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Neuroanatomical Studies

Thoracic myelopathy secondary to ossified ligamentum flavum and dural ossification – A series of 19 cases and review of literature

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ABSTRACT

Objective: Thoracic myelopathy has gradually risen to be a prominent diagnosis in patients with persistent upper back pain, bladder symptoms and spastic paraparesis. Often encountered, these conditions pose a serious dilemma to neurosurgeons with respect to surgical planning, timing of surgery, prognosis and possible complications and outcome assessment. In view of these queries and to clarify the indications of when to intervene the following study has been undertaken.

To analyze the clinical presentation, radiological features, clinical implications and surgical nuances and outcomes in patients with single and multiple level dorsal canal ossified ligamentum flavum (D-OLF) and associated dural ossification (DO).

Patients and methods: Nineteen patients with the diagnosis of thoracic myelopathy (TM) were identified between January 2012 and March 2017. All patients were treated surgically, with decompressive laminectomies, in a single tertiary care center in Southern India. mJOA was calculated preoperatively and assessed postoperatively and a mean mJOA was calculated to assess the significance in neurological improvement. The data was collected from the medical records department and various factors were analyzed, using SPSS software, for correlation.

Results: Mean age of our group was 50.84 years with a range of 29 to 71 years. It comprised of 11 males and 8 females. All patients had features of myelopathy. Surgery did have a positive effect on neurological improvement ($p = 0.001$) in all patients except one. Dural ossification had correlation with pre op and post op urinary disturbances with *p* value of 0.02. (Mann Whitney Test for 2 independent variables used). A total of ten patients had urinary symptoms pre operatively, out of which six patients showed postoperative improvement at the end of one year. Four of these patients continued to have symptoms, two patients were on Clean Intermittent Catheterisation (CIC), and one patient had features of hesitancy and frequency. Preoperative bladder dysfunction was a strong predictor for continued bladder dysfunction at the end of 1 year ($p < 0.004$).

Conclusions: All patients with D-OLF and or DO presented with myelopathic features. MRI with concurrent CT spine helps to delineate dural ossification from D-OLF and helped to rule out other differentials. The classical *"tram track"* and *"comma sign"* is well noted in CT spine and helps to plan surgical approach and anticipate probable complications.

Patients with concurrent D-OLF and DO and long segment pathology had increased risk of intraoperative dural tears and postoperative CSF leaks. These subset of patients had a peaked incidence of bladder involvement or non-improvement of existing bladder dysfunction, postoperatively. Patients with D-OLF and DO seemed to do better after surgical decompression. Surgery should be offered once diagnosis is confirmed on imaging, as all patients in out study, except one, showed postoperative neurological improvement.

Our study concluded that patients with prolonged preoperative symptoms persisted to have them even after surgery. Patients with concurrent D-OLF and DO showed more significant improvement, postoperatively, in terms of mJOA – postop with a $p = 0.002$ as compared to patients with D-OLF alone.

We recommend that each case be treated individually and treatment should be planned appropriately, based on the radiology and levels involved, keeping in mind the preoperative symptoms and their duration.

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1. Introduction

Dorsal ossified ligamentum flavum (D-OLF) with canal stenosis is a common entity and has been listed as a differential diagnosis, among others, in patients presenting with dorsal myelopathic features. Though the exact mechanism of how OLF develops is unknown, many hypotheses have been proposed. Several investigators suggested that repetitive cyclical stressors in the spinal ligaments caused mesenchymal fibroblastic cells to transform into chondrocytes and osteoblasts in association with increased expression of cytokines like BMP-2, TGFβ, and Sox. The association of dural ossification with OLF is quite significant and studies have quoted as high as 62–65% in the Japanese population. Here we attempt at understanding this florid condition in the Indian subcontinent and the association with dural ossification (DO), clinical presentation, surgical dilemmas and outcomes and complications in the Indian population.

1.1. Patients and methods

A retrospective analysis of data from the medical records department of Kasturba Medical College, Manipal (KMC, Manipal) spanning from 2012 to 2017 and collecting the data of all the patients with the diagnosis of thoracic OLF who have been operated in KMC, Manipal. SPSS software was used to analyze the data and determine the correlation between the variables. All 19 patients underwent decompressive laminectomies as a definitive surgical procedure. Follow-up and neurological assessment was done at 3, 6 and 12 months by the registrars posted in the OPD and confirmed with a faculty who was not involved with the surgical procedure. mJOA was calculated preoperatively and assessed postoperatively and a mean mJOA was calculated to assess the significance in neurological improvement.

1.1.1. Demographics and symptoms

We encountered 19 diagnosed cases of D-OLF, which comprised of 11 males and 8 females. There seemed to be no male preponderance as noted in other studies [13]. Mean age of our group was 50.84 years with a range of 29 to 71 years. 11 patients presented to us with backache, all patients had features of myelopathy and 5 out of them presented with ataxia secondary to posterior column involvement. 11 patients has preoperative bladder symptoms of which 6 showed postoperative improvement. Twelve patients had D-OLF had associated DO (63.15%) which is at par with the Japanese population. Details of the patients have been noted in Table 1.

1.1.2. Surgical procedure

All the patients underwent surgical procedures in the form of decompressive laminectomies. None of the patients had to be stabilized. All the procedures were done by Associate Professors with at least 4–5 years of experience, post residency. The surgical procedures were done under General anaesthesia, in prone position, over bolsters, using a high speed precision drill to make the lateral gutters and thin out the lower 3rd of the lamina before completing the procedure. This was done using a 4 mm cutting drill bit and the final thinning of the lamina and the dural ossification was thinned out using a diamond drill. 12 out of the 19 patients had dural ossification which was tackled using a diamond drill (Figs. 6, 7). In about 10 of the cases, DO was thinned down using a diamond drill and floated over the thecal sac. In 2 of them the outer layer of the dura, along with the ossification, was teased out and excised. None of them underwent dural excision and duroplasty/graft placement as described by Aizawa et al. [9]. The prior knowledge of dural ossification on imaging helped us to avoid inadvertent dural injuries, however trivial dural injures did occur while trying to peel away the thinned out dural ossification. Three patients who underwent repeat surgeries were cases which had been operated elsewhere primarily. Dural tears which were accessible were primarily sutured with 4-0 prolene and glue was instilled over the tear. None of the patients had frank dural tears or developed CSF leak or meningitis, postoperatively.

2. Results

2.1. Demographics and clinical features

Mean age of our group was 50.84 years with a range of 29 to 71 years. It comprised of 11 males and 8 females. There seemed to be no male preponderance as noted in other thoracic myelopathy series. Among the various symptoms at presentation, 11 patients came with backache and three patients underwent surgery twice for the disease. All patients had features of myelopathy and 11 patients had preoperative urinary symptoms. Neurological examination showed spastic paraparesis with exaggerated reflexes. Patients had brisk knee and ankle reflexes with absent superficial reflexes and extensor plantars. These patients had a band like loss of sensation signifying the level of compression. 5 patients presented with ataxia secondary to posterior column involvement.

2.2. Urinary symptoms

A total of 11 patients had urinary symptoms pre operatively, out of which 6 showed postoperative improvement at the end of 1 year. Urinary symptoms included features of a spastic bladder i.e. small capacity toned bladder with frequent passage of small amount of urine after profuse straining. Four of these patients continued to have symptoms, 2 patients were on CIC, and 1 patient had features of hesitancy and frequency which did not improve following surgery. No patients showed immediate deterioration of symptoms in the postoperative period. Preoperative bladder dysfunction was a strong predictor for continued bladder dysfunction at the end of 1 year with a p value of 0.004.

2.3. mJOA calculation

All patients were evaluated with Modified Japanese Orthopaedic Association (mJOA) Score for calculation of thoracic myelopathy. A maximum score of 14 was used, after exclusion of scores for the upper extremity. All patients were evaluated at 3, 6 and 12 months and their mJOA at 6 months was used to assess the post-operative recovery.

Mean preoperative mJOA was 6.7 with a range of 0–12 and postoperative mJOA was 10.7 with a range of 1–14. Improvement in mJOA score was calculated using the formula (Post-operative mJOA − Preop mJOA) / (14 − Preop mJOA) × 100%.

2.4. Surgical nuances

Surgery did have a positive effect on neurological improvement ($p = 0.001$) in all patients except one. One patient was lost to follow up after surgery. The mean number of levels removed by surgery was 3.05. Ossification had correlation with pre op and post op urinary disturbances with p value of 0.02. (Mann Whitney Test for 2 independent variables used). Of the 19 patients with D-OLF, 12 had associated DO (63.15%) with a $p = 0.002$ and 9 of these had intraoperative dural tears and associated complications (75%) with a $p < 0.005$. This was statistically significant.

2.5. Postoperative outcomes

A mean improvement of 57.3% was seen with only 1 patient deteriorating. This patient had a high dorsal compressive myelopathy and presented to us after being symptomatic for over 84 months. One patient with a long standing history of 84 months of symptoms, deteriorated in his mJOA Bladder Function score of 4 to 0.

Table 1
Details and demographics of the 19 patients involved in the study.

S. no	Age	Sex	Diagnosis	Presenting complaints	Dural ossification	Urinary symptoms	Number of levels involved	Complications	Outcome	mJOA - preop	mJOA - postop	mJOA – outcome (p value)
1	29	Female	Dorsal D9–D11 compressive myelopathy	Low backache, weakness B/L LL L≫R, swaying, urinary retention × 4 months	Present, multiple dural tears during surgery	Present	3 levels	Catheter	Good	2	7	0.416667
2	57	Male	D10–11 cord compression	Low back ache	Nil	Nil	2 levels	Nil	Good	0	0	0
3	61	Male	Dorsal canal stenosis	LBA radiating to B/L LL and stiffness since 1 year, posterior column present	Nil	Nil	3 levels	Nil	Good	9	12	0.6
4	35	Male	D10 ligamentum hypertrophy	Backpain 1.5 years, difficulty in walking × 9 months, swaying × 6 months	Nil	Nil	1 level	Nil	Good	8	14	1
5	55	Male	D2-D4, D5-D6 & D7-D9 dorsal canal stenosis secondary to OLF	Difficulty in walking since 3 months, no posterior column	Present, multiple dural tears during surgery	Present	6 levels	Nil	Good	5	10	0.555556
6	65	Male	D8–10 OLF, L4–5 Potts Spine	Back pain × 8 months, weakness in B/L LL × 4 months, bladder involvement	Present, multiple dural tears during surgery	Present	4 levels	Catheter	Good	0	2	0.142857
7	64	Male	D2,3 OLF, OPLL with severe canal stenosis and myelomalacia	Weakness in B/L LL since 10 months, bladder involvement	Present, multiple dural tears during surgery	Present	4 levels	Paralytic Ileus	Good	4	1	−0.3
8	51	Female	D10–D11 OLF with canal stenosis	Difficulty in walking since 3 months, no posterior column	Present, multiple dural tears during surgery	Present	2 levels	Nil	Good	11	14	1
9	56	Female	D10–D11 cord compression with stenosis	Weakness, tingling and numbness in B/L LL × 10 days, Bladder symptoms	Present, no tear	Present	2 levels	Nil	Good	9	9	0
10	48	Female	D6–8 OLF with canal stenosis	Progressive spasticity and weakness of LL × 3 months	Present, multiple dural tears during surgery	Absent	4 levels	Nil	Good	6	12	0.75
11	71	Female	D10–11 canal stenosis - OLF	LBA × 3 months, Progressive weakness in both LL × 2 months, bladder involvement	Present, multiple dural tears during surgery	Present	2 levels	Nil	Good	6	13	0.875
12	54	Male	OLF with canal stenosis	Stiffness of B/L LL and difficulty in walking × 5 months	Nil	Absent	3 levels	Nil	Good	12	13	0.5
13	56	Male	D9–11 canal stenosis OLF	LBA radiating to B/L LL and stiffness since 3 months, posterior column present	Nil	Absent	3 levels	Nil	Good	9	13	0.8
14	53	Male	D11–12 and D12-L1 canal stenosis with OLF	Swaying while walking since 6 months, altered sensorium over thigh × 1 month	Nil	Absent	2 levels	Nil	Good	12	13	0.5
15	36	Female	D9–D10 canal stenosis with OLF	LBA radiating to B/L LL and stiffness since 6 months, posterior column present	Nil	Absent	2 levels	Nil	Good	7	14	1
16	45	Female	D9–11 canal stenosis	LBA radiating to B/L LL and stiffness since 3 months, posterior column present	Present, multiple dural tears during surgery	Present	3 levels	CSF leak	Good	5	10	0.555556
17	45	Female	D6–8 canal stenosis	Difficulty in walking since 3 months, no posterior column	Present, multiple dural tears during surgery	Present	3 levels	CSF leak	Good	6	10	0.5
18	49	Male	D11–12 canal stenosis - OLF	Difficulty in walking × 1 month, bladder involvement, constipation × 2 months	Present, no tear	Present	2 levels	Catheter	Good	11	13	0.666667
19	36	Male	D10–11, D11–12 OLF	LBA radiating to B/L LL × 1 month, posterior column, spasticity	Present, no tear	Present	3 levels	Catheter	Good	6	12	0.75

2.6. Concurrent D-OLF with DO outcomes

In the 12 patients with D-OLF and DO the following findings were noted, which showed statistical significance. They involved atleast 2 levels to a maximum of 6 levels. Patients with D-OLF with DO showed more significant improvement in terms of mJOA – postop with a $p = 0.002$ as compared to patients with OLF alone. All the 11 patients with preoperative urinary symptoms had DO (100%) and 8 of these patients had intraoperative dural tear (72.7%). Thence, it can also be interpreted that most of the patients with DO had urinary symptoms, 11 out of 12 patients with DO, $p < 0.004$. Of all the patients with urinary symptoms and DO, 9 out of 11 patients had a compression at T9–11 level (81.2%) with a $p = 0.001$.

In the current study, we encountered DO in 12 out of the 19 patients with D-OLF, this accounted for 63.15%. This correlation was statistically significant and 9 of these patients had intraoperative dural tears ($p < 0.005$). Most of the long standing cases of thoracic myelopathy had associated dural ossification and these patients seemed to do better with decompressive laminectomies as compared to patients with pure D-OLF.

2.7. Complications

A total of 11 patients had urinary symptoms pre operatively, out of which 6 showed postoperative improvement at the end of 1 year. Four of these patients continued to have symptoms, 2 patients were on CIC, and 1 patient had features of hesitancy and frequency which did not improve following surgery. One patient with a long standing history of 84 months of symptoms, deteriorated in his mJOA Bladder Function score of 4 to 0. No patients showed immediate deterioration of symptoms in the postoperative period. Preoperative bladder dysfunction was a strong predictor for continued bladder dysfunction at the end of 1 year with a *p* value of 0.004.

None of the patients required instrumentation and no one developed kyphosis (long segment involvement) over the follow-up period.

Out of the 12 patients with DO, 9 patients had intraoperative dural tears and only 2 patients (22.2%) of these developed postoperative CSF leak from the primary wound. This was managed conservatively with secondary suturing and carbonic anhydrase inhibitors. None of the patients developed meningitis, postoperatively.

A definitive cause and outcome relationship can be drawn only with larger series, however there is a definitive significant relationship between pure OLF and OLF with concurrent DO and their outcomes thereafter.

2.8. 3 year and 5 year followup

Long term followup was available for 13 patients among the 19 operated cases. The 3 year followup was only available for 5 patients and 5 year followup for 8 patients. Apart from occasional back pain, none of the postop patients, presented with any new symptoms. Two patients in the 3 year followup group were on CIC and they showed gradual improvement in bladder function over the next year. One patient in the 5 year followup group persisted to be on CIC and 2 others showed improvement in sphincteric function to various degrees.

3. Discussion

Dorsal Ossified Ligamentum Flavum is the ossification of the yellow ligament present posteriorly just above the thecal sac and below the lamina. Often seen in the lower dorsal level from T9 to T12, these can happen at other vertebral levels as well. D-OLF has often been seen in the Asian continent, much less likely in India. Many studies have emerged regarding its prevalence, surgical outcomes and even regarding the probable theories to its aetiopathogenesis from Japan. To date, no studies have addressed D-OLFs with facts and statistical data within the Indian subcontinent.

D-OLF was previously considered to be a very intriguing entity with very little insight into its pathogenesis. Sato et al. and Muthukumar et al. [3,5,6] have stated various theories for the development of OLF and DO.

3.1. Theories behind D-OLF and DO

Bo et al. [1] had proposed theories for the development of DO which primarily depended on the development of D-OLF. Bo suggested that the repetitive cyclical stressors in the spinal ligaments caused mesenchymal fibroblastic cells to transform into chondrocytes and osteoblasts in association with increased expression of cytokines like BMP-2, TGFβ, and Sox [1]. This was the molecular basis for the development of D-OLF. In the presence of D-OLF, the spinal cord gets stretched over the dura and ossified ligamentum flavum during flexion and extension. This causes local inflammatory changes in the overlying dura, following multiple minor trauma, and osteogenic cytokines migrate from the D-OLF into the dura. This forms the basis of development of DO. We could also extrapolate this theory to suggest that DO is more common and severe in long standing, long segment compressive myelopathies and that though the surgical complications are quite moribund the recovery have been remarkable [2,4,7].

A genetic predisposition has been considered in patients with D-OLF with and without DO. Their prevalence in the Japanese population has always intrigued neurosurgeons and as such the radiological evidence of a D-OLF with DO in asymptomatic Japanese can be as high as 6.2% in males and 4.8% in females [8]. Yayama et al. [12] also suggested that the development of DO adjacent to D-OLF was probably due to the dilution of cytokines related to osteogenesis namely, BMP-2, TGFβ from the ligamentum flavum, during the process of ossification.

3.2. Dorsal ossified ligamentum flavum and dural ossification (D-OLF)

To understand the surgical implications of D-OLF one should attempt to understand the pathogenesis behind this entity. The ligamentum flavum, bilaterally, has 2 portions, medially, the interlaminar portion and laterally, the capsular portion. D-OLF starts as a pathological ossification in the capsular portion and then spreads to involve the inter-laminar portion [9]. Ossification then proceeds anteriorly towards the spinal canal. Bilateral ossifications then fuse in the midline and thicken to form a tuberous mass.

On this basis, the CT classification of OLF divides the ossification into 5 types as follows:

(1) lateral type,
(2) extended type,
(3) enlarged type,
(4) fused type, and
(5) tuberous type.

Li et al. [11] had yet another classification for D-OLF. He divided them into three types, depending on imaging. They were (a) thickened nodular, (b) lateral and (c) diffuse. Li and Aizawa [9–11] suggested that a French door laminectomy was adequate for patients with a lateral type D-OLF and en-bloc removal was appropriate in patients with fused type of D-OLF and thickened nodular variety. Japanese literature states that 62–65% of the patients with D-OLF have concurrent DO [5], we concur with this finding.

3.3. Dural ossification (DO)

Miyakoshi et al. [2] reported a significant number of patients with D-OLF and concurrent DO, as high as 62%. In the current study, we encountered DO in 12 out of the 19 patients with D-OLF, this accounted for 63.15% (Figs. 1, 2). This correlation was statistically significant and

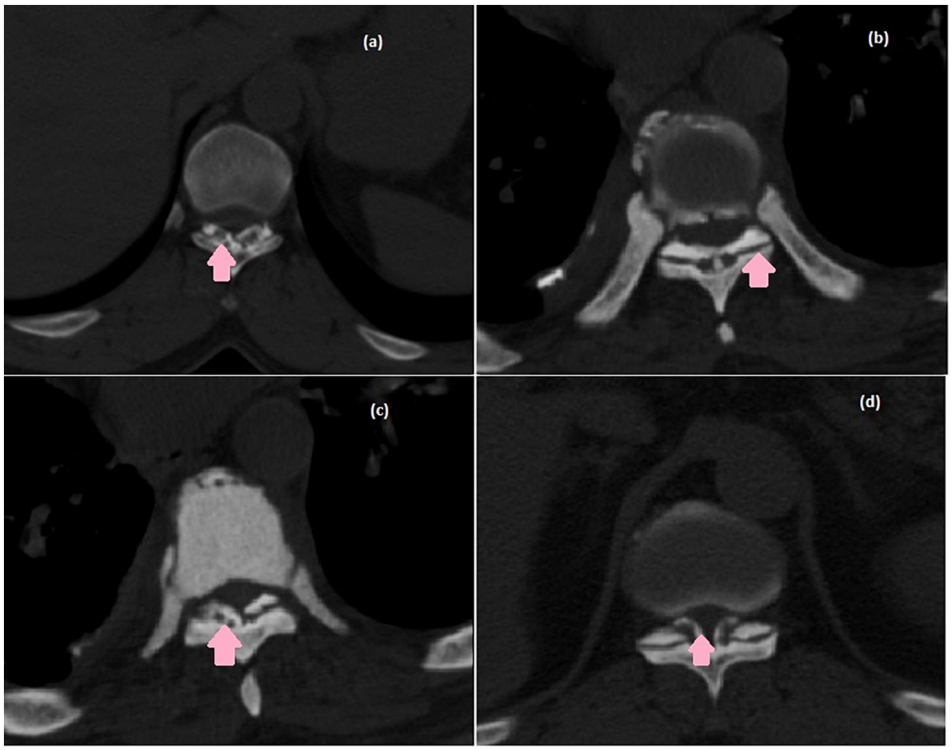


Fig. 1. Preoperative Computed tomographic (CT scan) scan of the dorsal spine, axial section, through the dorsal ossified ligamentum level showing D-OLF (a, b) with pink arrow and tram track sign (c, d) shown with pink arrow, suggestive of dural ossification. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

9 of these patients had intraoperative dural tears ($p < 0.005$). Most of the long standing cases of thoracic myelopathy had associated dural ossification and these patients seemed to do better with decompressive laminectomies as compared to patients with pure D-OLF. The dural ossification seemed to be more densely adherent in patients with long standing disease and we encountered more intraoperative and postop complications in this subset of patients (Figs. 3, 4). Presence of DO had a detrimental effect on the preoperative and post-operative neurological status of these patients. The present study showed a significant correlation between DO and neurological deterioration as is evidenced by the increased risk of intraoperative dural tears in these patients with concurrent DO and the presence of bladder symptoms pre-operatively.

In our study D-OLF with concurrent DO was found to be a florid moribund entity, however the outcomes following surgery makes us hopeful in terms of surgical intervention. Preoperative bladder symptoms were encountered in all patients with D-OLF and DO (11 out of the 12 patients) and most of these patients had a compression at T9-T11 level (9 out of the 11 cases). Post-surgical decompression, 10 out of the 11 patients, with bladder dysfunction, showed significant recovery of sphincteric function to various degrees (Table 2, Graph 1). A mean improvement of 57.3% was seen with only 1 patient deteriorating. This patient had a high dorsal compressive myelopathy and presented to us after being symptomatic for over 84 months. One patient with a long standing history of 84 months of symptoms, deteriorated in his mJOA Bladder Function score of 4 to 0.

Sphincter dysfunction was not an isolated indicator for poor prognosis in patients with dorsal myelopathy. However, in patients with long-standing disease and prolonged sphincteric dysfunction, the

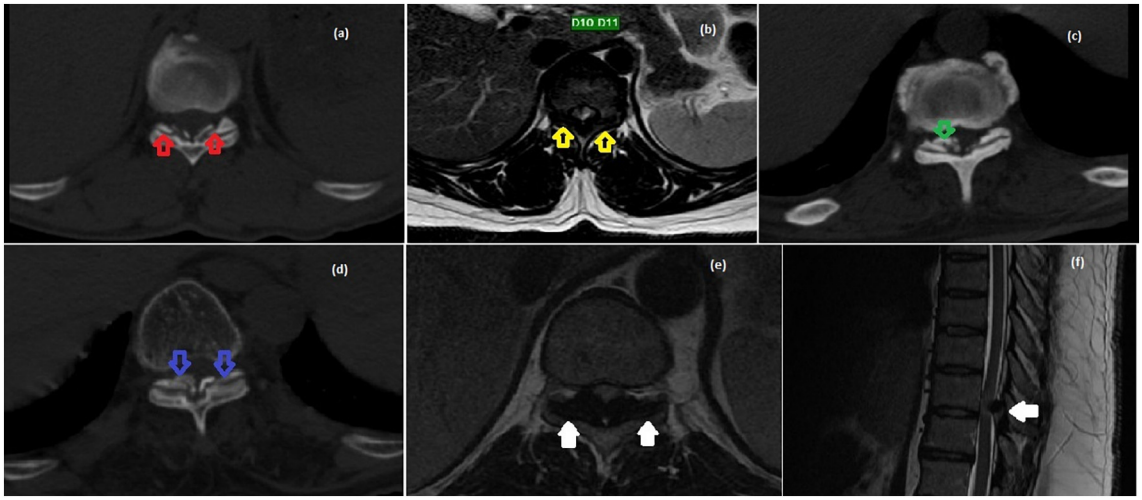


Fig. 2. Preoperative CT dorsal spine, axial section, showing D-OLF (a) with red arrow and corresponding MRI axial section (b) with yellow arrow. Tram track sign of dural ossification is seen in the axial CT of the dorsal spine (c) with green arrow and (d) with blue arrow. The same findings can also be evidenced on MRI dorsal spine (e, f) with white solid arrows in axial and sagittal sections respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

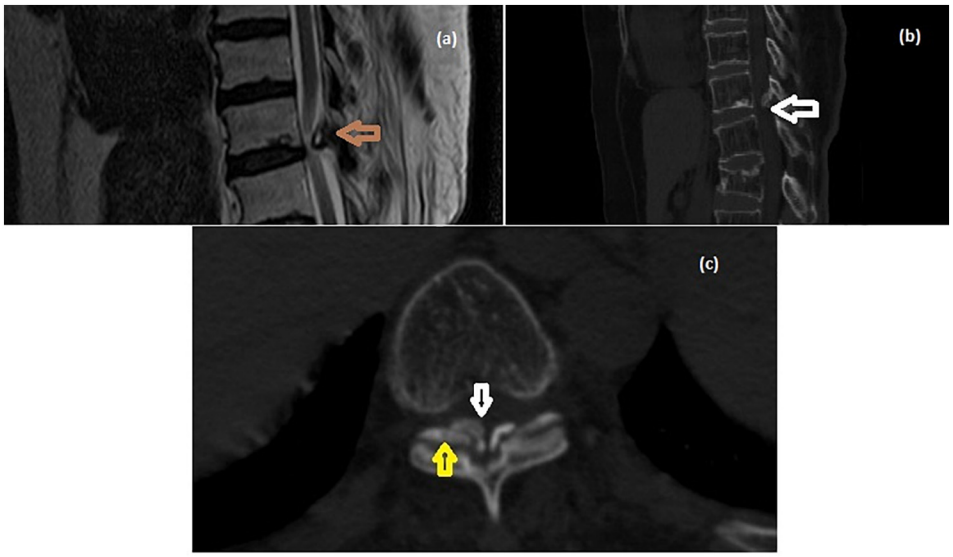


Fig. 3. Preoperative MRI Dorsal spine (a) and CT dorsal spine (b), sagittal sections showing D-OLF in brown and white arrows respectively. Corresponding level CT axial section (c) showing concurrent D-OLF (yellow arrow) with tram track sign of dural ossification (white arrow). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

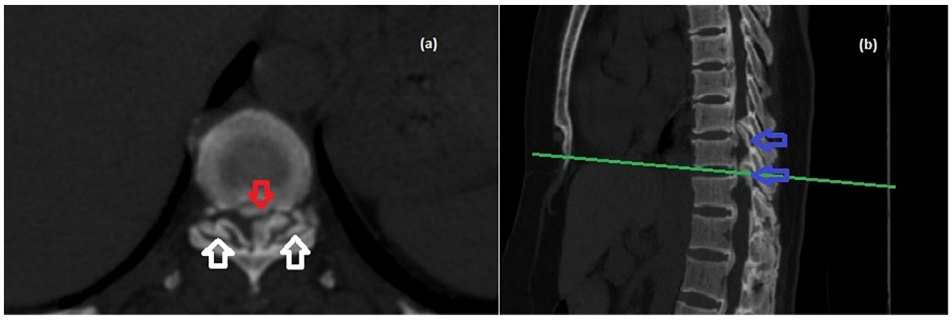


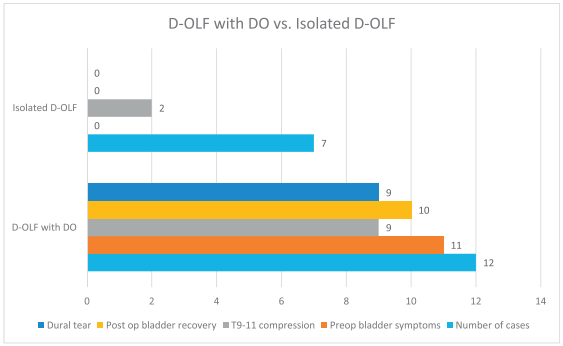
Fig. 4. Preoperative CT dorsal spine, axial section (a) and sagittal section (b) showing concurrent D-OLF with white arrow and comma sign of dural ossification with red arrow in (a) also shown with blue arrow in sagittal section (b). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

postop outcome was trivial. 10 out of the 11 patients with bladder symptoms showed an improvement in the mJOA bladder from 0 and 1 to 3 and 4, postoperatively. P was calculated to be 0.001. Only one patient deteriorated in this cohort.

Patients with isolated D-OLF were fewer and did not have any preoperative sphincteric dysfunction. This subset also showed palpable recovery from symptoms. Overall the patients with D-OLF with DO seemed to fair better as compared to D-OLF alone in terms of postop recovery and convalescence.

3.4. Preoperative symptoms and outcomes

Among the various symptoms at presentation, 11 patients presented with backache and three patients underwent surgery twice for the disease. The mean number of levels removed by surgery was 3.05. Ossification had correlation with pre op and post op urinary disturbances with p value of 0.02. (Mann Whitney Test for 2 independent variables used). All the 11 patients with preoperative urinary symptoms had DO (100%) and 8 of these patients had intraoperative dural tear (72.7%). Thence, it can also be interpreted that most of the patients with DO had urinary symptoms, 11 out of 12 patients with DO ($p < 0.004$). Of all the patients with urinary symptoms and DO, 9 out of 11 patients had a compression at T9–11 level (81.2%) with a



Graph 1. Bar graph comparing the preop symptoms and recovery in patients with D-OLF and concurrent DO versus isolated D-OLF.

$p = 0.001$. All patients showed improvement to various degrees after surgical decompression (Fig. 5), except one patient with long standing symptoms. All of the patients showed adequate decompression on imaging and follow-up MRI showed a reduction in the signal changes on T2 sagittal section. None of the patients with single or multiple level pathologies developed kyphosis or spinal instability on long term follow-up.

Table 2
Breakdown of symptoms and outcomes in patients with D-OLF and concurrent DO versus isolated D-OLF.

Diagnosis	Number of cases	Preop bladder symptoms	T9–11 compression	Postop bladder recovery	Dural tear
D-OLF with DO	12	11	9	10	9
Isolated D-OLF	7	0	2	0	0

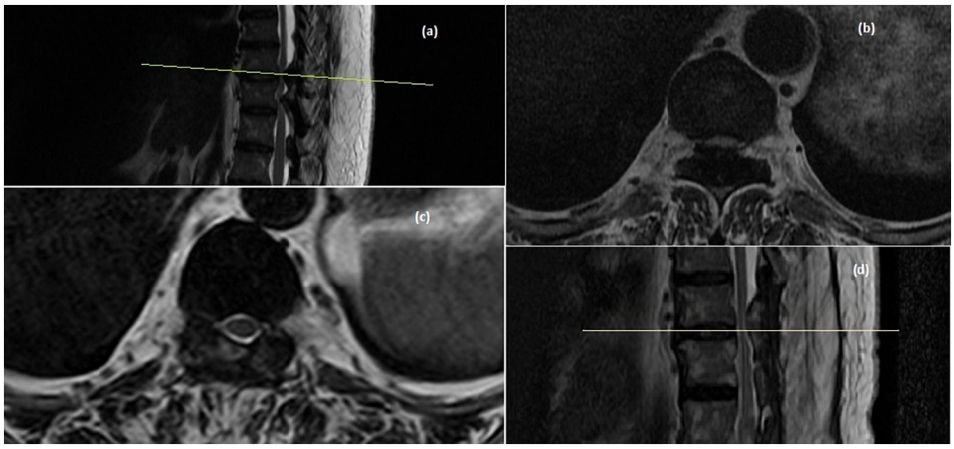


Fig. 5. Preoperative Magnetic resonance imaging (MRI dorsal spine) of the thoracic spine, sagittal section (a) and corresponding axial section (b) showing complete obliteration of the canal space and compression over the cord. Postoperative MRI spine at the same level, sagittal section (d) and axial section (c) showing a decompressed cord and maintenance of anterior and posterior subarachnoid space.

3.5. Newer outcomes

Our study was able to conclude the following:

a) Patients with prolonged preoperative symptoms persisted to have them even after surgery. Statistical significance was seen in patients with preoperative bladder dysfunction.
b) Dural ossification had correlation with pre op and post op urinary disturbances with *p* value of 0.02. (Mann Whitney Test for 2 independent variables used).
c) Preoperative bladder dysfunction was a strong predictor for continued bladder dysfunction at the end of 1 year ($p < 0.004$).
d) One patient with a long standing history of 84 months of symptoms, deteriorated in his mJOA Bladder Function score of 4 to 0.
e) Of the 19 patients with D-OLF, 12 had associated DO (63.15%) with a $p = 0.002$ and 9 of these had intraoperative dural tears and associated complications (75%) with a $p < 0.005$. This was statistically significant.
f) In patients with D-OLF and DO, atleast 2 levels to a maximum of 6 levels seemed to be involved.
g) Patients with D-OLF with DO showed more significant improvement in terms of mJOA – postop with a $p = 0.002$ as compared to patients with OLF alone.
h) Our study also precluded that, severe and long segment thoracic myelopathy associated with D-OLF was definitely associated with DO with a significant $p = 0.0001$.
i) We could also infer that the DO was more adherent in these cases and were strongly associated with per-operative complications and postop complications.
j) All the 11 patients with preoperative urinary symptoms had DO (100%) and 8 of these patients had intraoperative dural tear (72.7%). Two of these patients (22.2%) had postoperative CSF leak from the wound.
k) We noticed a significant increase in the incidence of dural tears (intraop) in patients with dural ossification. It can also be interpreted that dural ossification is the cause for the dural tear, rather than dorsal ossified ligamentum flavum.
l) It can also be interpreted that most of the patients with DO had urinary symptoms, 11 out of 12 patients with DO, $p < 0.004$. Of all the patients with urinary symptoms and DO, 9 out of 11 patients had a compression at T9–11 level (81.2%) with a $p = 0.001$. This was similar to the Hitchon et al. study [13].

3.6. Limitations

- It is very difficult to conduct a randomized control trial (RCT) for a condition with a simple surgery as the standard of care. Hence we had to rely on a retrospective observational study to arrive at the

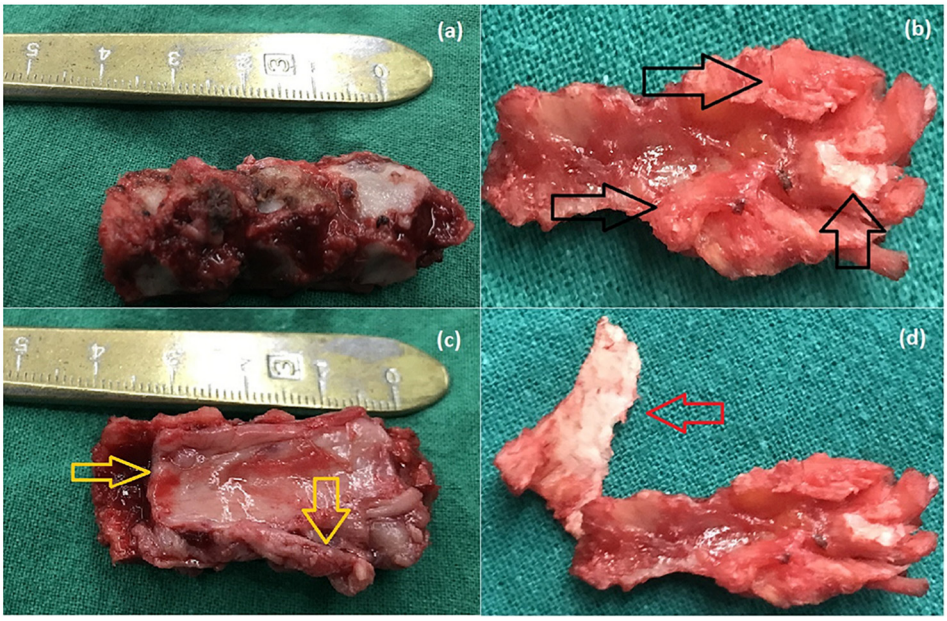


Fig. 6. Intraop colour plates showing the laminectomy specimen in toto (a) with ossified ligamentum flavum marked by hollow black arrows in (b) and hollow yellow arrows in (c). The ossified ligamentum with dura has been removed in toto, highlighted by a hollow red arrow in (d). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

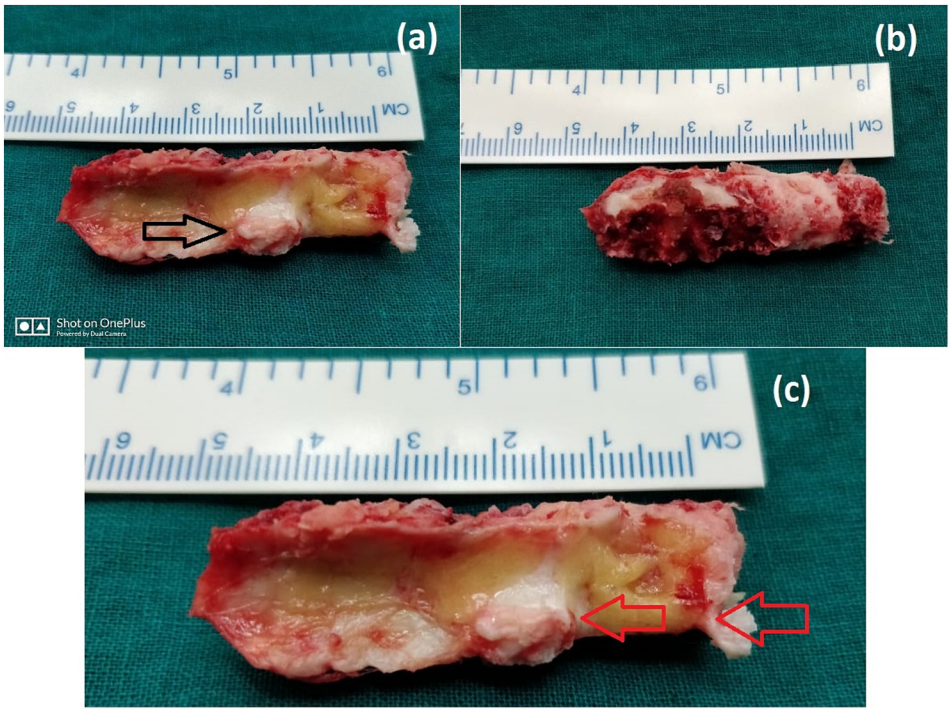


Fig. 7. Intraop colour plates showing the laminectomy specimen in toto in (b) with ossified ligamentum flavum with dural ossification shown in hollow black and hollow red arrows respectively in (b) and (c). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

conclusions derived here.

- Selection and inter-observer bias was unavoidable.
- Multiple variables have been assessed which blurs the take home message from this study.
- All surgeries were not done by the same surgeon and hence a slight variations in the years of experiences, surgical technique and finesse is obvious.
- Small sample size and absence of long term follow-up does not help us to arrive at a consensus.

4. Conclusions

Out of the nineteen patients included in our study we had 11 males and 8 females.

Here are the conclusions derived from the present study.

- D-OLF is often associated with DO
- All the patients with preoperative bladder symptoms had DO and these patients showed improvement in bladder function after decompressive laminectomies.
- Dural injury was often encountered in patients with DO and these were associated with patients who had long standing disease and long segment involvement.
- Most of the patients with preoperative bladder involvement seemed to have a T9–T11 localization.
- Preoperative bladder dysfunction was a strong predictor for continued bladder dysfunction at the end of 1 year.
- All patients showed neurological improvement after surgery especially the patients with D-OLF and concurrent DO.

A definitive cause and outcome relationship can be drawn only with larger series, however there is a definitive significant relationship between OLF and OLF with DO and their outcomes thereafter. The final verdict, the jury is still out.

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