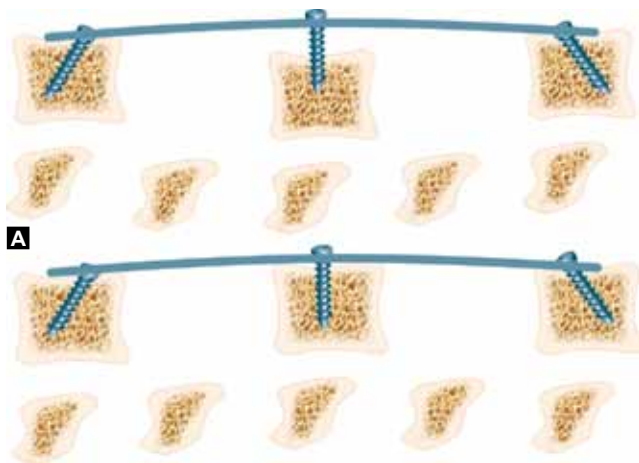


Fig. 1: Anterior decompression and deformity correction



B Figs 2A and B: The ventral deformity correction technique of Bazel

The treatment of fixed cervical kyphosis with myelopathy using circumferential spinal osteotomies and instrumented reconstruction is technically demanding; however, restoration and maintenance of a neutral or lordotic cervical profile and excellent clinical outcomes are achievable as demonstrated by O'Shaughnessy et al.²⁷

Mummaneni²⁵ reported on circumferential correction of cervical kyphosis, with decompression, osteotomy and stabilization from both anterior and posterior approaches to restore cervical lordosis. They reported measurable improvements in neurological function (as measured with Nurick grades and MJOA scores) and achieved high fusion rates. They reported a significant rate of complications.

Aguste KI et al³ pointed out the advantages of cervical expandable cages, i.e. ease of insertion, reduced endplate trauma, direct application/maintenance of interbody distraction force, and one-step kyphosis correction. They found expandable cylindrical cages to be well suited for cervical reconstruction and for correcting sagittal malalignment.

In Tables 1 and 2 reproduced from Ke Han et al²² demographic data and clinical outcomes can be reviewed of various surgical series dealing with cervical kyphosis.

OUTCOMES

Outcome analysis in CSM is not an easy proposition due to the range of variables and a few prospective multicenter studies with independent clinical review have been published.²⁹ Etame et al¹² reviewed the long-term functional and radiographic outcomes following surgery (ventral, dorsal or circumferential approaches) for symptomatic cervical kyphosis and found on analysis of the degree of deformity correction and functional parameters significant postsurgical improvement. Overall, patient satisfaction appeared to be high. Five studies reported mortality with rates ranging from 3.1 to 6.7%. Major medical complications after surgery were reported in 5 studies with rates ranging from 3.1 to 44.4%. The overall neurological complication rate was 13.5%.

Ferch et al¹³ in a series of 28 patients reported local deformity was corrected to neutral or lordosis in 24 cases (89%), and the overall cervical curve was corrected to neutral or lordosis in 20 cases (74%). There was a significant improvement in myelopathy scores in those patients in whom the target (0 to 4° of lordosis) local angle was achieved ($p = 0.04$). There was a variable change in overall cervical sagittal alignment following local correction.

Zedlick and Bohlman⁴¹ reported on treatment of by anterior corpectomy and strut-grafting in series of patients with cervical kyphosis and myelopathy and an average correction kyphotic deformities of 32°, a reduction from an average of 45° to an average of 13° was achieved and they concluded that, in the presence of severe cervical kyphosis and myelopathy, adequate anterior decompression of the spinal cord, correction of the kyphosis, and anterior arthro-

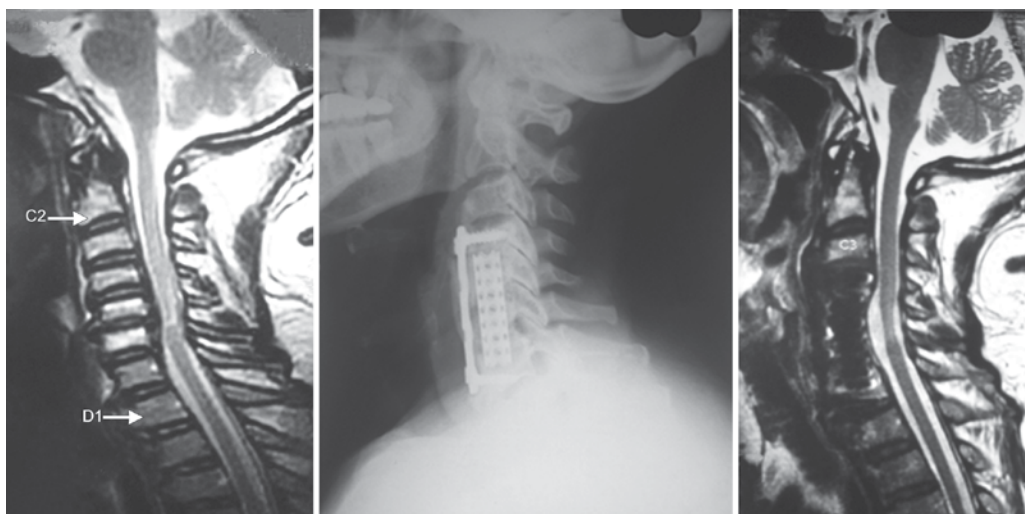


Fig. 3: Anterior decompression median corpectomy and deformity correction using cage and plate



Fig. 4: Radiograph showing decompression, deformity correction and stabilization

desis using a strut graft can yield excellent results without undue risk.

COMPLICATIONS

Neurological deterioration, implant failure, pseudoarthrosis, inadequate deformity correction and progression of deformity are possible. Mummaneni et al²⁵ reported a series of circumferential correction of kyphosis but the overall rate of complications (major and minor) was 33.3%. Winestone et al⁴⁰ highlight the need for maintaining adequate intraoperative blood pressure during operative treatment, and the higher risk of spinal cord injury associated with operative treatment of kyphotic deformity. Intraoperative neurophysiological monitoring is also essential to avoid complication.

Table 1: Summary of clinical studies with regard to the surgical treatment of cervical kyphosis (demographic data)

Authors	Main correction strategy	No. of patients	Mean age	Male/female	Follow-up	Study type
Zdeblick et al	Ventral	14	46	11/3	27.9 months	Retrospective
Zdeblick et al	Ventral	8	50	4/4	46.3 months	Retrospective
Riew et al	Ventral	18	54	11/7	2.7 years	Retrospective
Herman et al	Ventral	20	58	14/6	27.6 months	Retrospective
Gülmen et al	Ventral	4	30	Not known	1.7 years	Retrospective
Ferch et al	Ventral	28	57	17/11	25 months	Retrospective
Steinmetz et al	Ventral	12	40	7/3	9 months	Retrospective
Park et al	Ventral	23	56	16/7	44.5 months	Retrospective
Mummaneni et al	Combined	30	56	16/14	2.6 years	Retrospective
O'Shaughnessy et al	Combined	41	61	20/21	19 months	Retrospective
Nottmeier et al	Combined	41	61	20/21	19 months	Retrospective
Abumi et al	Dorsal/combined	30	47	17/13	42 months	Retrospective

Total 248

Source: Ke Han, Chang Lu, Jing Li, et al. Surgical treatment of cervical kyphosis. Eur Spine J 2011;20:523-536.

Table 2: Summary of clinical studies with regard to surgical treatment of cervical kyphosis (clinical outcome)

Authors	Clinical outcome
Zdeblick et al	No patients lost neural function. Nurick scores improved from 3.6 points before operation to 1.3 points at follow-up. Of four patients unable to walk before surgery, one remained unchanged, one was able to walk with a cane, and two could walk independently.
Zdeblick et al	Six patients had excellent results, one had a good result, and one patient had a poor result.
Riew et al	Twelve patients improved neurologically by at least one Nurick grade and none of the patients worsened neurologically. Nurick grade improved from 3.1 preoperatively to 2.0 postoperatively.
Herman et al	Two patients improved neurologically by at least one Nurick grade and none of the patients worsened neurologically; 6 patients had pain improvement but neurological function at follow-up.
Gülmen et al	One patient died of respiratory complications 20 days after surgery; two patients with tetraparesis improved significantly; the neck pain in one patient resolved completely 1 month after surgery.
Ferch et al	Myelopathy scores improved in 11 patients, remained stable in 15 patients and deteriorated in 1 patient. Cervical pain scores were similar before and after surgery.
Steinmetz et al	All patients improved postoperatively; three patients had complete resolution of their symptoms.
Park et al	Nurick grades improved from 2.52 to 1.04; VAS scores improved from 6.22 to 2.30; the neck disability index improved from 27.09 to 10.48. Nine patients had complete resolution of symptoms; all patients achieved neurological improvements of at least one or more Nurick grades.
Mummaneni et al	Nurick scores improved from 3.2 to 1.3; the mJOA scores improved from 10.5 to 15. None of the surviving patients worsened neurologically after the surgery.
O'Shaughnessy et al	Nurick classification score improved from 2.4 before surgery to 1.5 after surgery. In terms of Odom criteria, six patients had excellent result; eight had good result; there was one fair and one poor result. With regard to postoperative swallowing function, nine had no difficulty; six had minor difficulty and one had major difficulty.
Nottmeier et al	Preoperative symptoms were improved in 39 patients; unchanged in 1 patient and worsened in 1 patient.
Abumi et al	Of the 24 patients with myelopathy before surgery, 3 obtained a two-grade improvement of Frankel grading, 11 patients obtained one grade, and 10 patients were unchanged.

Source: Ke Han, Chang Lu, Jing Li, et al. Surgical treatment of cervical kyphosis. Eur Spine J 2011;20:523-536.

FUTURE POSSIBILITIES

The computer guided finite element studies are already guiding the development of newer instrumentation. Implantable materials that share closer biological properties to the bone and tissues of the human body are slowly replacing the steel and titanium constructs. Sekhon³¹ has elaborated on the role of disk arthrodesis in CSM. Goel et al¹⁷ hypothesise that development of a patient specific optimized finite element model that takes muscle forces into consideration may help resolve the discrepancies between biomechanics of total disk replacement (TDR) and the clinical studies. They further reiterate the importance of parameters like preserving unciniate processes, disk placement and its orientation within the cervical spine. Dynamic implants with limited and programmed range of allowed deformation are going to play a greater role in the treatment of CSM. Controlled dynamism, i.e. allowing axial deformation and not sagittal deformation are leading to a new era of dynamic stabilization and motion preserving surgery.

CONCLUSION

Neurosurgeons are increasingly managing the problems of biomechanics and deformity in the spondylotic cervical spine. Better understanding of the etiopathogenesis, imaging and improving instrumentation allows for the tackling of these deformities. Correcting deformity is a very important and essential surgical adjunct in management of CSM. Anterior correction using the technique of Benzel gives good results. Correction requires to be tailored to each patient and may require anterior, posterior or combined approaches.

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