Clinico-Radiological Correlation of Outcome Following Posterior Decompression and Instrumented Fusion in Patients With Degenerative Cervical Myelopathy Due to Multisegmental Ossification of Posterior Longitudinal Ligament

AJIT SINGH

MCh THESIS

2022

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM

An Institution of National Importance established by an Act of the Indian Parliament
(Act No.52 of 1980)

Dept. of Science and Technology, Govt. of India
www.sctimst.ac.in

Clinico-Radiological Correlation of Outcome Following Posterior Decompression and Instrumented Fusion in Patients With Degenerative Cervical Myelopathy Due to Multisegmental Ossification of Posterior Longitudinal Ligament

A THESIS SUBMITTED BY

Dr Ajit Singh

TO

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE AWARD OF

MCh NEUROSURGERY

2022

DECLARATION

This thesis titled — Clinico-Radiological Correlation of Outcome Following Posterior Decompression and Instrumented Fusion in Patients With Degenerative Cervical Myelopathy Due to Multisegmental Ossification of Posterior Longitudinal Ligament, is a consolidated report based on a bonafide study of the period from Apr 2011 to Apr 2021, done by me under the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram.

This thesis is submitted to SCTIMST in partial fulfillment of rules and regulations of the MCh Neurosurgery examination.

Dr. Ajit Singh,

Dept of Neurosurgery,

SCTIMST,
Thiruvananthapuram.

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

CERTIFICATE BY THE RESEARCH GUIDE

Name of the Guide: Dr Krishnakumar K

Department: Neurosurgery

This is to certify that Dr Ajit Singh, Department of Neurosurgery of this institute has fulfilled the requirements prescribed for the MCh Neurosurgery degree of the Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum.

The thesis entitled, "***Clinico-Radiological Correlation of Outcome Following Posterior Decompression and Instrumented Fusion in Patients with Degenerative Cervical Myelopathy Due to Multisegmental Ossification of Posterior Longitudinal Ligament***" was carried out under my direct supervision. No part of the thesis was submitted for the award of any degree or diploma prior to this date.

*Clearance was obtained from the Institutional Ethics Committee of this institute (IEC-1762/2021) for carrying out the study.

Signature

Krishnakumar K

Date: 11 Aug 2022

Dr Krishnakumar K,
Professor
Department of Neurosurgery,
SCTIMST, Trivandrum

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

CERTIFICATE BY THE RESEARCH CO-GUIDE

Name of the Co-Guide: Dr Ganesh Divakar

Department: Neurosurgery

This is to certify that Dr Ajit Singh, Department of Neurosurgery of this institute has fulfilled the requirements prescribed for the MCh Neurosurgery degree of the Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum.

The work under the thesis entitled, "***Clinico-Radiological Correlation of Outcome Following Posterior Decompression and Instrumented Fusion in Patients with Degenerative Cervical Myelopathy Due to Multisegmental Ossification of Posterior Longitudinal Ligament***" was carried out under my direct supervision. No part of the thesis was submitted for the award of any degree or diploma prior to this date.

*Clearance was obtained from the Institutional Ethics Committee for carrying out the study.

Signature

Date: 10 Aug 2022

Dr Ganesh Divakar
Assistant Professor,
Department of Neurosurgery,
SCTIMST, Trivandrum

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

CERTIFICATE BY THE RESEARCH CO-GUIDE

Name of the Co-Guide: Dr Easwer HV

Department: Neurosurgery

This is to certify that Dr Ajit Singh, Department of Neurosurgery of this institute has fulfilled the requirements prescribed for the MCh Neurosurgery degree of the Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum.

The work under the thesis entitled, "***Clinico-Radiological Correlation of Outcome Following Posterior Decompression and Instrumented Fusion in Patients with Degenerative Cervical Myelopathy Due to Multisegmental Ossification of Posterior Longitudinal Ligament***" was carried out under my direct supervision. No part of the thesis was submitted for the award of any degree or diploma prior to this date.

*Clearance was obtained from the Institutional Ethics Committee for carrying out the study.

Signature

Date: 11/8/2022

Dr Easwer H V
Professor and Head,
Department of Neurosurgery,
SCTIMST, Trivandrum

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

APPROVAL OF THE THESIS

The thesis entitled

Clinico-Radiological Correlation of Outcome Following Posterior Decompression and Instrumented Fusion in Patients with Degenerative Cervical Myelopathy Due to Multisegmental Ossification of Posterior Longitudinal Ligament

Submitted by

Dr Ajit Singh

for the degree of

MCh NEUROSURGERY(AFTER MS)

of

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM

is evaluated and approved by

Krishnakumar.K
.....DR. KRISHNAKUMAR . K

(Name & Signature of the Guide)

.....

(Name & Signature of thesis examiner)

ACKNOWLEDGEMENT

I owe a deep sense of gratitude to Dr Easwer H V, Professor and Head, Department of Neurosurgery, for his invaluable advice, encouragement, and guidance, without which this work would not have been possible. His critical remarks, suggestions, helped me in achieving a high standard of work.

The guidance of Dr Krishnakumar K, Professor, Department of Neurosurgery, has been invaluable and I am extremely grateful and indebted for his contributions and suggestions, which were of invaluable help during the entire work. He will always be a constant source of inspiration to me.

I owe a deep sense of gratitude to Dr Ganesh Divakar, Assistant Professor, Department of Neurosurgery, Co-Guide, for his invaluable advice, encouragement, and guidance, without which this work would not have been possible. His critical remarks, suggestions, helped me in achieving a high standard of work.

I am deeply indebted to Dr Mathew Abraham, Dr George C Vilanilam, Dr Jayanand Sudhir, Dr Prakash Nair, Dr Tobin George, and colleagues and I thank them for their constant encouragement and support.

I am very grateful to Wg Cdr (Dr) Gurpreet Singh Multani, MD, PhD scholar, AMCHSS, SCTIMST, Trivandrum, for his invaluable contribution in the conduct and analysis of this study. His constant support and guidance were inspirational and helped immensely in going through the process of this project.

Ajit Singh

INDEX

Introduction

Cervical ossification of posterior longitudinal ligament is a common cause of myelopathy in the Asian countries with highest incidence reported from Korea and Japan[1]. Being a benign disorder with potential for causing significant functional impairment, surgical strategies are aimed at providing maximal improvement in the symptoms with as less complications as feasible. This has led to the development of a variety of surgical approaches, thus deciding the best surgical approach for a patient may be difficult at times[2]. Recent studies have shown relatively lower complication rates and good symptom relief with posterior approaches which aim to decompress the spinal canal and may be combined with instrumented fusion[3]. Posterior decompression and fusion is considered to be advantageous as compared to decompression alone or laminoplasty as it leads to reduction in the hypermobility of cervical spine which has been postulated to be one of the causes of progression of the OPLL after surgery. Same has been evaluated by various investigators and the rate of progression of OPLL has been found to be less in the patients who have undergone fusion[4,5]. Despite being a feasible and favorable approach, not all the patients treated with this approach have a favorable outcome.

Whether decompression alone or in combination with fusion leads to improvement in clinical and functional status is thus not conclusively validated. Moreover, changes in the radiological parameters after the surgery and their correlation with the clinical findings has also not been extensively studied. With this study we aim to study the pre-operative and post operative imaging parameters, and their correlation with the clinical findings with regards to the functional outcome. The results of this study are likely to be helpful in prognostication and surgical decision making in patients with degenerative cervical myelopathy due to multisegmental OPLL.

AIM AND OBJECTIVES

Aim

To study the clinico-radiological correlation of outcome following posterior decompression and instrumented fusion in patients with degenerative cervical myelopathy due to multisegmental ossification of posterior longitudinal ligament.

Objectives

1. To study the outcome of patients following posterior decompression and instrumented fusion for degenerative cervical myelopathy due to multisegmental ossification of posterior longitudinal ligament.
2. To correlate the post operative imaging findings with the outcome in the patients undergoing posterior decompression and instrumented fusion for degenerative cervical myelopathy due to multisegmental ossification of posterior longitudinal ligament.

Review of Literature

Ossification of the cervical posterior longitudinal ligament was first reported in 1838 by Key[6]. However, his description of the disease did not attract significant attention at that time, probably due to its relative rarity. Oppenheimer also described a few cases of spinal ligament ossification in 1942. However, most of his cases involved ossification of the anterior longitudinal ligament. He did not consider the ossification of posterior longitudinal ligament (OPLL), to be associated with significant neurological symptoms[7]. OPLL got recognition as an important cause for myelopathy after Tsukimoto reported an autopsy case in 1960[8]. Given a significantly higher incidence of the disease in Japan, further epidemiological studies were carried out by the Investigation Committee on Ossification of the posterior longitudinal ligament, constituted by the Japanese Public health and welfare department in 1975[9]. Extensive population-based studies were carried out by the subsequent committees in an attempt to establish the genetic basis of the disease, and also to understand the pathophysiology of compressive myelopathy caused by OPLL[10]. Although, the incidence of disease was significantly low in rest of the world, cases were being reported from other regions as well,

prompting active research in the quest for optimal management strategy of the disease.

In Japan, studies have reported a prevalence of 1.9 to 4.3%[11] in people aged thirty years or more. This is significantly higher than anywhere else in the world. Even the neighboring Asian countries have lower incidence of OPLL as compared to Japan. China and South Korea, similarly, have a reported prevalence of 0.2 to 1.8%[12,13] and 0.95%[14] respectively. Prevalence in the western countries is low with USA having a reported prevalence of around 0.12% and Germany around 0.1%[ix]. Males are affected more commonly as compared to females with most epidemiological studies reporting a male: female ratio of around 2:1[15]. Genetic studies have shown a positive correlation between the occurrence of OPLL and various genetic factors. Mutations of the A2 gene on the short arm of chromosome 6 and A1 gene on the chromosome 21 have been proposed as the possible genetic loci for OPLL[16,17]. However, mutations at these loci have not been conclusively associated with occurrence of OPLL and are a matter of continuing research.

Etiopathogenesis

Genetic Factors

In 1989, Terayama K reported a significantly higher prevalence of cervical OPLL in the parents and siblings of the probands from 347 families with cervical OPLL[18]. Similarly, Human Leucocyte Antigen (HLA) studies among siblings with OPLL showed association of OPLL with D6S276[19]. This prompted further research to establish the genetic basis of this disease and to find the associated genetic loci. Subsequently, a genome wide linkage study showed potential OPLL associated loci at 20p12, 16q24, 7q22, 2p22-2p24, and 1p21[20]. A genome wide association study identified six genetic loci, 6p21.1, 8q23.1, 8q23.3, 12p11.22, 12p12.2, and 20p12.3 potentially associated with development of OPLL[21]. There has also been interest in the role of Transforming growth factor-β (TGF-β), as it acts as promoter of mesenchymal cell proliferation and causes an increase in osteoblastic activity and new bone formation. TGF-β superfamily is thus considered an important factor in development of OPLL[22]. More recent research also suggests role of mutations in the genes encoding various forms of collage, including COL6A1, COL11A2, and COL17A1[23,24]. Despite extensive studies on the subject, conclusive evidence with regards

to the genetic loci associated with occurrence of OPLL is still lacking and is a matter of continuing research.

Physical Stress

Cyclical mechanical stress has been seen to be associated with increased expression of a multitude of genes which promote bone remodelling, calcification and new bone formation. Important among these are the osteopontin, BMP-2 (Bone Morphogenetic Protein-2), alkaline phosphatase (ALP), Type I collagen, BMP receptors, Cbfa-1 and integrin β1[25]. Moreover, in vitro studies have shown increased osteoblastic activity secondary to increased prostaglandin synthesis in response the mechanical stress over the spinal ligaments[26]. Reduction in the levels of vimentin has also been seen to be associated with progression of OPLL[27]. All these factors tend to affect the formation and propagation of OPLL.

Mesenchymal Stem Cells

Mesenchymal stem cells are progenitor cells which have a potential to develop into various matured tissue components like bone and cartilage. Like other locations, the mesenchymal stem cells of the spinal ligaments also have a potential to develop into chondrogenic or osteogenic cells. Development of mesenchymal stem cells into mature tissues is controlled and monitored by various transcription factors, which include Runx2,

Sox9, Osterix, Indian hedgehog and Msx2[28]. Any abnormality in the signalling pathway may thus lead to abnormal bone and cartilage formation and may also predispose to development and progression of ossification of spinal ligaments. Sugita et al noticed an increased expression of Indian Hedgehog, Sox9 and Parathormone related peptide, in the patients with OPLL[29].

Dietary factors

A relationship between increased daily salt intake and occurrence of OPLL was first reported by Wang et al in 1999[30]. Similarly, increased intake of pickled and salted foods were also associated with an increased probability of developing OPLL[31].

Biological Markers of OPLL

Increased levels of Leptin, osteocalcin and insulin has been seen to be associated with OPLL[32]. Various markers of bone proliferation are also similarly associated with increased propensity of developing OPLL and include nebulin related anchoring protein and osteoglycin[33].

Pathophysiology

OPLL is considered to be an ectopic calcification with a potential to compromise the spinal canal and cause myelopathy. It has also been seen in combination with Diffuse Idiopathic Spinal Hyperostosis (DISH)[34] and can be considered as a subtype of DISH. However, association of OPLL with ossifications elsewhere in the body and also in other spinal ligaments has not been clearly elucidated and should be a subject for further research.

Mechanism of Myelopathy

Direct compression of the spinal cord by the ossified portion of the posterior longitudinal ligament seems to be the most obvious cause for development of myelopathy in OPLL. However, it has been observed that the severity of myelopathy does not correlate well with the severity and extent of ossification. This observation generated interest in other factors which may inflict spinal injury, including the dynamic compression and vascular insufficiency. In 1972, Yamazaki and co-workers published their autopsy report of anterior spinal artery compression caused by ossification of the posterior longitudinal ligament[35]. Additionally, Breig and co-workers showed that compression of the extraspinal arteries by the osteophytes in cervical spondylosis may lead to ischemic injury to the

spinal cord[36]. Moreover, venous stasis leading to congestion and necrosis may also play an important role in development of myelopathy due to long standing spinal compression. Kameyama and co-workers showed evidence of venous congestion in the form of prominent, thick-walled venules around the cysts that are often seen in association with dilated perivascular spaces[37].

To study the effect of static and dynamic compression and stress distribution in the spinal cord, Nishida and co-workers used a 3-D Finite Element Package (3-D FEM). They used a bovine spinal cord as substrate and the 3D FEM model used in the study included grey matter, white matter and pia mater. They however excluded denticulate ligament, dura and nerve root sheaths to avoid potentially complicated calculations. The study showed increasing mechanical stress over the cord with increase in static compression. However, with addition of the dynamic component exponentially increased the amount of mechanical stress over the cord structures. The study concluded that the cervical myelopathy results from a combination of static and dynamic compression and that addition of dynamic compression significantly increases the stress over the cord structures, potentially increasing the severity of myelopathy[38]. Toshitaka and co-workers used kinematic computed tomography myelography to

study the effect of cervical spine mobility on the severity of compression in patients with OPLL. They reported a significant increase in the compression on extension when compared with neutral position. They also reported reduction in compression with flexion at the affected segments, thus highlighting the effect of cervical spine mobility on severity of compression and development of myelopathy[39].

Pathologic Changes in Spinal cord

Gray Matter

The gray matter changes associated with OPLL includes flattening of anterior horn cells alongwith loss of neurons and secondary gliosis. These findings were used to pathologically classify the disease into stages that correlate with the severity of disease[40]. In advanced stages (stage 2 and 3), there is near complete obliteration of neurons with frequent cavitation and necrosis (Table 1).

Table 1: Pathological stages of myelopathy

Stage	Description
0	Normal (Age related changes)
1	Mild Compression
2	Moderate compression with neuronal loss
3	Intrinsic cystic necrosis

White Matter

Pathological changes in white matter are not as pronounced as they are in the gray matter of spinal cord. The changes observed are destruction of myelin and axonal loss. Most intense injury is usually observed at the centre of gray matter, extending posteriorly to involve the posterior column along with formation of necrotic cavity[41].

Clinical Manifestations

The clinical presentation of patients with OPLL depends on multiple factors including the severity and duration of spinal canal compromise, type of OPLL and a history of trauma. The clinical syndrome of OPLL can be divided into three broad groups based on the pathology:

- Spinal cord injury causing spasticity and urinary disturbances
- Cervical radiculopathy due to involvement of cervical nerve roots
- Mechanical neck pain

Most patients present with overlapping clinical findings owing to varying degree of spinal canal compromise and other related pathologies. In presence of significant spinal canal stenosis, even minor trauma can cause significant spinal cord injury and the presentation may be with acute quadriparesis.

Pain and paraesthesia over upper limbs seems to be the most common initial presentation of cervical OPLL. In study done by the investigation committee on ossification of spinal ligaments of the Japanese ministry of public health and welfare, upper limb sensory symptoms were the presenting complaints in 48% of patients followed by neck pain/stiffness and lower limb sensory symptoms[42] (Table 2). Of the clinical syndromes associated with cervical OPLL, myelopathy appears to be the most common[43]

Table 2: Symptoms associated with cervical OPLL

Symptom Frequency	(%)
Pain/numbness of the upper limb	48
Neck and nuchal pain/stiffness	42
Pain/numbness of the lower limb	19

Table 3: Clinical syndromes associated with cervical OPLL

Syndrome	(%)
Myelopathy	45
Neck and nuchal pain/stiffness	25
Radiculopathy	07
Combined	43

Diagnostic Imaging

X-Ray

Cervical OPLL has traditionally been diagnosed on lateral cervical spine X- rays. It is seen as calcifications occupying the anterior portions of the spinal canal. It has been classified as focal (focal ossifications at posterior margins of the vertebral bodies at the level of intervertebral disc), segmental (ossification only at the posterior aspects of vertebral bodies, not crossing the intervertebral discs), continuous (continuous ossification encompassing two or more vertebral levels) and mixed variants (Fig 1)[44] based on the pattern of calcification seen on lateral plain radiographs of the cervical spine. Dynamic X Rays including flexion and extension radiographs are useful for detection of compression attributable to spinal motion segments, however their utility in routine assessment of patients with cervical OPLL is not defined. Lateral cervical radiographs are also used for evaluation of various parameters defining the cervical sagittal balance which may have bearing on the surgical planning and prognosis. The concept of 'K-line' was also described on lateral cervical spine radiographs. The K-line is an imaginary line extending from the mid-point of spinal canal at C2 to the C7 vertebral levels. Its relationship with the

OPLL can be defined as either positive or negative depending on whether the OPLL is ventral or dorsal to the K-line respectively[45] (Fig 2).

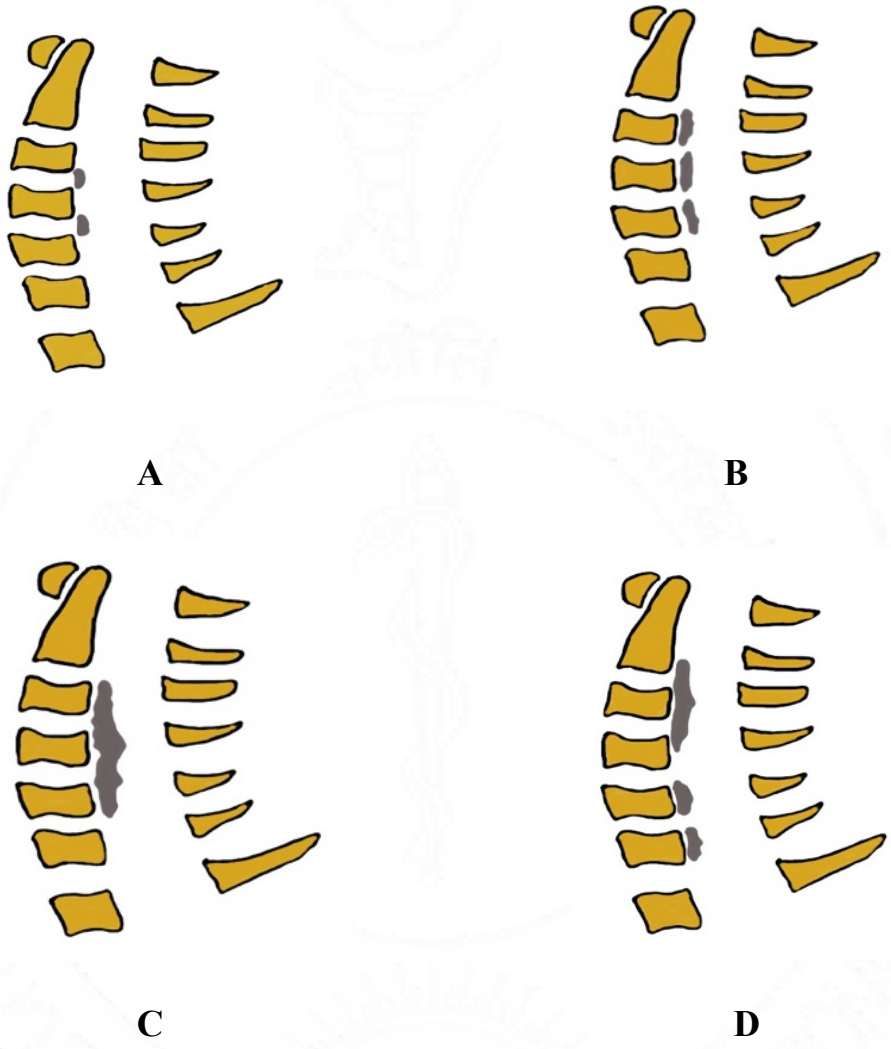


Fig 1: Classification of OPLL

A: Focal, B: Segmental, C: continuous, D: Mixed

A **B**

Fig 2: A: Positive K-line B: Negative K-line

CT Scan

CT scan is perhaps the most useful and also the most commonly used imaging modality for cervical OPLL. It not only facilitates the diagnosis, it is also crucial for planning the surgical approach. It gives a comprehensive three-dimensional view of the extent and type of cervical OPLL. CT myelography has been used to see the extent of spinal cord compression in patients where MRI is not feasible or contraindicated. A double layer sign seen on CT scan has been associated with higher probability of dural penetrance by the ossified mass[46]. In addition, the anatomy of the vertebrae is very nicely delineated on CT scans, aiding the planning for instrumentation, if such approach is utilized for management.

MRI

MRI is the gold standard imaging modality to evaluate the extent of spinal cord damage caused by chronic compression of the spinal cord by the calcified mass. T2 weighted images are likely to show features of myelomalacia, seen as hyperintense signal within the cord. Long standing compression may lead to cavitation and syrinx formation which can be easily appreciated on MRI. Shape of the spinal cord at the level of compression has been defined as tear drop, triangular or boomerang shaped[47]. Presence of hyperintense signal in the spinal cord is considered to be a poor prognosticator.

Treatment options

Non-surgical management

Dynamic factors are known to play an important role in development of myelopathy in patients with OPLL[48]. Conservative management is thus aimed at providing symptomatic relief and control of dynamic factors. Means to reduce the cervical motion include use of cervical orthosis like cervical collars. Nonsteroidal anti-inflammatory drugs are effective for relief of local pain and stiffness, and in addition to cervical orthosis can achieve significant symptom relief.

Surgical treatment

Surgery is indicated for patients with progressive myelopathy in the form of worsening numbness, paraesthesia, limb weakness, spastic gait. Both anterior and posterior approaches have been used with favorable results in most of the patients. Selection of appropriate approach for a patient needs careful assessment of clinical and radiological findings. Multiple factors have been used to guide surgical decisions, with mixed results.

The anterior approaches for management of cervical OPLL target direct removal of the OPLL along with fusion of adjacent structures. This approach is most suitable for segmental OPLL with or without dural ossification and has remained mainstay of treatment for cervical OPLL. Toshitaka Yoshi et al reviewed the outcomes of patients undergoing anterior decompression and fusion for cervical OPLL and compared the same with patients who had undergone a posterior decompression and fusion. They had included patients with severe spinal canal stenosis, defined as an occupation ratio of more than 50% in their study. The study showed good neurological outcomes with posterior and anterior approaches. However, the patients with severe kyphotic deformity showed better result with anterior approach. They also reported a relatively higher rate of complications with anterior procedures. Posterior approaches are

most preferred for the patients with multisegmental involvement with three or more vertebral segments involved with the pathology. Anterior approaches in these cases are associated with significantly higher complication rates[49]. In a comparative study, Koda M and co-workers found anterior decompression + fusion and posterior decompression + fusion as optimal surgical approaches for management of cervical OPPL where the K-line was negative. Laminoplasty in their study population was associated with suboptimal neurological outcomes[50]. This probably related to progression of kyphotic deformity in the patients where no instrumentation was involved. In a recently published meta-analysis comparing different surgical approaches for management of cervical OPLL, anterior approaches were associated with better overall outcomes when compared with laminoplasty without fusion. However, posterior decompression with fusion was associated with good neurological outcomes. It was also reported that CSF leak was more common after anterior procedures and C5 root palsy was more commonly seen after posterior procedures[51]. Posterior approaches have the advantage of being technically more feasible, especially for long segment involvement. These approaches also have lesser complication rates as compared with anterior approaches as seen in the studies described above. Studies comparing

laminectomy/laminoplasty with laminectomy + fusion have shown better overall outcomes by addition of instrumentation to the surgical approach[64]. Various reasons have been cited for such observations, including correction of abnormal cervical motion, and cessation of progressive kyphosis.

Radiological predictors of outcome

Severity of spinal canal stenosis can be assessed by measuring the spinal canal diameter at a given level, mostly at the level of maximum thickness of OPLL. Other parameter that can be utilised for this purpose is an OPLL occupation or occupancy ratio, which is calculated by dividing the maximum thickness of OPLL mass by the total antero-posterior diameter of the spinal canal at the same level. Shunji Matsunga and co-workers studied the radiological parameters that could predict the outcome in patients with cervical OPLL and found that an OPLL occupation ratio of more than 60% was associated with poor outcome[62]. They also reported poorer outcomes in patients with a mixed or continuous types of OPLL. The K-line or the kyphosis line was first described in 1976 as a tool for guiding surgical approach to a patient with cervical OPLL. The authors observed that the patients with a K-line negative status were likely to have

poor outcome following posterior decompression due to inadequate anterior motion of the spinal cord[45]. With the addition of instrumented fusion to posterior decompression, later studies reported an equivalent outcome in even K-line negative patients.

The sagittal balance of cervical spine has generated significant interest among the clinicians and researchers managing cervical OPLL. As described earlier, the dynamic component in the pathogenesis of cervical OPLL plays and important role in overall outcome after surgical intervention. Various parameters for defining the cervical sagittal balance have been used. The C7 SVA has been used to assess the amount of kyphotic deformity of the cervical spine. A C7 SVA of more than 4 cms has been traditionally considered to represent significant sagittal imbalance and has been associated with poorer neurological outcomes[63]. The C2-C7 angle is also representative of the amount of cervical lordosis. A lower C2-C7 angle has been associated with poorer outcomes after posterior decompression without fusion. This is probably related to progression of spinal deformity in absence of surgical arthrodesis. This observation was also supported by a recent retrospective review comparing the outcomes of anterior and posterior approaches. It was reported that patients with a C7 SVA of more than 4 cms did poorly with

laminoplasty and the C2-C7 angle showed progressive worsening in absence of surgical fusion[52]. These observations strengthened the belief that surgical fusion should be included for most patients with cervical myelopathy caused by OPLL, especially in patients with multisegmental involvement. Despite extensive research on the question of finding the best possible surgical approach for management of cervical OPLL, the quest for the answer still continues. At present with the available literature, it appears that posterior decompression with fusion is appropriate for management of multisegmental OPLL, and anterior approaches are likely to result in good neurological outcomes in short segment OPLL.

Material and methods

Patient selection

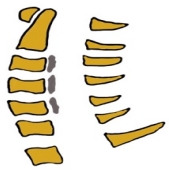
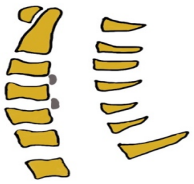
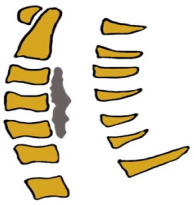
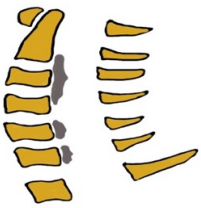
The data of all patients who underwent a posterior decompression along with instrumented fusion between 2011 and 2021 was retrospectively reviewed. Patients who have been previously operated for same disease by either a posterior or anterior approach were excluded from the study. Patients who had associated neurological disorders or neuraxial tumors were also excluded from the study to avoid confounders in assessment of post-operative outcome. Patients whose records were inadequate in the form of missing radiological images or follow up data were also not included in the analysis for present study.

Radiological parameters

Classification of OPLL: OPLL was classified in four categories, based on the appearance on sagittal CT images as per the classification system given by the investigation committee on OPLL of the Japanese ministry of public health and welfare. OPLL was classified as focal (focal ossifications at posterior margins of the vertebral bodies at the level of intervertebral disc), segmental (ossification only at the posterior aspects of vertebral bodies, not crossing the intervertebral discs), continuous

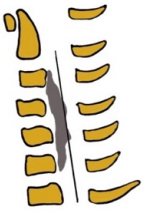
(continuous ossification encompassing two or more vertebral levels) and mixed variants (Table 4).

Table 4: Classification of OPLL

Radiological Parameter	**Diagrammatic representation**	**Remarks**
Classification of OPLL		
Segmental		Ossification only at the posterior aspects of vertebral bodies, not crossing the intervertebral discs
Focal		Focal ossifications at posterior margins of the vertebral bodies at the level of intervertebral disc
Continuous		Continuous ossification encompassing two or more vertebral levels
Mixed		Continuous and segmental ossification of the posterior longitudinal ligament

K-line: K-line (kyphosis line) was defined as an imaginary straight line joining the mid points of spinal canal at C2 and C7 vertebral levels on a lateral cervical spine radiograph. The K-line was said to be positive if the OPLL mass lied ventral to the above line and negative if the OPLL mass extended dorsal to the above line (Table 5).

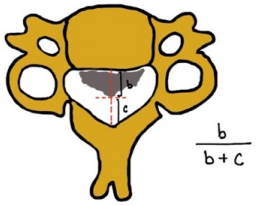
Table 5: K-line

Radiological Parameter	**Diagrammatic representation**	**Remarks**
K-Line		
Positive		OPLL lies ventral to the line
Negative		OPLL extends dorsal to the line

Minimum spinal canal diameter: The minimum spinal canal diameter was defined as the antero-posterior dimension of the spinal canal at the level of maximum thickness of OPLL. The values were recorded in millimeters (mm).

OPLL occupation ratio: The ratio of the maximum thickness of the OPLL mass to the diameter of the spinal canal at that level was defined as the OPLL occupation ratio (Table 6).

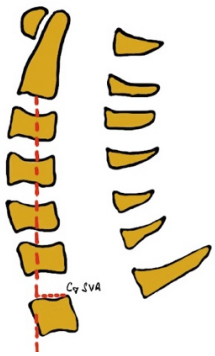
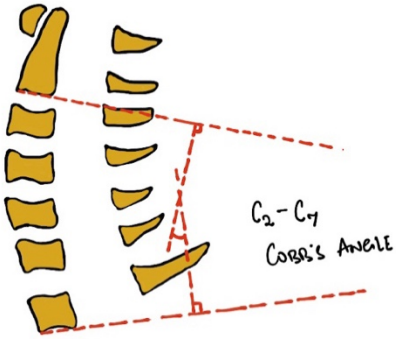
Table 6: Parameters of spinal canal stenosis

Radiological Parameter	**Diagrammatic representation**	**Remarks**
Degree of Spinal canal compromise		
Minimum spinal canal diameter		Antero-posterior dimension of the spinal canal at the level of maximum thickness of OPLL
OPLL occupation ratio		Ratio of maximum thickness of OPLL mass to the diameter of the spinal canal at that level

C2-C7 Cobb's angle: C2-C7 Cobb's angle was defined as the angle between the lines drawn parallel to the bases of C2 and C7 vertebral bodies on a lateral cervical spine radiograph.

C7 Sagittal vertical axis (SVA): C7 SVA was defined as the distance between a C2 plumb line and the postero-superior end of the C7 vertebral body. The distance was recorded in millimeters (mm) (Table 7).

Table 7: Parameters of cervical sagittal balance

Radiological Parameter	**Diagrammatic representation**	**Remarks**
Sagittal balance		
C7 SVA		Distance between a C2 plumb line and the postero-superior end of the C7 vertebral body
C2-C7 Cobb's angle		Angle between the lines drawn parallel to the bases of C2 and C7 vertebral bodies

Above radiological parameters were recorded from the preoperative radiographs and CT scans. As per the institute's protocol, a lateral cervical radiograph was taken at the time of first follow up (3 months). Same was utilized for calculating the post operative C7 SVA and the C2-C7 Cobb's angle.

Surgical intervention

All patients included in the study had undergone posterior decompression and instrumented fusion for cervical OPLL involving at least 3 vertebral levels. Patients with involvement of one or two vertebral levels were considered for anterior approach and were not included in the present study. After administration of general anesthesia, the patient was placed prone with head fixed on MFK clamp. Pre-determined vertebral levels were exposed under C-Arm guidance using a midline vertical incision. Lateral mass screws were placed under C-Arm guidance using the technique described by Magerl et al[53]. Laminectomy was performed and rods were placed and fixed to complete the instrumentation. Autologous bone graft was placed around the construct to aid in fusion. All patients were prescribed hard cervical collar for a period of two to four weeks.

Outcome

Modified Japanese Orthopedic Association (mJOA) score as proposed by Benzel et al[54] was recorded pre-operatively and at follow up on three months, six months, one year and at last follow up. The mJOA score at last follow up was used for calculating an mJOA recovery rate using Hirabayashi method[55].

$$\text{Recovery Rate} = \frac{\text{Post-operative mJOA} - \text{Pre-operative mJOA}}{18 - \text{Pre-operative mJOA}} \times 100$$

Patients with an mJOA rate of 50% or more were considered to be having an optimal outcome and those with an mJOA rate of less than 50% were considered to be having suboptimal outcome.

Statistical Analysis

Mean (SD) for numerical variables and percentages with 95% confidence interval (CI) for qualitative variables were calculated. Inferential statistics including t-test, Wilcoxon rank sum test and Chi-square tests were carried out to determine associations. Correlation coefficients were calculated to determine the strength of linear association between continuous variables. Analysis was carried out using R version 4.0.2.

RESULTS

Study Population

A total of 44 patients underwent posterior decompression and instrumented fusion for cervical myelopathy due to OPLL, during the study period. Seven patients were excluded from the study due to non-availability of imaging as per the study protocol. One of the patients had co-existing Parkinson's disease and was hence excluded from the study. A total of 36 patients were included in the study and the data was used for analysis.

Patient characteristics

The study included 31 male and 5 female patients. Mean age of the patients was 54 years. Twenty-one patients had associated co-morbid conditions including diabetes, hypertension or chronic obstructive pulmonary disease. The mean Body Mass Index (BMI) of the study population was 30.1 Kg/m^2. Mean follow up duration was 4.52 years, with a range of one to ten years. The mean duration of symptoms was 12 months (SD 13) (Table 8).

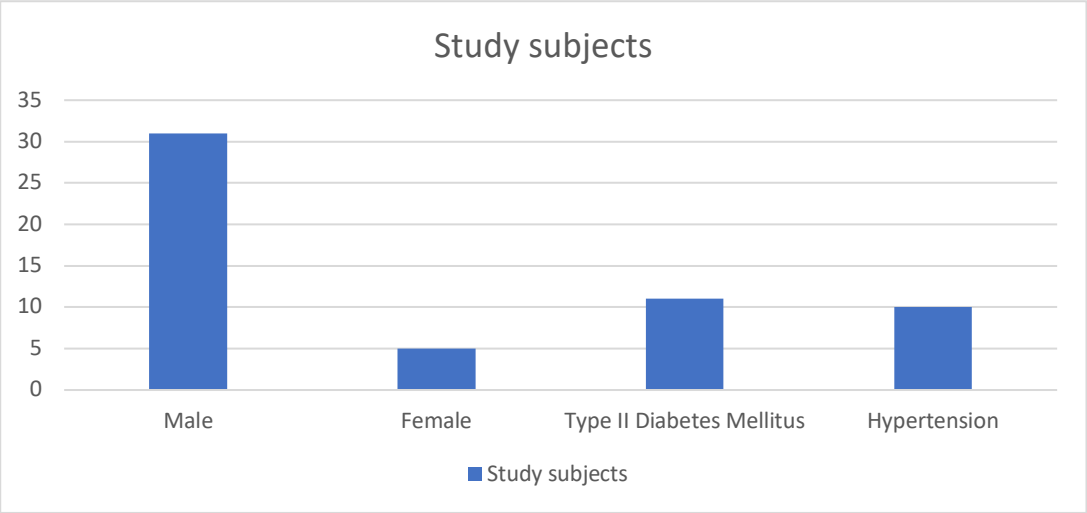


Fig 3: Study Subjects

Table 8: Patient characteristics

Variable	**No/Mean**	**SD/%**
Total no of patients	36	-
Gender		
Male	31	-
Female	05	-
Age	54	8
Co-morbid conditions		
Type II Diabetes Mellitus	11	31
Hypertension	10	28
BMI	30.1 Kg/m^2	4.2

Clinical presentation

Most common presentations included unsteadiness of gait (67%), limb weakness (75%) and sensory symptoms including numbness and paraesthesia (81%). Associated neck pain and radiculopathy was seen in 42% and 19% of the patients respectively. 22% of the patients had urinary symptoms in addition to above complaints. Most of the patients had increased tone in all limbs (75%) and exaggerated reflexes (86%) on examination. The mean pre-operative modified Japanese Orthopaedic Association (mJOA) score was 12.69.

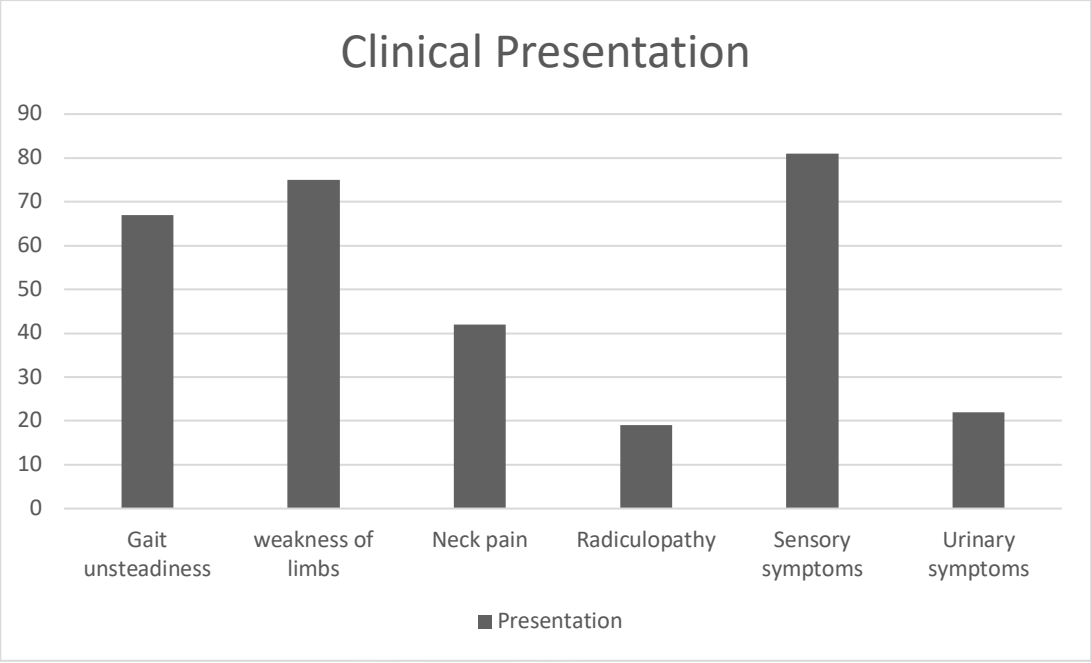


Fig 4: Clinical findings

Pre-operative Nurick Grading

The mean of pre-operative nurick grade was 2.47, with almost half of the patients having a Nurick grade of 3 at the time of initial presentation.

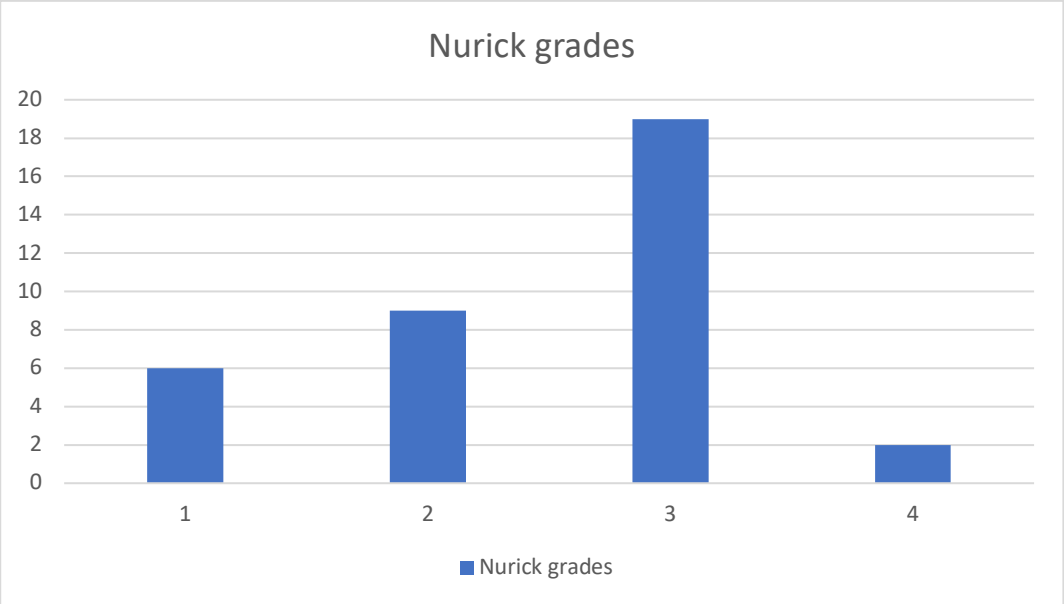


Fig 5: Pre-operative Nurick Grading

Pre-operative mJOA scores

The mean pre-operative mJOA score was 12.69. Most number of patients had a mJOA score between 11 and 14.

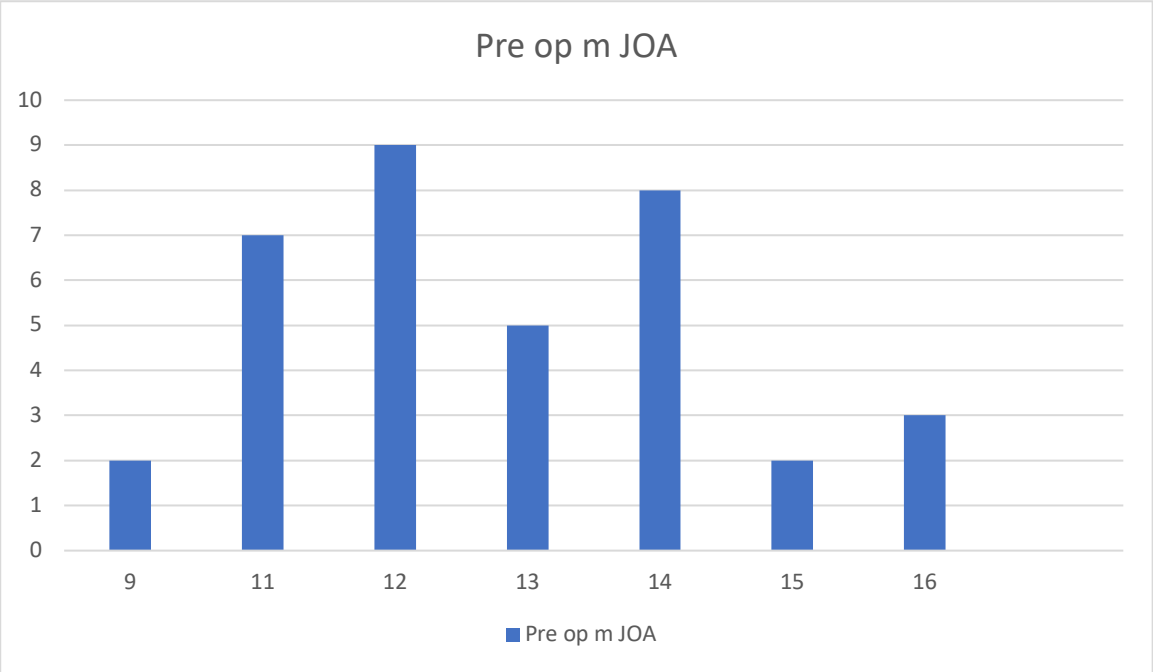


Fig 6: Pre-operative mJOA scores

Pre-operative radiological parameters

Commonest type of OPLL in the study population was segmental (n=18) followed by mixed (n=13) and continuous (n=05). Mean minimum spinal canal diameter was 5.58 mm (SD 1.43), with a mean OPLL occupation ratio of 0.42 (SD 0.12). The K-line was negative in 28% of the patients (n=10) and positive in 72% (n=26). The mean pre-operative C2-C7 Cobb's angle was 10.7 degrees (SD 7) and the mean C7 SVA was 1.9 cm (SD 0.95) (Table 9).

Table 9: Pre-operative radiological parameters

Variable	**No of patients/Value**	**SD/%**
Type of OPLL		
Continuous	05	14%
Mixed	13	36%
Segmental	18	50%
Min spinal canal diameter	5.58 mm	1.43
OPLL occupation ratio	0.42	0.12
K-line		
Negative	10	28%
Positive	26	72%
C2-C7 Cobb's angle	10.7^0	7
C7 SVA	1.90 cms	0.95

Surgical Variables

Patients in the study group underwent at least 4 levels laminectomy. Of the 36 patients in the study, two patients underwent laminectomy at six levels, nine patients underwent laminectomy at five levels and twenty-five patients underwent laminectomy at 4 levels. Mean number of levels at which laminectomy was performed was 4.36. Patients underwent fusion from two to six levels, most common being three and four levels fusion. The mean of number of levels fused was 3.36. None of the patients had intra-operative complications including dural tears or CSF leak.

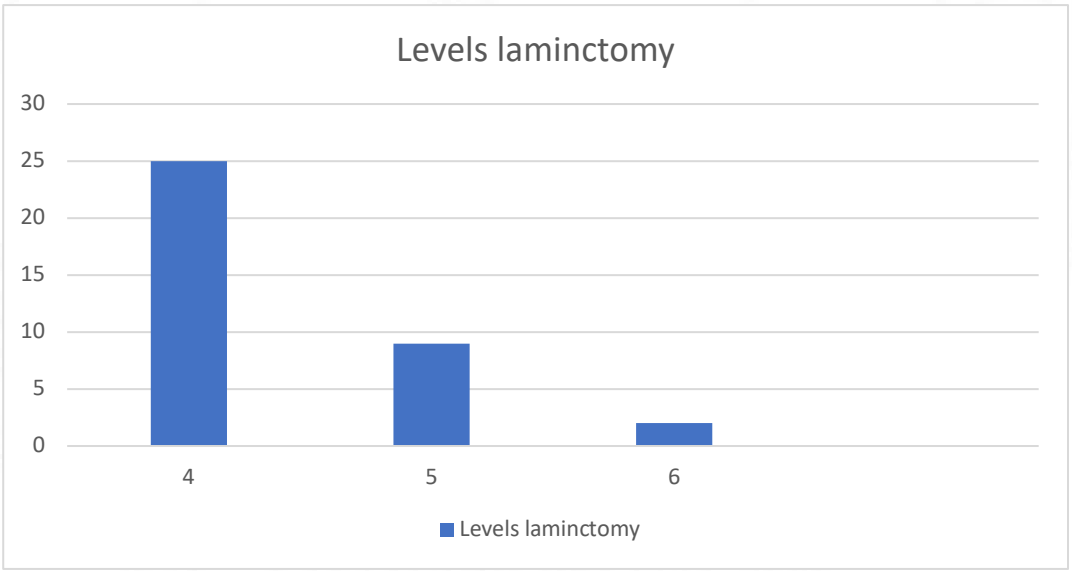


Fig 7: No of levels where laminectomy was performed

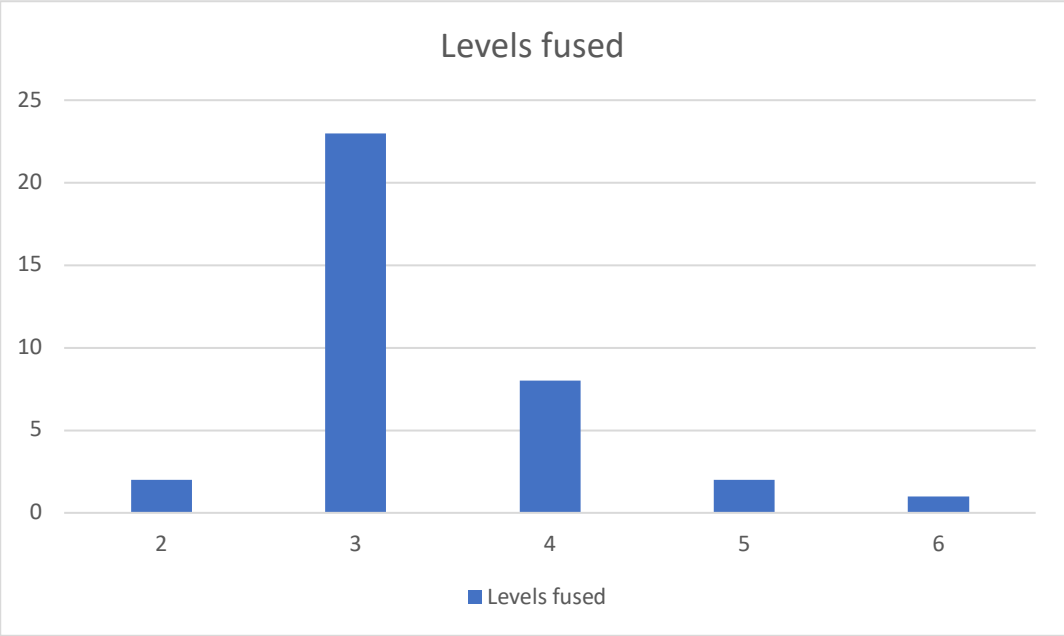


Fig 8: No of levels fused using instrumentation

Complications

We looked for wound related and neurological complications in our study group. Three patients in the study group had surgical site infection, of which one patient required re-exploration. However, no implant removal was required. Other patients had superficial SSI and were managed with local dressings and a short course of antibiotics. Four patients had C5 palsy, which was seen in immediate post operative period in 3 patients and during first week in one patient. All four patients had complete recovery over the period of follow up. Two patients had neurological deterioration in the immediate post-operative period. These patients showed some neurological improvement on follow up, however their post-operative mJOA scores remained lower than the pre-operative scores.

Outcome variables

Post-operative nurick grades and mJOA scores showed improvement in most of the patients. The mean post-operative nurick grades showed marginal improvement from a pre-operative mean of 2.47 to 2.19 at the time of last follow up. Post-operative mJOA scores improved in thirty out of a total of thirty-six patients. The mean post-operative mJOA scores were 13.44, 14.11, 14.08 and 14.58 at three months, six months, one year and at the time of last follow up respectively. The mJOA recovery rate was calculated. Twenty-two patients had an mJOA recovery rate of 50% or more and were considered as having an optimal outcome. Fourteen patients had an mJOA recovery rate of less than 50% and were considered as having a sub-optimal outcome.

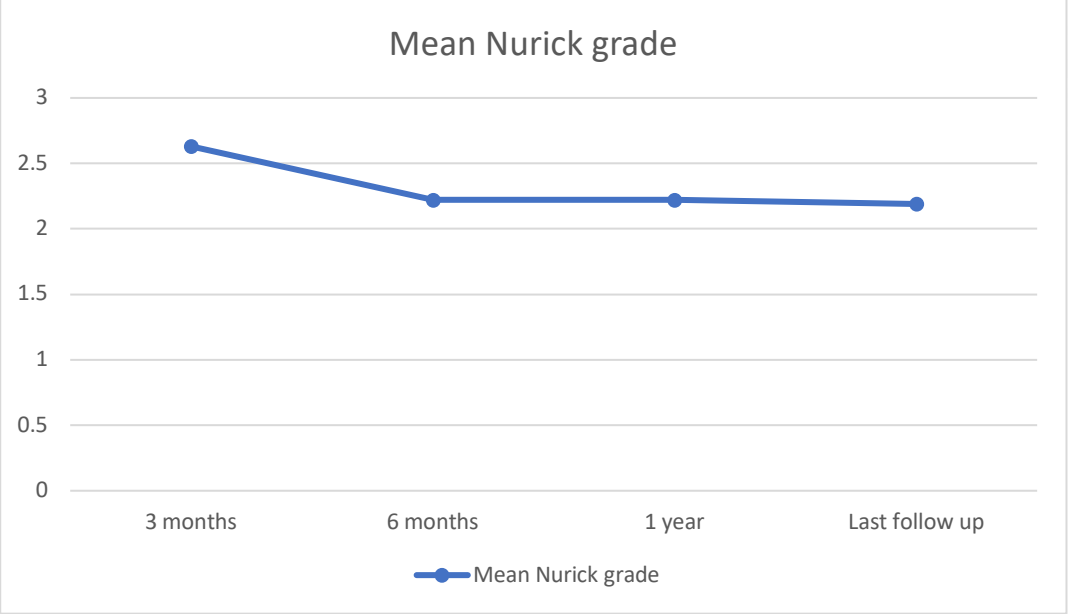


Fig 9: Mean Nurick grading

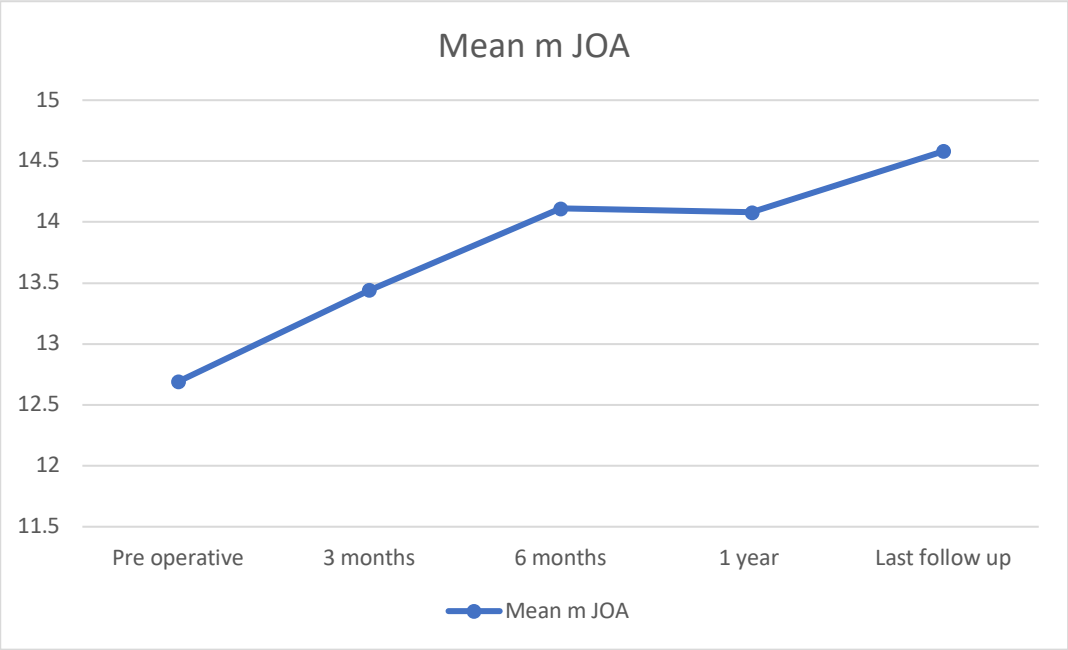


Fig 10: Mean mJOA scores

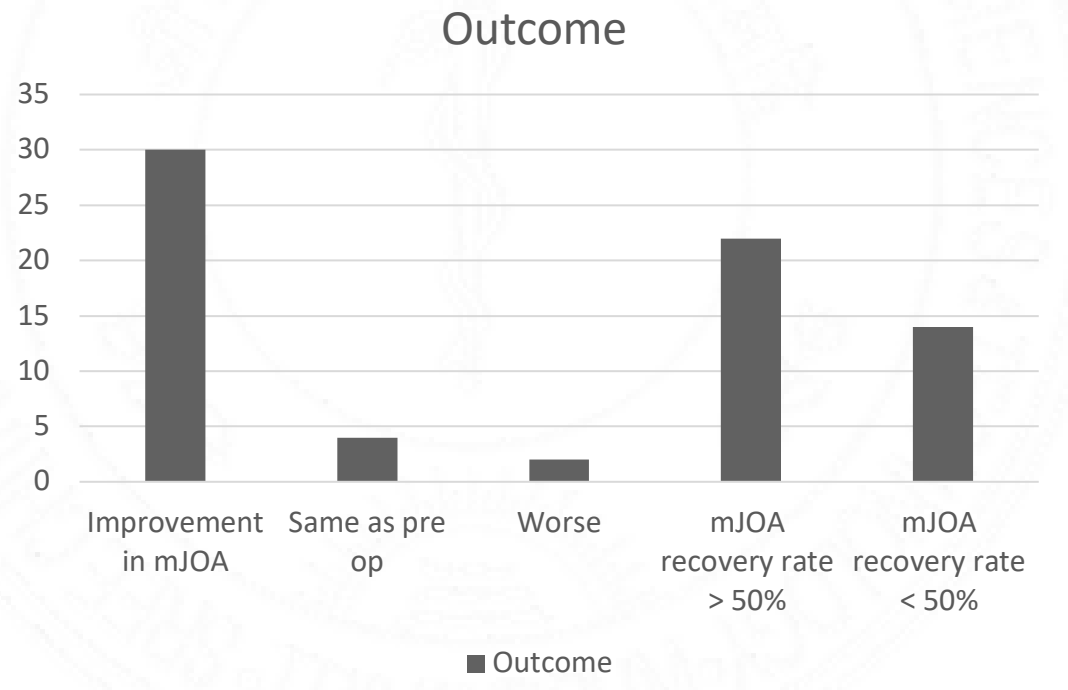


Fig 11: Outcome variables

Post-operative radiological parameters

Minimum spinal canal diameter and the OPLL occupation ratio was not noted post-operatively in view of post laminectomy status. The K-line was negative in 4 (11.1%) patients and positive in 32 (88.9%) patients. The mean post-operative C2-C7 Cobb's angle was 12.9 degrees (SD 7.1) and the mean post-operative C7 SVA was 2.07 cm (SD 0.93).

Bi-variate analysis

On bivariate analysis, the patient characteristics were comparable between the group of patients having optimal and the group of patients having sub-optimal outcome. No significant difference was seen in the clinical presentation, co-morbid conditions and the duration of symptoms between the two groups. The mean pre-operative mJOA scores were lower in the patients with sub-optimal outcome, however, this difference did not reach statistical significance (p-value = 0.058).

Table10: Bi-variate analysis: Patient's characteristics

Variable	**Optimal outcome (n=22)**	**Sub-optimal outcome (n=14)**	**p-Value**
Age	54	55	0.4
Gender			0.6
F	4 (18%)	1 (7.1%)	
M	18 (82%)	13 (93%)	
BMI	31.0 (4.9)	28.6 (2.0)	0.078
Co-morbid conditions			
DM type II	8	3	0.5
HTN	6	4	0.9
Follow up (years)	4.92 (2.92)	3.89 (2.03)	0.4
Duration of symptoms (months)	14 (16)	8 (4)	0.8

Table 11: Bi-variate analysis: Clinical findings

Clinical Presentation	**Optimal outcome (n=22)**	**Sub-optimal outcome (n=14)**	**p-Value**
Sensory symptoms	19	11	0.7
Gait unsteadiness	14	10	0.7
Weakness of limbs	17	10	0.69
Spasticity	15	9	0.9
Neck pain	8	7	0.4
Radiculopathy	4	7	0.9
Mean pre-operative mJOA	13.09	12.14	0.058

Pre-operative Radiological Parameters

On bivariate analysis it was seen that the patients having sub-optimal outcome were more likely to have either a continuous or mixed type of OPLL, whereas the patients with optimal outcome were more likely to

have a segmental type of OPLL. This difference was statistically significant with a p-value of 0.04. It was also seen that patients with sub-optimal outcome had more severe spinal canal compromise in the form of a lower minimum spinal canal diameter and a higher OPLL occupation ratio. The difference was statistically significant with a p-value of 0.017. Similarly, patients with sub-optimal outcome were also noted to be having a higher value of C7 SVA. This difference was also statistically significant with a p-value of 0.049. Other radiological parameters did not show statistically significant difference between the two groups. The findings are summarized in table 12.

Table 12: Bi-variate analysis: Pre-operative radiological parameters

Variable	**Optimal outcome (n=22)**	**Sub-optimal outcome (n=14)**	**p-Value**
Type of OPLL			**0.04**
Mixed/Continuous	08	10	
Segmental	14	04	
Min Spinal canal diameter	6.06 (1.30)	4.82 (1.32)	**0.017**
Occupation Ratio	0.38 (0.11)	0.47 (0.13)	**0.049**
C7 SVA	1.62 cm	2.35 cm	**0.044**
C2-C7 Cobb's angle	12.10 deg	8.70 deg	0.13
K-line			0.5
Negative	05	05	
Positive	17	09	

Surgical Variables

Surgical intervention did not differ between the groups having optimal or sub-optimal outcome. The mean levels of laminectomy and mean number of levels fused were statistically similar between the two groups.

Table 13: Bi-variate analysis: Surgical variables

Variable	Optimal outcome (n=22)	Sub-optimal outcome (n=14)	p-Value
Levels Laminectomy (Mean)	4.36	4.57	0.17
Levels Fused	3.36	3.37	0.49

Change in the radiological parameters after surgery

The mean values of C2-C7 Cobb's angle increased after the surgical intervention, however the difference was not statistically significant. Also, the change in C2-C7 angle was not significantly related to the outcome. Similarly, there was no significant change in the values of C7 SVA post-operatively. However, the patients with sub-optimal outcome were found to be having a higher value of C7 SVA, as was seen with the pre-operative values. The change in the values of C7 SVA was also not associated with the outcome. Similarly, the changes in K-line after surgery were also not statistically significant and were not related to the overall outcome.

Table 14: Bi-variate analysis: Post-operative radiological parameters (dC2-C7 Cobb's angle = Change in the C2-C7 Cobb's angle; dC7SVA = Change in C7 SVA)

Variable	**Optimal outcome (n=22)**	**Sub-optimal outcome (n=14)**	**p-Value**
C2-C7 Cobb's angle	14.4	10.5	0.12
C7 SVA	1.81	2.48	0.046
dC2-C7 Cobb's angle	2.01	2.00	0.6
dC7 SVA	0.19	0.13	0.5

Discussion

Cervical OPLL is an important cause of myelopathy, especially in the older male population and can cause devastating functional impairment. Although it is much more common in the East Asian countries, cases have been reported from all over the world. With the present study we had aimed at identifying the radiological findings that can be used for prognostication and also guide in the surgical decision making, in the patient population belonging predominantly to the southern Indian states.

The mean age of patients in our study population was 54 years, which is commensurate with the published literature on the subject. Most studies have reported a male:female ratio of around 2:1[15]. A relatively more skewed male:female ratio was observed in our study. The same is likely to be the result of a limited number of patients due to strict inclusion criteria of the study and thus it is not likely to represent the actual male:female ratio. Most patients in our study group presented with sensory symptoms, unsteadiness of gait and weakness of the limbs. This is similar to the clinical presentation as recorded by the investigation committee on ossification of spinal ligaments of the Japanese Ministry of Public Health

and Welfare[42]. Seventy-five percentage of patients in our study group, which shows that most patients had established myelopathy at the time of presentation to our institute and is suggestive of significant disease in the form of long standing and severe cord compression in these patients.

. The mean pre-operative mJOA scores were low (12.69) in our study group, signifying the severity of illness in the patients included in our study. This probably represents the more severe disease related to the multisegmental involvement, which was the study criteria. The mean duration of symptoms was 12 months, underscoring the chronic and insidious nature of the illness as has been previously reported by various epidemiological studies[42].

Improvement in mJOA scores was seen in most patients (83.3%) after surgery. The mJOA scores showed steady improvement in these patients over the follow up period, and the mean mJOA at last follow up increased to 14.58. The improvement in the mJOA scores seen in our study shows the effectiveness of posterior decompression and fusion for management of multisegmental OPLL. Posterior decompression and fusion for management of myelopathy caused by cervical OPLL has been studied extensively with most studies showing good to excellent neurological outcomes[56]. There have been apprehensions that the posterior

approaches are associated with inadequate decompression as the anterior compression by the OPLL mass is not addressed. However, studies evaluating the post-operative spinal canal dimensions and spinal cord compression have shown adequate ventral decompression after laminectomy and fusion in patients with cervical OPLL. Morio Y and co-workers studied the effect of posterior decompression and fusion on the spinal canal dimensions in 51 patients and found significant increase in the spinal canal diameter and the dimensions of the dural tube, thus supporting the view that laminectomy and fusion provide adequate dorsal and ventral decompression of the spinal canal[57].

Four patients in the study group had no improvement and two had worsening of the pre-operative mJOA scores after the surgery. Both the patients who had worsening of the mJOA score had neurological deterioration in the immediate post operative period. These patients had a severe spinal canal compromise with minimum spinal canal diameter less than 5 mm. They were also noted to be having a continuous or a mixed type of OPLL. One of these patients has been followed up for only one year, till the time of result analysis and may show improvement in mJOA scores on further follow up. Three patients in the study group had surgical site infection in the post operative period, of which one patient required

re-exploration and wound debridement. Other patients did not require any other intervention apart from regular dressings and recovered without consequences. Four of the patients were noted to be having C5 palsy in the post-operative period. All patients recovered over the duration of follow up. Complication rates following surgery for cervical OPLL have wide variations in the reported literature. A systematic review encompassing twenty-seven retrospective study and 1558 patients, reported a cumulative complication rate of around 21.8% with all approaches for cervical OPLL[58]. Rate of wound related complications has not been extensively studied, probable due to their relative rarity as compared to other complications. Few studies have reported a rate of 3 - 5 % in patients undergoing surgery of cervical OPLL[59]. Rates of C5 palsy after posterior decompression and fusion also varies widely between studies and ranges between 1.5 and 23 % with an average of 7.8%[60]. A retrospective analysis addressing the issue of C5 palsy after cervical spine surgery for OPLL reported an incidence of 5.7%, with no difference between the different surgical approaches[61]. However, most studies have shown a relatively higher incidence of C5 palsy in the patients undergoing posterior decompression and fusion as compared to the patients managed with anterior approaches[72].

An mJOA recovery rate was calculated using the pre and the post operative mJOA scores taken at last follow up and the same was used to define the outcome. We considered a recovery rate of >/= 50% as optimal outcome. With this definition, 22 patients (61%) in our study group had optimal outcome. In a retrospective study Yu Chen et al had reported a recovery rate of 50% or more in 59 of 83 patients (71.1%) undergoing posterior decompression and fusion for cervical OPLL[62]. A marginally lower recovery rate seen in our study is likely due to inclusion of only patients who had involvement of 3 or more vertebral segments, thus having a widespread and more severe disease. Studies addressing the question of best approach for multisegmental OPLL have shown favourable results with posterior approaches. In a retrospective analysis of patients with cervical OPLL involving 4 or more vertebral levels, SK Jain and co-workers found significantly higher complication rates with anterior approaches. Their study also showed good neurological outcomes with the posterior approaches, thus favouring a posterior rather than an anterior approach for management of multisegmental OPLL[63]. The studies comparing anterior approaches with posterior decompression alone (without fusion) have shown suboptimal outcomes with posterior decompression alone when compared to the anterior approaches.

However, the results with posterior decompression and fusion were comparable to the anterior approaches with lesser perioperative complications[64]. This difference in the outcome underscores the role of dynamic compression and cervical motion in pathogenesis and progression of cervical OPLL.

A variety of radiological parameters were included in our study, including the ones representing the severity of spinal cord compression and those representing the cervical spinal sagittal balance. However, all the parameters representing the sagittal balance could not be studied due to limitation of the available imaging studies. The spinal sagittal balance was assessed using the C7 SVA and C2-C7 Cobb's angle. The normal spinal canal dimensions in the sub-axial cervical spine roughly ranges from 13 to 15 mm in normal individuals[65]. The mean minimum spinal canal diameter in our study population was 5.58 mm, which shows very severe spinal canal compromise. An OPLL occupation ratio was also calculated at the same level, with both the variables signifying the severity of spinal canal compromise. On bivariate analysis, it was found that the patients who had a suboptimal outcome, also had more severe spinal canal compromise in the form of a significantly lower minimum spinal canal diameter and a higher OPLL occupation ratio. OPLL occupation ratio has

been identified as an independent risk factor for development of myelopathy in various studies[66]. An OPLL occupation ratio of more than 0.6 (60%) is said to be associated with a significant risk of developing myelopathy[67]. Zijian H et al have also reported that a higher OPLL occupation ratio is associated with suboptimal outcome after surgical intervention done for cervical OPLL. Same was observed in the present study, where the patients with suboptimal outcome were noted to be having a significantly higher OPLL occupation ratio (0.47 Vs 0.38). In the present study, the type of OPLL (Segmental/Focal Vs Mixed/continuous) was also found to be associated with outcome of the patients after posterior decompression and fusion, with the patients having a mixed or continuous type of OPLL being more likely to have a suboptimal outcome. Similar to the present study, Yudoyono F et al, in a retrospective review of outcome following surgical intervention for cervical OPLL, found that the patients with mixed or continuous type of OPLL had poorer Visual Analog Scale (VAS) scores and a lower mJOA scores.[68] This observation probably relates to the multisegmental involvement and more severe compression seen in mixed and continuous types of OPLL. We also studied the K-line (Kyphosis line) with regards to the outcome following posterior decompression and instrumented fusion. No association was found

between the status of K-line (whether positive or negative) and outcome of the patients. Our study thus shows that a posterior decompression and instrumented fusion seems to be a viable surgical option, both in cases with K-line positive and negative status. In a systematic review and meta-analysis, Lei Ma et al had also reported good outcomes in K-line negative patients who underwent a posterior decompression and instrumented fusion, as compared to posterior decompression alone[69].

The role of sagittal balance of the cervical spine is being extensively investigated in ongoing research world over with numerous parameters defining the normal balance of the cervical spine being described. We used the C2-C7 Cobb's angle and the C7 SVA to assess the cervical sagittal balance. We could not study other parameters of cervical sagittal balance, such as the T1-slope, as the first thoracic vertebra was not routinely included in the lateral cervical radiographs done at our institute at that time. Our results showed that patients who had a suboptimal outcome, also had a higher C7 SVA. The mean C7 SVA in the patients with suboptimal outcome was 2.35 cms, and was 1.62 cms in those with optimal outcome, and this difference was statistically significant. The mean C2-C7 Cobb's angle in the patients with optimal outcome was 12.1 degrees as compared to 8.7 degrees in patients with sub-optimal outcome. Though the C2-C7

Cobb's angle was higher in patients with optimal outcome, this difference did not reach statistical significance. Importance of sagittal balance and C7 SVA in prognostication and guiding the surgical approach in patients having myelopathy due to cervical OPLL, has been highlighted by multiple studies. A C7 SVA of more than 4 cms is usually considered to be an indicator of significant kyphotic deformity of the cervical spine and has been independently associated with poor outcomes following posterior decompression without instrumentation[70]. Patients who have been treated with laminoplasty alone for multisegmental cervical OPLL with significant kyphotic deformity, have shown to be having a greater progression of OPLL and kyphotic deformity, leading to overall poor results[71]. Most studies thus recommend addition of instrumentation to the surgical strategy while treating multilevel cervical OPLL. Anterior approaches have been the main stay of treatment for cervical myelopathy caused by cervical OPLL. However, these approaches are limited by a significantly higher complication rates, including dural tears and CSF leak, when applied for management of multisegmental and extensive disease. Posterior decompression and instrumented fusion in these cases seems to be the appropriate surgical approach[72].

Our study also showed a marginal increase in the C2-C7 Cobb's angle (10.7 Vs 12.9) post operatively, however this increase was not significant statistically. C7 SVA did not show any significant change after surgery (1.93 cm Vs 2.07 cm). Further, the changes in these parameters did not lead to a statistically significant difference in the outcome. Our study shows that although the parameters of sagittal balance are important prognostic indicators and can guide the surgical strategy, correction or persistence of sagittal deformity after the surgical intervention may not be related to the overall outcome of the patients. This observation also signifies the multifactorial pathogenesis of myelopathy and clinical syndrome caused by cervical OPLL, with alteration of sagittal balance, severity of static and dynamic compression and morphology of abnormal calcification playing important roles.

We believe that the neurological improvement in the patients undergoing posterior decompression and fusion is mostly related to the cessation of dynamic component of the compression, decompression of the spinal canal and arrest of progression of the OPLL. Importance of the dynamic compression has been evaluated in both laboratory and clinical studies. Nishida and co-workers had used a bovine spinal cord as substrate and demonstrated increasing mechanical stress over the cord with increase

in static compression. However, the addition of the dynamic component exponentially increased the amount of mechanical stress over the cord structures[38]. Similarly, Toshitaka et al, used kinematic computed tomography myelography and reported significant increase in the cord compression with cervical motion, especially during extension[39]. These studies underscore the importance of dynamic compression in the pathogenesis of myelopathy in cervical degenerative diseases including OPLL. Further, increased cervical motion has also been associated with progression of OPLL and increase in spinal compression. Keishi Maruo and co-workers studies the impact of this dynamic motion on the progression and outcome after posterior decompression in patients with cervical OPLL. They concluded that the patients having a higher range of C2-C7 motion were four times more likely to have progression of OPLL and worsening of neurological status[73]. Posterior decompression and fusion thus addresses the dynamic compression and the range of cervical spine motion, leading to lesser degree of progression and significant neurological improvement.

Limitations of the study

1. Retrospective nature of the study with its inherent shortcomings including missing data and imaging, which led to exclusion of some of the patients, causing reduction in the size of study population.

2. Being a retrospective study spanned over 10 years, there is a possibility of variation in the imaging protocols which could have affected the measurements of radiological parameters in the study population.

3. We could not study all the parameters of the sagittal balance as the first thoracic vertebra was not included in all the cervical spine radiographs available.

4. We included the patients with a minimum of one year follow up, however a longer follow up duration is desirable in view of the insidious and chronic nature of the disease.

5. Further, few of the patients who had a sub-optimal outcome may show improvement in subsequent follow up, thus altering the result.

CONCLUSIONS

1. Decompressive laminectomy with lateral mass fusion is a relatively simple, safe and effective treatment for patients with compressive myelopathy caused by multisegmental cervical OPLL.
2. Severity of spinal canal compromise and severe kyphotic deformity are predictors of poor outcome in such patients.
3. There is no significant change in sagittal balance parameters after posterior decompression and fusion. Even in patients with pre-operative kyphotic deformity, significant neurological improvement in terms of mJOA scores post-operatively despite non-correction of deformity suggests the role of a dynamic component also in the pathogenesis and progression of myelopathy. This underscores the importance of surgical stabilization in addition to neuraxial decompression in all patients with cervical OPLL associated myelopathy.

REFERENCES

1. Jeon TS, Chang H, Choi BW. Analysis of demographics, clinical, and radiographical findings of ossification of posterior longitudinal ligament of the cervical spine in 146 Korean patients. Spine (Phila Pa 1976). 2012 Nov 15;37(24):E1498-503

2. Yudoyono F, Cho PG, Park SH, et al. Factors associated with surgical outcomes of cervical ossification of the posterior longitudinal ligament. Medicine (Baltimore). 2018 Jul;97(29):e11342.

3. Ma L, Liu FY, Huo LS, et al. Comparison of laminoplasty versus laminectomy and fusion in the treatment of multilevel cervical ossification of the posterior longitudinal ligament: A systematic review and meta-analysis. Medicine (Baltimore). 2018 Jul;97(29):e11542

4. Yuan W, Zhu Y, Liu X, et al. Postoperative three- dimensional cervical range of motion and neurological outcomes in patients with cervical ossification of the posterior longitudinal ligament: Cervical laminoplasty versus laminectomy with fusion. Clin Neurol Neurosurg. 2015 Jul;134:17-23.

5. Kim KS. Clinical Effectiveness of Posterior Cervical Decompression and Fusion in Terms of Reducing OPLL Growth Versus Cervical Motion Preservation. Neurospine. 2019 Sep;16(3):492-493.

6. Key G A. On paraplegia depending on the ligament of the spine. Guy's Hosp Rep, 3: 17-34, 1838

7. Oppenheimer A. Calcification and ossification of vertebral ligaments (Sondylitis ossificans ligamentosa): roentegen study of pathogenesis and clinical significance. Radiology 38:160-173. 1942.

8. Tsukimoto H. A case report – Autopsy of the syndrome of compression of the spinal cord owing to ossification within the spinal canal of cervical spine (in Japanese). Nihon Geka Hokan (Arch Jpn Chir) 29:1003-1007. 1960

9. Sakou T, Tomimura K, Maehara T, Kawamura H, Morizono Y, Nagamine T. Epidemiological study of Ossification of the posterior longitudinal ligaments in the cervical spine in Okinawa (in Japanese). In: Investigation committee 1977 report on the ossification of the spinal ligaments of the Japanese Ministry of Public health and Welfare, Tokyo, 172-173. 1978

10. Ohtsuka K, Terayama K, Wada K, et al. Epidemiological study of Ossification of the posterior longitudinal ligaments in the cervical spine in Yachiho, Nagano (in Japanese). In: Investigation committee 1983 report on the ossification of the spinal ligaments of the Japanese Ministry of Public health and Welfare, Tokyo, 63-67. 1984.

11. Matsunaga S, Yamaguchi M, Hayashi K, Sakou T: Genetic analysis of ossification of the posterior longitudinal ligament. *Spine* 24:937–939, 1999

12. Liu K. Epedemiological study on ossification of the posterior longitudinal ligament (OPLL) in the cervical spine: comparison of prevalence between Japanese and Tiawanese. J Jpn Orthop Assoc. 1990;64: 401-408.

13. Tomita T, Harata S, Ueyama K et al. Epidemiological study of ossification of posterior longitudinal ligament (OPLL) of cervical spine and cervical spondylotic changes in China. In: Investigation committee 1993 report on the ossification of the spinal ligaments of the Japanese ministry of Public Health and welfare. Tokyo: Japanese Ministry of Public health and welfare; 1994: 101-105

14. Izawa K. Comparative radiographic study on the incidence of ossification of cervical spine among Japanese, Koreans, Americans and Germans. J Jpn Orthop Assoc. 1980;54:461-474.

15. Wu JC, Liu L, Chen YC, Huang WC, Chen TJ, Cheng H. Ossification of the posterior longitudinal ligament in the cervical spine: an 11-year comprehensive national epidemiology study. Neurosurg Focus. 2011 Mar;30(3).

16. Koga H, Sakou T, Taketomi E, et al. Genetic mapping of ossification of the posterior longitudinal ligament of the spine. Am J Hum Genet. 1998;62:1460-1467.

17. Tanaka T, Ikaki K, Fukushima K, et al. Genomewide linkage disequilibrium analyses identify COL6A1 on chromosome 21, as the locus for ossification of the posterior longitudinal ligament of the spine. Am J Hum genet. 2003;73: 812-822.

18. Terayama K. Genetic studies on ossification of the posterior longitudinal ligament of the spine. *Spine.* 1989;14:1184–1191.

19. Matsunaga S, Yamaguchi M, Hayashi K, Sakou T. Genetic analysis of ossification of the posterior longitudinal ligament. *Spine.* 1999;24:937–939.

20. Karasugi T, Nakajima M, Ikari K, et al. A genome-wide sib-pair linkage analysis of ossification of the posterior longitudinal ligament of the spine. *J Bone Miner Metab.* 2013;31:136–143.

21. Nakajima M, Takahashi A, Tsuji T et al. A genome-wide association study identifies susceptibility loci for ossification of the posterior longitudinal ligament of the spine. *Nat Genet.* 2014;46:1012–1016.

22. Kamiya M, Harada A, Mizuno M, Iwata H, Yamada Y. Association between a polymorphism of the transforming growth factor-beta1 gene

and genetic susceptibility to ossification of the posterior longitudinal ligament in Japanese patients. *Spine.* 2001;26:1264–1266.

23. Kim KH, Kuh SU, Park JY, et al. Association between BMP-2 and COL6A1 gene polymorphisms with susceptibility to patients and family members. *Genet Mol Res.* 2014;13:2240–2247.

24. Kong Q, Ma X, Li F, et al. COL6A1 polymorphisms associated with ossification of the ligamentum flavum and ossification of the posterior longitudinal ligament. *Spine.* 2007;32:2834–2838.

25. Iwasaki K, Furukawa KI, Tanno M, et al. Uni-axial cyclic stretch induces Cbfa1 expression in spinal ligament cells derived from patients with ossification of the posterior longitudinal ligament. *Calcif Tissue Int.* 2004;74:448–457.

26. Ohishi H, Furukawa K, Iwasaki K, et al. Role of prostaglandin I2 in the gene expression induced by mechanical stress in spinal ligament cells derived from patients with ossification of the posterior longitudinal ligament. *J Pharmacol Exp Ther.* 2003;305:818–824.

27. Zhang W, Wei P, Chen Y, et al. Yan. Down-regulated expression of vimentin induced by mechanical stress in fibroblasts derived from patients with ossification of the posterior longitudinal ligament. *Eur Spine J.* 2014;23:2410–2415.

28. Nishimura R, Hata K, Matsubara T, Wakabayashi M, Yoneda T. Regulation of bone and cartilage development by network between BMP signalling and transcription factors. *J Biochem.* 2012;151:247–254.

29. Sugita D, Yayama T, Uchida K, et al. Indian hedgehog signaling promotes chondrocyte differentiation in enchondral ossification in human cervical ossification of the posterior longitudinal ligament. *Spine.* 2013;38:E1388–E1396.

30. Wang PN, Chen SS, Liu HC, Fuh JL, Kuo BI, Wang SJ. Ossification of the posterior longitudinal ligament of the spine. A case-control risk factor study. *Spine.* 1999;24:142–144.

31. Okamoto K, Kobashi G, Washio M, et al, Japan Collaborative Epidemiological Study Group for Evaluation of Ossification of the Posterior Longitudinal Ligament of the Spine (OPLL). Risk Dietary habits and risk of ossification of the posterior longitudinal ligaments of the spine (OPLL); findings from a case-control study in Japan. *J Bone Miner Metab.* 2004;22:612–617.

32. Sugimori K, Kawaguchi Y, Ohmori K, Kanamori M, Ishihara H, Kimura T. Significance of bone formation markers in patients with ossification of the posterior longitudinal ligament of the spine. *Spine.* 2003;28:378–379.

33. Zhang Y, Liu B, Shao J, Song J, Zhang J. Proteomic profiling of posterior longitudinal ligament of cervical spine. *Int J Clin Exp Med.* 2015;8:5631–5639

34. Rensick D, Niwayam G. Radiographic and pathologic features of spinal involvement in diffuse idiopathic skeletal hyperostosis (DISH). Radiology. 1976; 119:559-568.

35. Yamazaki Y, Toda N, Nubotani T, et al. Anterior spinal artery syndrome by the ossification of the posterior longitudinal ligament in the cervical spine, an autopsy case. Chubuseiaishi. 1972;15:849-858.

36. Breig A, Turnbull I, Hassler O. Effects of mechanical stress on the spinal cord in cervical spondylosis. A study on fresh cadaver material. J Neurosurg. 1966 Jul;25(1): 45-56.

37. Kameyama T, Hashizume Y, Sobue G. Spinal cord cysts in compressive myelopathy: a neuropathological study. In: Investigation Committee Report on the Spinal Ligaments of the Japanese Ministry of Public Health and Welfare. Tokyo: Japanese Ministry of Public Health and Welfare; 1996.

38. Nishida N, Kanchiku T, Kato Y, et al. Cervical ossification of the posterior longitudinal ligament: Biomechanical analysis of the influence of static and dynamic factors. *J Spinal Cord Med*. 2015;38(5):593-598.

39. Yoshii T, Yamada T, Hirai T, et al. Dynamic changes in spinal cord compression by cervical ossification of the posterior longitudinal ligament evaluated by kinematic computed tomography myelography. Spine (Phila Pa 1976). 2014 Jan 15;39(2):113-9.

40. Mizuno J, Nakagawa H, Iwata K, Hashizume Y. Pathology of spinal cord lesions caused by ossification of the posterior longitudinal ligament, with special reference to reversibility of the spinal cord lesion. Neurol Res. 1992 Sep;14(4):312-4.

41. Hashizume Y, Iijima S, Kishimoto H, Yanagi T. Pathology of spinal cord lesions caused by ossification of the posterior longitudinal ligament. Acta Neuropathol. 1984;63(2):123-30.

42. Terayama K, Kurokawa K, Seki H. Report on the ossification of the spinal ligaments. In: Terayama K, editor. Investigation Committee report on the ossificationof the spinal ligaments of Japanese Ministry of Public Health and Welfare, Tokyo; 1976. p. 8–33.

43. Kawai S. Clinical manifestation of cervical ossification of the posterior longitudinal ligaments. In: Yonenobu K, Sakou T, Ono K, editors. OPLL: ossification of posterior longitudinal ligament. Tokyo: Springer; 1997. p. 81–4.

44. Mizuno J, Nakagawa H, Isobe M. Surgical results of anterior approach in ossi!cation of the posterior longitudinal ligament in the cervical spine. Spinal Surg. 1997;11:39-46 [in Japanese].

45. Fujiyoshi T, Yamazaki M, Kawabe J, et al. A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. Spine (Phila Pa 1976). 2008 Dec 15;33(26).

46. Hida K, Iwasaki Y, Koyanagi I, Abe H. Bone window computed tomography for detection of dural defect associated with cervical ossified posterior longitudinal ligament. Neurol Med Chir (Tokyo). 1997 Feb;37(2):173-5; discussion 175-6. doi: 10.2176/nmc.37.173. PMID: 9059040.

47. Matsuyama Y, Kawakami N, Yanase M, et al. Cervical myelopathy due to OPLL: clinical evaluation by MRI and intraoperative spinal sonography. J Spinal Disord Tech. 2004 Oct;17(5):401-4.

48. Matsunaga S, Kukita M, Hayashi K, et al. Pathogenesis of myelopathy in patients with ossification of the posterior longitudinal ligament. J Neurosurg. 2002;96(suppl 2):169-172

49. Yoshii T, Sakai K, Hirai T, et al. Anterior decompression with fusion versus posterior decompression with fusion for massive cervical ossification of the posterior longitudinal ligament with a ≥50% canal occupying ratio: a multicenter retrospective study. Spine J. 2016 Nov;16(11):1351-1357.

50. Koda M, Mochizuki M, Konishi H, et al. Comparison of clinical outcomes between laminoplasty, posterior decompression with instrumented fusion, and anterior decompression with fusion for K-line (-) cervical ossification of the posterior longitudinal ligament. Eur Spine J. 2016 Jul;25(7):2294-301.

51. Li S, Peng J, Xu R, Zheng R, et al. Comparison of the surgeries for the ossification of the posterior longitudinal ligament-related cervical spondylosis: A PRISMA-compliant network meta-analysis and literature review. Medicine (Baltimore). 2021 Mar 5;100(9).

52. Sakai K, Yoshii T, Arai Y, et al. Impact of preoperative cervical sagittal alignment for cervical myelopathy caused by ossification of the posterior longitudinal ligament on surgical treatment. J Orthop Sci. 2021 Sep 28:S0949-2658(21)00278-5.

53. Jeanneret B, Magerl F, Ward EH, Ward JC. Posterior stabilization of the cervical spine with hook plates. Spine (Phila Pa 1976). 1991 Mar;16(3 Suppl):S56-63.

54. Benzel EC, Lancon J, Kesterson L, Hadden T. Cervical laminectomy and dentate ligament section for cervical spondylotic myelopathy. J Spinal Disord. 1991 Sep;4(3):286-95.

55. Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K. Operative results and postoperative progression of ossification among

patients with ossification of cervical posterior longitudinal ligament. Spine (Phila Pa 1976). 1981 Jul-Aug;6(4):354-64.

56. Huang RC, Girardi FP, Poynton AR, Cammisa FP Jr. Treatment of multilevel cervical spondylotic myeloradiculopathy with posterior decompression and fusion with lateral mass plate fixation and local bone graft. J Spinal Disord Tech. 2003 Apr;16(2):123-9.

57. Morio Y, Yamamoto K, Teshima R, Nagashima H, Hagino H. Clinicoradiologic study of cervical laminoplasty with posterolateral fusion or bone graft. Spine (Phila Pa 1976). 2000 Jan 15;25(2):190-6.

58. Li H, Dai LY. A systematic review of complications in cervical spine surgery for ossification of the posterior longitudinal ligament. Spine J. 2011 Nov;11(11):1049-57.

59. Tetreault L, Tan G, Kopjar B, et al. Clinical and Surgical Predictors of Complications Following Surgery for the Treatment of Cervical Spondylotic Myelopathy: Results From the Multicenter, Prospective AOSpine International Study of 479 Patients. Neurosurgery. 2016 Jul;79(1):33-44.

60. Li H, Dai LY. A systematic review of complications in cervical spine surgery for ossification of the posterior longitudinal ligament. Spine J. 2011 Nov;11(11):1049-57.

61. Pan FM, Wang SJ, Ma B, Wu DS. C5 nerve root palsy after posterior cervical spine surgery. J Orthop Surg (Hong Kong). 2017 Jan;25(1)

62. Chen Y, Guo Y, Chen D, Wang X, Lu X, Yuan W. Long-term outcome of laminectomy and instrumented fusion for cervical ossification of the posterior longitudinal ligament. Int Orthop. 2009 Aug;33(4):1075-80.

63. Jain SK, Salunke PS, Vyas KH, Behari SS, Banerji D, Jain VK. Multisegmental cervical ossification of the posterior longitudinal ligament: anterior vs posterior approach. Neurol India. 2005 Sep;53(3):283-5.

64. Qin R, Chen X, Zhou P, Li M, Hao J, Zhang F. Anterior cervical corpectomy and fusion versus posterior laminoplasty for the treatment of oppressive myelopathy owing to cervical ossification of posterior longitudinal ligament: a meta-analysis. Eur Spine J. 2018 Jun;27(6):1375-1387.

65. Lee MJ, Cassinelli EH, Riew KD. Prevalence of cervical spine stenosis. Anatomic study in cadavers. J Bone Joint Surg Am. 2007 Feb;89(2):376-80.

66. Yone K, et al. Diagnosis and treatment of ossification of the posterior longitudinal ligament. Image evaluation of the spinal cord in ossification of the posterior spinal ligament. Orthopaedics. 1991;(40):29-36. Japanese.

67. Matsunaga S, Nakamura K, Seichi A, et al. Radiographic predictors for the development of myelopathy in patients with ossification of the

posterior longitudinal ligament: a multicenter cohort study. Spine (Phila Pa 1976). 2008 Nov 15;33(24):2648-50.

68. Yudoyono F, Cho PG, Park SH, et al. Factors associated with surgical outcomes of cervical ossification of the posterior longitudinal ligament. Medicine (Baltimore). 2018 Jul;97(29):e11342.

69. Ma L, Liu FY, Huo LS, et al. Comparison of laminoplasty versus laminectomy and fusion in the treatment of multilevel cervical ossification of the posterior longitudinal ligament: A systematic review and meta-analysis. Medicine (Baltimore). 2018 Jul;97(29):e11542.

70. Sakai K, Yoshii T, Arai Y, et al. Impact of preoperative cervical sagittal alignment for cervical myelopathy caused by ossification of the posterior longitudinal ligament on surgical treatment. J Orthop Sci. 2021 Sep 28:S0949-2658(21)00278-5.

71. Masaki Y, Yamazaki M, Okawa A, et al. An analysis of factors causing poor surgical outcome in patients with cervical myelopathy due to ossification of the posterior longitudinal ligament: anterior decompression with spinal fusion versus laminoplasty. J Spinal Disord Tech. 2007 Feb;20(1):7-13.

72. Houten JK, Cooper PR. Laminectomy and posterior cervical plating for multilevel cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament: effects on cervical alignment, spinal cord

compression, and neurological outcome. Neurosurgery. 2003 May;52(5):1081-7.

73. Maruo K, Moriyama T, Tachibana T, Inoue S, Arizumi F, Daimon T, Yoshiya S. The impact of dynamic factors on surgical outcomes after double-door laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine. J Neurosurg Spine. 2014 Dec;21(6):938-43.

PROFORMA

Sr No :
Age :
Date of Surgery :
Date of discharge. :

Symptoms/Signs

Neck pain :
Radiculopathy :
Motor weakness :
Stiffness :
Gait unsteadiness :
Sensory impairment :
Duration :

Pre-operative Nurick grade :

Pre-operative mJOA score :

Pre-operative Radiological parameters

C2-C7 angle :
C7 SVA :
Type of OPLL :
Min spinal canal diameter :
OPLL occupation ratio :
K-line :

Surgery

Laminectomy

Levels fused

Post op symptoms/signs

Neck pain :
Radiculopathy :
Motor weakness :
Stiffness :
Gait unsteadiness :
Sensory impairment :

Post-operative Nurick grade :

Post-operative mJOA score :

Post-operative Radiological parameters

C2-C7 angle :
C7 SVA :
K-line :

ABBREVIATIONS

OPLL	Ossification of posterior longitudinal ligament
SVA	Sagittal Vertical Axis
JOA	Japanese Orthopaedic Association
mJOA score score	Modified Japanese Orthopaedic Association
HLA	Human Leucocyte Antigen
DISH	Diffuse Idiopathic Spinal Hyperostosis
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
CSF	Cerebro-spinal fluid
K-line	Kyphosis line
SD	Standard Deviation
BMI	Body Mass Index

ILLUSTRATIVE IMAGES

Fig A: Pre and post operative CT and MR images of a patient with continuous multisegmental OPLL. Patient underwent four levels laminectomy and lateral mass fusion. Adequate decompression of the spinal cord is evident with maintained anterior and posterior CSF spaces.

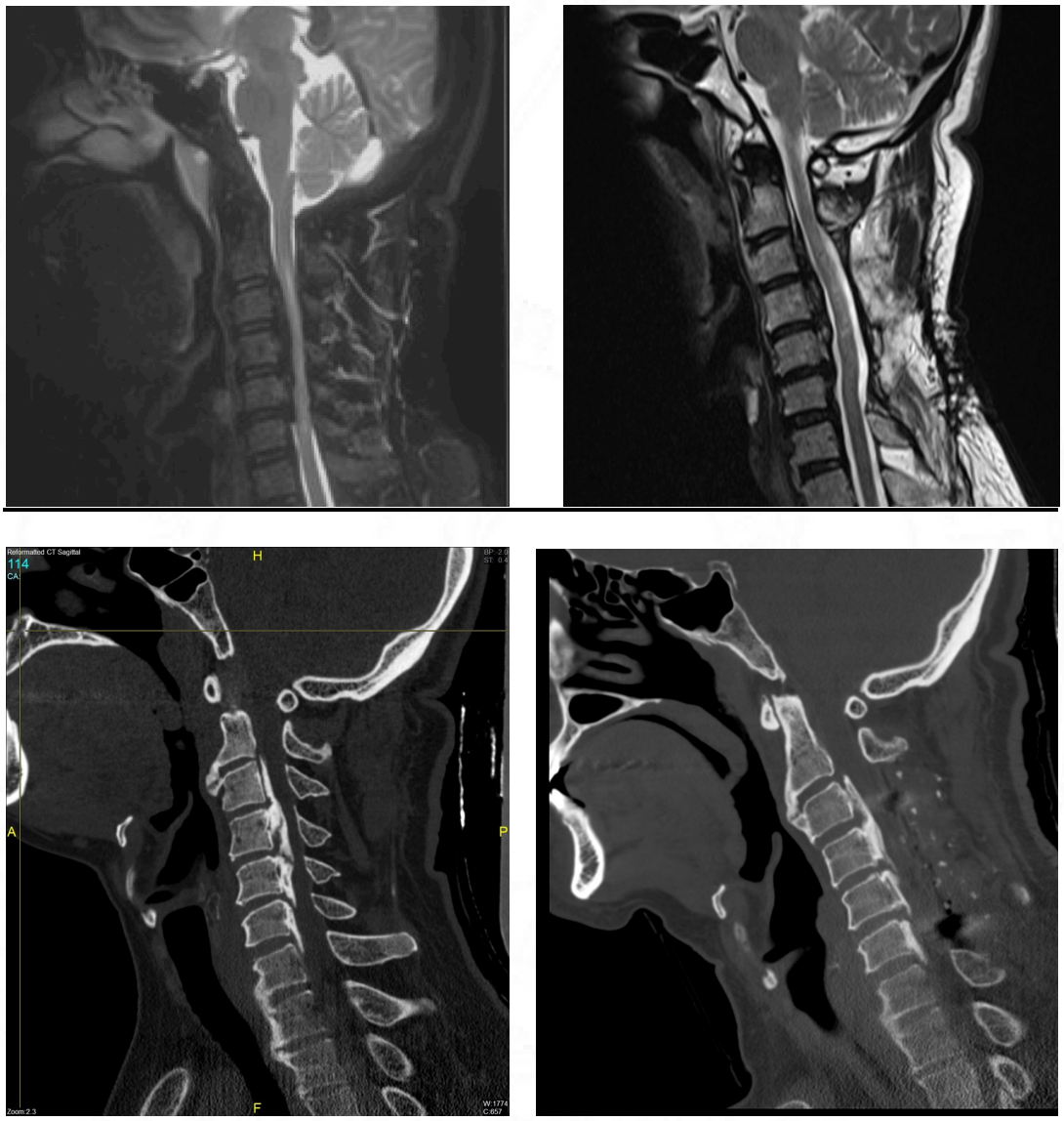


Fig B: Pre and post operative lateral radiographs demonstrating the C2-C7 Cobb's angle. The patient was managed with three levels laminectomy and lateral mass fusion.

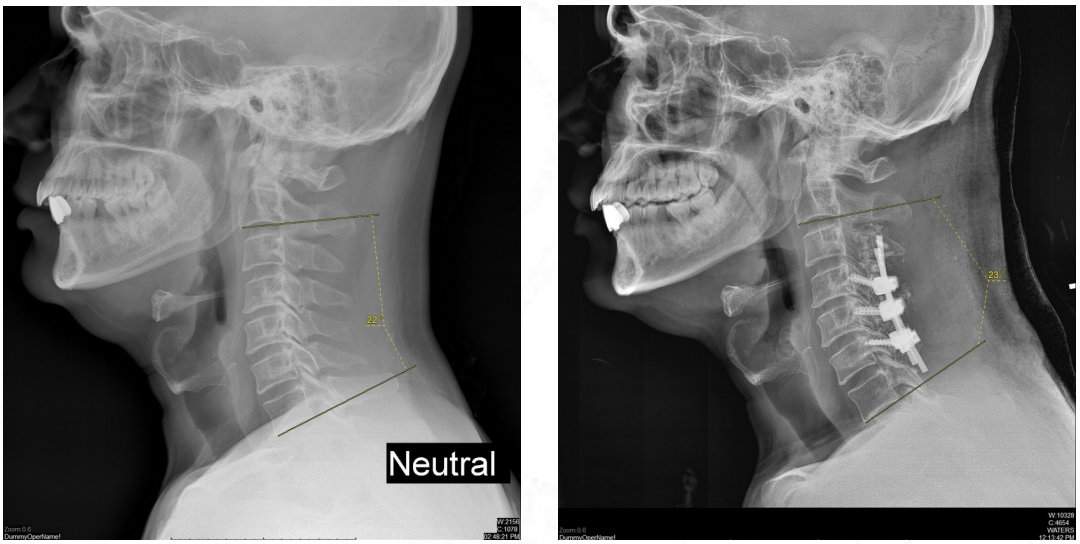


Fig C: Pre-operative and post operative images of a patient with segmental OPLL. He was managed with a four levels laminectomy and lateral mass fusion.

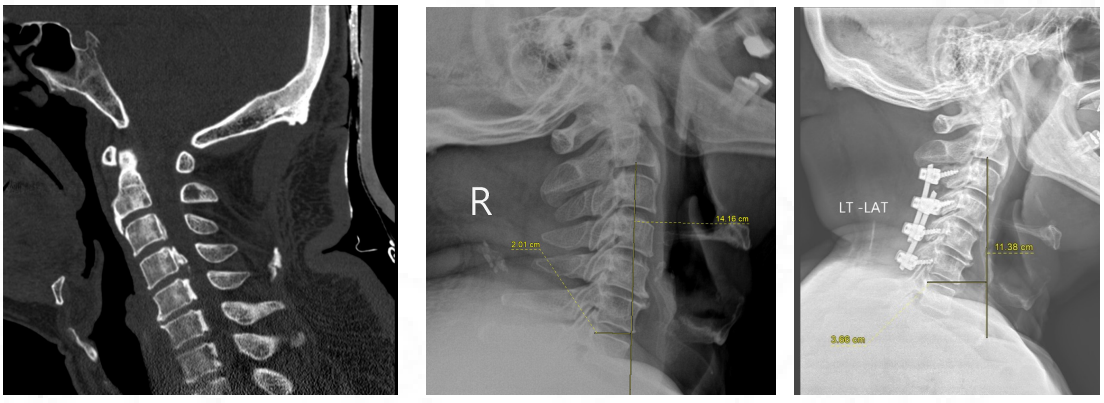


Fig D: Pre-operative CT and MR images of a patient with segmental OPLL involving multiple levels.

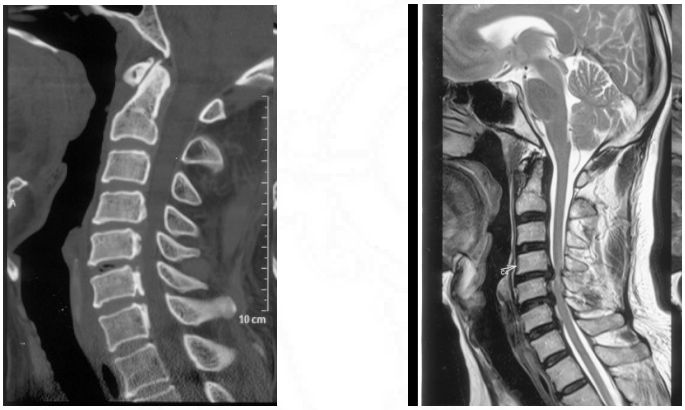


Fig E: Pre-operative MRI, radiographs and post-operative radiographs of a patient with continuous type of multisegmental OPLL

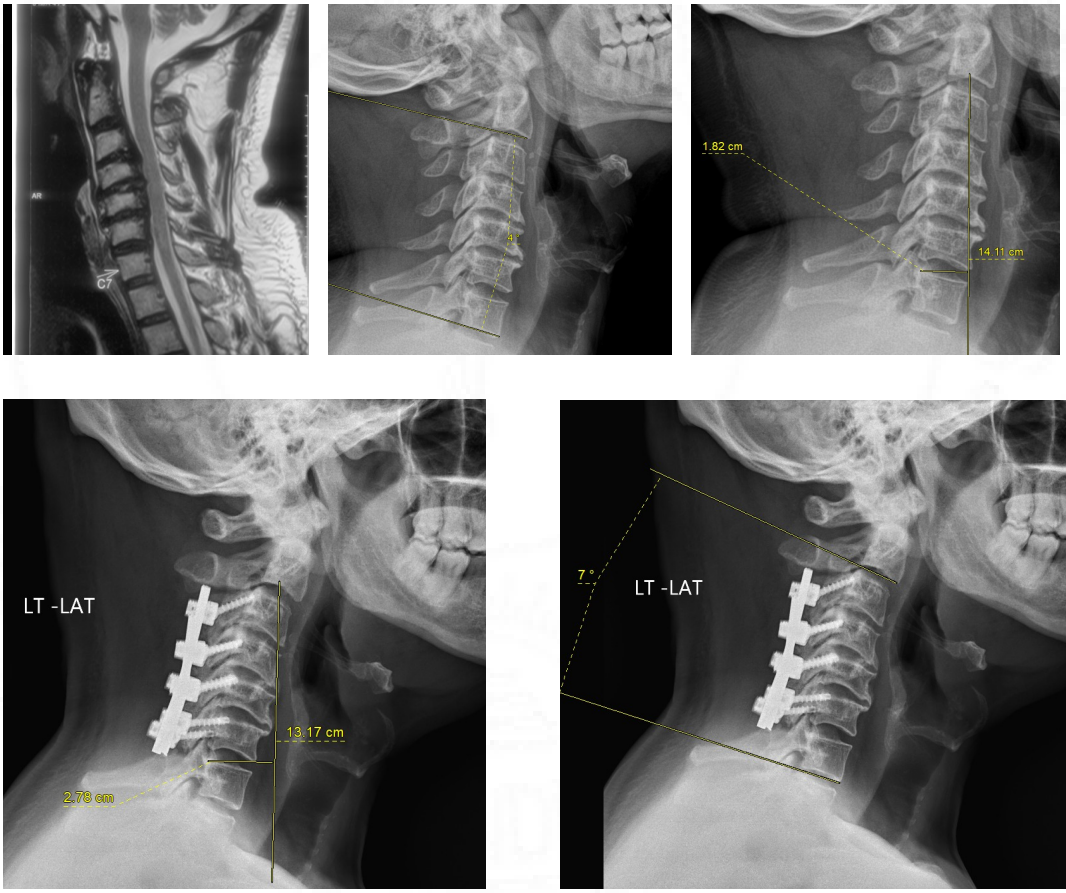


Fig F: Pre-operative CT and MR images and post-operative lateral and AP radiographs of patient with a mixed type of OPLL

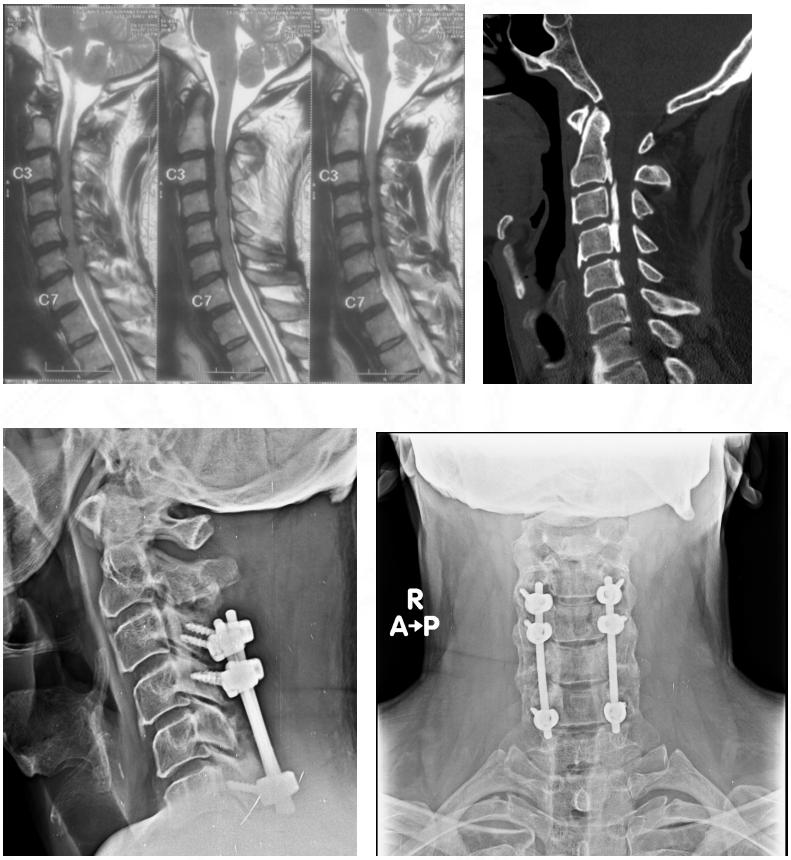


Fig G: Pre and post operative images of a patient with small, segmental OPLL.