Management of Acquired Compressive Myelopathy due to Spinal Fluorosis

Abstract

Background: Fluorosis is an endemic disease of India which causes compressive cervical and/or dorsal myelopathy. This study aims to evaluate the role of surgical management in the crippling fluorosis along with evaluation of radiological imaging as screening/diagnosing tool for the disease. Materials and Methods: This is a prospective cohort study of 33 patients operated at tertiary care center having nontraumatic involvement of spinal cord affecting neurology with history, clinical and radiological features (Ossified Posterior Longitudinal Ligament-, Ossified Ligamentum flavum) suggesting fluorosis as the cause of compression. Outcomes were measured in terms of improvement in Nurick grading, Rankins scale, spasticity, Oswestry Disability Index, modified Japanese Orthopaedic Association scores. Results: Spinal fluorosis is a male predominant disease affecting the elderly after years of fluoride intake. Cervical and/or dorsal spine are predominantly involved at multiple levels (>=2). Diagnosis of the disease poses difficulty due to lack of established laboratory parameters with high sensitivity, availability, and lack of awareness among surgeons. Skeletal survey alone has >90% sensitivity for diagnosing the disease. Once evaluated properly, decompression at correctly identified levels invariably improves the spasticity and quality of life immediately post-surgery. At final followup, there was on average improvement of 2 scales in nurick grade, rankins scale and ashworth grading whereas average improvement in ODI, mJOA and dorsal specific mJOA were 52%, 3.17 points and 2.7 points respectively. However, preoperative counselling for “apparent neurological deterioration” in immediate postoperative period is very important. Complications like infection and dural tear have to be prevented with special surgical tactics. Conclusion: Skeletal survey along with computed tomography and magnetic resonance imaging is cost-effective modality for the screening/diagnosis for fluorosis. Once developed, surgery, either curative or palliative, is the best treatment at crippling stage of the disease.

Keywords: Dorsal myelopathy, endemic, fluorosis, laminectomy, ossified ligamentum flavum, ossified posterior longitudinal ligament

Introduction

Fluorosis (excessive levels of fluoride ions in the blood) is an endemic disease in many countries of Asia, especially India, China, and Japan. The WHO has identified fluorosis as water-related disease. The main source of fluorine is unprocessed groundwater obtained through deep borewell. Musculoskeletal manifestations of fluorosis are quite varied and become crippling, especially when ligaments of the spinal column and spinal cord are involved by the disease process or there is ankylosis of the major weight-bearing joints of the body. Fluorosis is known to cause ossification in body tissues such as interosseous membranes, ligaments, and tendons. When this ossification occurs in the posterior longitudinal ligament (PLL) or ligamentum flavum (yellow ligament) or duramater, compressive myelopathy develops which leads to the neurological deficit and thereby crippling. Only patients, who consult orthopedic surgeons are those having severe neurological deficit causing disability- “tip of the iceberg”. And most of the spine surgeons do not want to burn their fingers by performing surgery in crippling fluorosis as literature has termed surgery to be futile. We have focused mainly on the operative outcomes of patients presenting with compressive cervical and/or dorsal myelopathy due to spinal fluorosis. We have also evaluated the role of radiological imaging as a screening/diagnostic tool for the disease.

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Materials and Methods
This is a prospective cohort study of 33 patients of fluorosis with compressive myelopathy who were operated at a tertiary care center from January 2014 to November 2016.

Inclusion criteria
- Patients having nontraumatic neurological deficit
- Patients having Nurick grade 3/4/5 disability
- Patients having magnetic resonance imaging (MRI)/computed tomography (CT) findings suggestive of OPLL and/or OLF
- Patients having a history of long term groundwater intake/skeletal features suggestive of fluorosis.

Exclusion criteria
- Traumatic spinal cord injury
- Patients having normal power (5/5) of lower limb muscles
- Patients with medical comorbidities who are unfit for surgery.

All the patients underwent standard preoperative imaging including skeletal survey, CT scan and MRI of the whole spine. All the patients were operated by extensive laminectomy/posterior decompression. Patients were followed up at 3, 6, and 12 months and their functional outcome assessed in terms of Nurick grading, Modified Rankins Scale, Oswestry Disability Index (ODI), modified Japanese Orthopaedic Association (mJOA) score, spasticity relief, improvement in neurology.

Results
The study included 33 patients who were followed for 22 months on an average (range 11–45 months). As observed in our study, mean age of presentation of patients to us was 60 years (range 40–73 years) with male-to-female ratio being 4.5:1. Source of drinking water intake was groundwater in 82% of patients [Figure 1].

Average time-lapse between onset of symptoms to presentation was 10 months (range 2 to 24 months). Most of the patients (90.9%) presented with the chief complaint of difficulty in walking. Time lapse between onset of chief complaint and time of presentation ranged from 3 days to 2 months. Distribution of the patients of our study according to level of involvement is shown in Table 1.

Median number of levels affected in patients of our study were 3 (range 2–8). Signal intensity changes of myelomalacia (Brighter images on T2-weighed MRI) were noted in 32/33 patients of our study. Preoperative and regular followup scores of the patients of our study are shown in Table 2.

Exact power could not be commented upon in majority of the patients due to spasticity. All the patients enrolled in our study were operated for multilevel (≥2) decompression (cervical/dorsal/both) by using ultrasonic bone scalpel/high-speed burr at the levels determined preoperatively based on clinicoradiological correlation. As many as 17 (52%) patients of our study had “Apparent Neurological Deterioration” in the immediate postoperative period which recovered in all the patients within 6 months postoperatively. Preoperatively, 18.2% (6/33) patients had involvement of bowel and bladder which also recovered postoperatively within 6 months. The sensitivity of various radiological investigations in our study are described in Table 3.

Complications noted in our study were- one case of dural tear with persistent cerebrospinal fluid (CSF) leak and two infections. Vocational Rehabilitation was achieved in only 8 out of 33 patients at the end of 1 year.

Discussion
Fluorosis is endemic disease in many countries of Asia, especially India, China, and Japan and many other countries of the world. Spinal fluorosis causes compressive myelopathy, mainly affecting the cervical and dorsal spine. Decompression in the late stage of spinal fluorosis is conventionally termed “futile”. However, this conventional thought process is based on various old studies published in the literature in 1990 and 2000s, but thereafter, there is paucity on this subject with decreased incidence of the disease which also is a trend at our institute. We, at our center, have this opportunity to operate these crippled/bedridden patients and then rehabilitate them at a dedicated spine institute that has changed our view regarding the surgical outcome of spinal fluorosis.

We have studied 33 patients operated for crippling spinal fluorosis at our tertiary care center for cervical and/or dorsal fluorosis. The average age of the patients in our study was 60 years indicating fluorosis of the spine is the disease of elderly and most probably occurs after years of fluoride intake. Male-to-female ratio in our study is 4.5:1 suggesting male predominance of the disease. Source of drinking water in 82% of patients was noted to be groundwater-deep bore/well (considered major source of fluorine intake in Indian population). Patients presenting to our hospital were generally clustered around definite districts of Gujarat (e.g., Banaskantha) and Rajasthan (e.g., Jesalmer) endemicity of the disease in such areas due to possibly high fluoride content of the drinking water. Still, none of the patients/relatives knew regarding the disease itself lest taking appropriate preventive steps (0% awareness).
In our study, 17 patients had involvement of cervical spine only with most common level affected being C3–C4 (15 patients). Of 10 patients having exclusive dorsal spine involvement, most common level affected was D8-D9 (7 patients). In our view, the reason of involvement of these specific segments is relative narrowing of the spinal canal at these specific levels, meaning thereby, though the fluorosis causes generalized ossification of ligamentum flavum and PLL, levels causing clinical symptoms are the ones with one of the narrowest diameters of spinal canal.5 6 patients had both cervical and dorsal spine involvement and were operated at both the levels in single sitting.

Preoperative decision-making for the level of decompression is challenging in fluorosis patients and plays pivotal role for the successful clinical outcome. The wrong level operative procedure can be of common occurrence given the generalized involvement of the spinal cord in these patients and lack of knowledge regarding the disease process. All the patients in our study had cord involvement at multiple levels (range 2–8) indicating that the generalized ossification in ligaments so radiological investigation alone cannot decide the level to be operated. Level of compression was determined by clinicoradiological correlation i.e., caudal most level with preserved sensation and power (whenever possible) was identified clinically and decompression was planned starting at the level caudal to the unaffected level correlating with positive radiological findings. Signal intensity changes of myelomalacia were noted in 32/33 patients at single/multiple levels, but there was no correlation noted between myelomalacia and immediate apparent postoperative deterioration and final functional outcome.

After all routine preoperative investigations (including MRI, CT scan, skeletal survey), patients were posted for decompression surgery. All the patients were operated by posterior decompression by using an ultrasonic bone scalpel or high speed burr at the levels determined preoperatively. Whenever in dilemma with multiple levels affected and no clear clinical correlation zeroing on definite level(s), extensive laminectomy was planned to avoid any second procedure. Instrumentation was not required in any of our cases, even after extensive laminectomy because of

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**Table 2: Average of Outcome measures at pre-op, immediate post-op, 3 months, 6 months, 12 months and final follow-up**

| Parameter                        | Pre-op | Immediate post-op | 3 months | 6 months | 12 months | Final follow-up | Average improvement in scale |
|----------------------------------|--------|-------------------|----------|----------|-----------|-----------------|-----------------------------|
| Nurick grade(†)                  | 4      | *                 | 3        | 3        | 2         | 2              | 2                          |
| Rankins scale(‡)                 | 4      | *                 | 3        | 3        | 2         | 2              | 2                          |
| Spasticity-ashworth grading(‡)   | 3      | 2                 | 2        | 1        | 1         | 1              | 2                          |
| Oswestry Disability Index (ODI)(#)| 90%    | 60%               | 52%      | 46%      | 40%       | 38%            | 52%                        |
| mJOA (out of 17)                 | 9.74   | -                 | -        | -        | -         | 12.91          | 3.17                       |
| Dorsal specific mJOA (out of 11) | 5.3    | -                 | -        | -        | -         | 8              | 2.7                        |

*Majority of Patients were not/could not be mobilized immediately post-operatively. Figures shown in the table are median. *Figures shown in the table are mean.

**Table 3: Sensitivity of various radiological investigations in our study**

| Modality                              | Sensitivity |
|---------------------------------------|-------------|
| Marble Bone like Appearance (Radiograph) | 90.9%       |
| Interosseous membrane ossification (Radiograph) | 63.63%       |
| Ankylosis (Radiograph)                | 33.33%       |
| OLF (CT scan/MRI)                     | 100%         |
| OPLL (X ray/CT scan/MRI)              | 69.69%       |
| Dural Ossification (CT scan/MRI)      | 15.15%       |

Contrary to view of various previous studies, we did not find any renal abnormality in our patients (checked with RFT and USG of kidney).

Average time lapse from the initiation of symptoms to the presentation was 10 months with chief presenting complaint in 82% of the patients being the inability to walk/stand or difficulty in walking suggesting presentation at the later stage of the disease due to disability. The reason for the late presentation was either lack of knowledge regarding disease process or ignorance of the patients by relatives until crippling ensued in 67% of cases.

Diagnosis of the fluorosis poses a great challenge as no definite diagnostic tests are readily available and in inexperienced hands, it may go unnoticed. We have evaluated the role of skeletal survey—which includes radiographs of bilateral radius-ulna, tibia-fibula in anteroposterior (AP) plane; Pelvis with both hips-AP plane; Cervical, dorsal, lumbar spine-in AP and lateral planes for screening/diagnosing disease. In our study, ossification of the interosseous membrane was noted in 63.63% of patients, ankylosing features were noted in 33.33% of patients whereas the increased density of bone and typical marble bone-like appearance was observed in 90.9% of patients. Causes of compressive myelopathy in fluorosis are- (1) OPLL (2) Ligamentum flavum ossification (3) Ossification within duramater (4) Preexistent stenosis being exaggerated.7,8 In our study, 100% of patients had ligamentum flavum ossification, 69.69% of patients had OPLL, and 15.15% patients had duramater ossification. Radiographs alone have showed 91% sensitivity in our study and can be used as a cost-effective screening and diagnostic tool [Figure 2].
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inherent ankylosing nature of the disease (Figures 3 and 4 shows pre and post operative imaging of operated patients).

Decompression in these patients differs from standard decompression in three ways:
1. Multilevel (extensive) laminectomy
2. Sclerosed/hard bone
3. Ossified and adhered dura.

Extensive laminectomy by using rongeurs only is extremely time consuming and tiring for surgeons and should better be avoided in these patients. Whenever available ultrasonic bone scalpel or burr should be used and laminectomy should be performed by lateral guttering technique in which lateral border of subsequent laminae to be excised are thinned out first. In majority of the cases, careful lifting of the lamina from dura and progression to extensive laminectomy in a gradual, stepwise pattern has to be done instead of en bloc excision. Specifics of these instruments along with tactics for protecting cord are described below:

- Ultrasonic bone scalpel (UBS) - Use UBS whenever available to perform extensive laminectomy and to avoid damaging cord and dura (due to its inherent oscillating back and forth micromotion mechanism of action that affects only bone and safeguards the softer structure like spinal cord and its covering dura) - this is our method of choice as it gives better precision with less complications and has less operating time. Disadvantage of this method is the cost of the equipment.

- Burr (or osteotome if burr is also not available) is used to perform cortical thinning of the lateral border of the laminae-sequential use of minisagittal burr followed by diamond burr and finally removal of thinned out lateral gutter cortex by rongeurs should be performed. This avoids inadvertent slippage of instrument and cord damage. Burr can cause extensive heat generation (due to excessive burring required to remove sclerosed bone) and possible cord damage.

- There may be cases of dural ossification where the surgeon needs to plan preoperatively regarding the method of decompression. In case of dural ossification along with OPLL, decompression can be performed by “Floating island technique.” Attempt to forcefully remove the entire mass should not always be made and whenever necessary bony island can be left behind as it may lead to dural tear and cord damage.

In the postoperative period, patients were assessed by nurick grading, rankins scale, ODI, mJOA score, spasticity relief, improvement of power. All the patients had immediate postoperative relief of spasticity with improvement of grading on scale of 1 on average. Average improvement in ODI in the immediate postoperative period was 30%. Postoperative Nurick grading and Rankins scale were assessed at 3 months followup for the first time (as not all patients were mobilized immediately in the postoperative period) and all the patients had improvement at 3 months. Three months followup showed further improvement in spasticity and ODI. Two types of mJOA scores were used in our study-first being mJOA score (maximum score = 17) which is routinely used for patients with cervical myelopathy (This score was used in patients having only cervical or cervical and dorsal involvement) and second being mJOA score specific for thoracic myelopathy (maximum score = 11) as described by Kim et al. (This score was used in patients with only dorsal involvement because these patients had only lower limb involvement). 11-13 Improvements in both the scores were statistically significant at the final followup ($P < 0.05$).

Trends in various grading improvement is shown in the charts below [Figure 5]. Direct negative correlation was noted between the time lapse since the onset of chief
complaint to the presentation and neurology improvement with Pearson correlation coefficient being $-0.80$ (minus 0.80) meaning thereby the later the presentation, the lesser the chances of recovery.

One major field of concern is power worsening in the immediate postoperative period which invariably recovered by 6 months postoperatively. In 52% of patients in our study, the power of the affected muscles deteriorated in the immediate postoperative period. Despite the deterioration of power, all the patients had improved quality of life as patients had relief of spasticity and back pain which were major cause of disability for them as walking and daily life activities were anyways not possible without assistance. In our view, immediate postoperative neurology worsening may be due to inadvertent microtrauma caused to the cord while performing laminectomy as the OPLL and OLF are hard-bone like structures in these patients and are in close contact with the spinal cord. They may rub against the cord and cause irritation. However, this cannot be controlled by operating surgeon and should not deter the surgeon to operate such cases. Positive factor indicating successful

Figure 3: Pre- and postoperative images of patient operated for dorsal fluorosis. (a) Preoperative X-ray. (b) Postoperative X-ray. (c) Comparison of pre- and postoperative sagittal magnetic resonance imaging. (d) Preoperative axial magnetic resonance imaging. (e) Postoperative axial magnetic resonance imaging. (f) Preoperative sagittal computed tomography scan. (g) Preoperative axial computed tomography scan. (h) Postoperative sagittal computed tomography scan. (i) Postoperative axial computed tomography scan. (j) Postoperative 3D computed tomography scan showing laminectomy.
Figure 4: Pre and Postoperative images of patient operated for cervical fluorosis. (a) Preoperative X-ray. (b) Postoperative X-ray. (c) Comparison of Pre- and postoperative sagittal magnetic resonance imaging. (d) Preoperative axial magnetic resonance imaging. (e) Postoperative axial magnetic resonance imaging. (f) Postoperative 3D computed tomography scan. (g) Postoperative sagittal computed tomography scan. (h) Postoperative axial computed tomography scan.
surgical outcomes in the immediate postoperative period are improvement in the spasticity and no flaccidity. None of the patients had worsened neurological status beyond 6 months of operation suggesting no significant cord handling on the part of the surgeon. The time period for regaining of power to preoperative status ranged from 6 hours to 6 months.

Preoperative counseling of the patients and their relatives is also important on surgeon’s part as there is going to be “apparent neurological worsening/deterioration” in the immediate postoperative period. Patients and minimum 2 of their close relatives were explained regarding the prognosis before surgery and necessary informed consent was taken on the day of admission. However, in majority of the cases, there was no hesitancy on the part of the patients or relatives for the consent because patients had already become dependent even for activities of daily living.

There were 2 infections and 1 dural tear with persistent CSF leak noted in our study. Both the infections were cured with debridement and 6 weeks of intravenous antibiotics postoperatively. These patients are prone to have dual tear due to ossified dura, but CSF leak is relatively uncommon. Dural tear with persistent leak noted in our study occurred while performing debridement of the patient having infection and was repaired primarily and no further management was required for the same.

Various studies have suggested conservative treatment for the patients presenting with paraplegia/quadriplegia, i.e., nurick stage 5 as cord ischaemia might have ensued. However in our study, at least grade 1 improvement in spasticity, nurick, and rankins scale was noted with 28% of such patients showing improvements up to grade 2 at 6 months followup. Although patients could not be rehabilitated fully, palliation could better be achieved with operative management only as conservative management has no scope for neurological improvement and further complications such as bedsore and infection, if developed, further deteriorate patients’ quality of life.

Vocational Rehabilitation was achieved in only 8 out of 33 patients at the end of 1 year. The reason for non-achievement of adequate vocational rehabilitation was the age of the patient (nearing retirement) in 84% patients.

Various studies have been published in literature regarding idiopathic OLF, idiopathic OPLL and its treatment but many of them have missed to check for fluorosis as the underlying cause showing lack of awareness among the surgeons, especially the western world. Following table shows the factors/indicators whose presence should alert the surgeon to the high possibility of fluorosis [Table 4].

In short, spinal fluorosis is a disease with
- No definite etiolog
ty
- Difficult prevention-no definite way of prevention
- Difficult screening-less awareness in general population
Table 4: Indicators of fluorosis

| Parameter               | Finding(s)                                      |
|-------------------------|-------------------------------------------------|
| History                 | Ground water intake- especially deep borewell   |
|                         | Residence in the endemic area of fluorosis     |
|                         | Positive family history                         |
|                         | Similar illness in nearby villages/districts    |
| Clinical Examination    | Spasticity of bilateral lower limb and/or upper |
|                         | limbs of ashworth grade 3/4                     |
|                         | Multiple joint stiffness including spine stiffness|
|                         | Dental enamel abnormalities                      |
| Radiological examination| X ray Interosseus ligament ossification         |
|                         | Marble bone like appearance of the bone especially evident on cervical spine lateral and PBH X rays |
|                         | CT scan Tram Track sign suggesting dural ossification on Axial cuts |
|                         | Beak type ossification of ligamentum flavum at >=2 levels on sagittal cuts |
|                         | MRI Multiple levels of                          |
|                         | Ossified Ligamentum Flavum (especially beak type) |
|                         | Ossified Posterior Longitudinal Ligament         |
|                         | Dural ossification                               |

and healthcare professionals
• Difficult medical treatment-no medication available to treat or prevent the disease progression
• Difficult diagnosis-lack of in-depth knowledge on surgeon’s part and therefore the diagnosis is missed
• Difficulty getting operated-meaning thereby majority of the surgeons when given a chance would conserve these patients due to the high rate of neurological complications
• Difficult surgical procedure-inexperienced surgeons may cause grave complications like dural tear and permanent cord damage as there are no proper guidelines on surgical technique available.

Limitations of our study include lack of in-depth demographic study for levels of drinking water fluoride levels and associated ions in the affected regions. Although midterm outcomes of operative procedure seems promising, long term followup (>5 years) is required to check for instability in the spine, recurrence of the disease.\textsuperscript{16}

**Conclusion**

Fluorosis is an endemic disease in many parts of the world, especially India with yet not recognized/well established definite diagnostic modalities and medical treatment. Although prevention remains the best option to avoid the disease, surgery remains the sole effective modality of treatment after the development of spinal fluorosis-either curative or palliative (contrary to the previous belief of surgery being futile). Apparent neurology worsening in the immediate postoperative period should not deter surgeons from performing surgeries as patient’s quality of life improves significantly after surgery due to immediate spasticity relief and power is regained/improved within 6 months postoperatively. Cost effective and easily available modality like skeletal survey along with CT, MRI can be used as a screening and/or diagnostic tool for fluorosis with more than 90% sensitivity as shown in our study.

**Declaration of patient consent**

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

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**Conflicts of interest**

There are no conflicts of interest.

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