Original Article

Venous pathology targeted surgical management in Hirayama disease: A comprehensive case series of nine cases exploring this potential etiology

ABSTRACT

Objective: Hirayama disease is a rare cause of cervical myelopathy predominantly affecting young individuals. The disease is classically characterized by muscle atrophy in the distal upper limbs. While various etiopathogenesis such as dural sac dysplasia, nerve root dysplasia, structural abnormalities of the spinal ligament, and venous dysplasia have been proposed, this study explores the potential role of venous pathology and surgical management on the basis of it.

Methodology: This is a prospective descriptive case series of nine cases. The diagnosis was made based on the Huashan diagnostic criteria which includes clinical manifestation, imaging, and electrophysiology. In cases where magnetic resonance imaging (MRI) failed to demonstrate engorged veins, a computed tomography (CT) venogram of the cervical spine was used as an imaging tool. All patients underwent cervical laminectomy and coagulation of the posterior epidural venous plexus with or without laminoplasty. All the patients were followed up regularly; clinical improvement and neck disability index were assessed.

Results: All nine patients were male and exhibited classical clinical features, electrophysiological abnormalities, and MRI findings except, in one patient where a CT venogram helped in establishing the diagnosis as the MRI was inconclusive. Postoperatively, all patients had neurological improvement and stabilization of the disease. All patients who underwent CT venogram and cervical spine X-ray in neutral and dynamic position demonstrated no recurrence of engorged venous plexus or significant instability except one patient developing kyphosis. One patient experiencing symptoms in the other limb underwent a second surgery.

Conclusion: This comprehensive case series strongly supports venous pathology as a potential etiology of Hirayama disease. Surgical management with laminectomy and venous coagulation with or without expansile laminoplasty has delivered consistent improvement in neurological outcomes and long-term disease stabilization without the restriction of movements and lesser complications. However, further research is warranted to elucidate the mechanism underlying cervical venous dilatation.

Keywords: Cervical myelopathy, cervical venous plexus engorgement, coagulation of venous plexus, Hirayama disease, laminectomy, venous pathology

INTRODUCTION

Hirayama disease was described in 1959 by a Japanese neurologist and is a well-known cause of lower cervical myelopathy in Asian countries.[1] Hirayama disease is a very rare disease, and in a Japanese survey, the prevalence was estimated at 1/30,000 people.[2] Several cases or small series of patients have been reported from various countries and regions, including India, North America, Europe, and Australia.[3-6] Various etiopathogenesis have been proposed

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Submitted: 17-Dec-23 **Accepted:** 31-Dec-23
Published: 13-Mar-24

Access this article online	
Website: www.jcvjs.com	Quick Response Code
DOI: 10.4103/jcvjs.jcvjs_179_23	

How to cite this article: Sharma DN, Yerramneni VK, Yerragunta T, Gaikwad GB, Rangan VS, Akurati S. Venous pathology targeted surgical management in Hirayama disease: A comprehensive case series of nine cases exploring this potential etiology. J Craniovert Jun Spine 2024;15:37-44.

such as dural sac dysplasia, nerve root dysplasia, structural abnormalities of the spinal ligament, and venous dysplasia.[7-10]

The disease preferentially affects young men between 15 and 20 years of age and is characterized by muscle weakness and atrophy in the distal portion of one or both upper limbs.[11] It is progressive and painless, without long tract signs. Presentation is most often unilateral in the beginning, but bilateral involvement occurs during the progression of the disease in up to one-third of patients.[2] It mainly affects the metameric territories of C7-T1. The brachioradialis muscle, with C6 innervation, is classically spared, which results in a clinical presentation of oblique atrophy. The course of the disease is characterized by gradual worsening of symptoms, and although it is a nonlethal disease, its clinical consequences can be extremely disabling for patients.[11] The differential diagnoses among motor neuron diseases are amyotrophic lateral sclerosis (rare in young patients), multifocal motor neuropathy, and spinal muscular atrophy. Modalities like electroneuromyography and magnetic resonance imaging (MRI) are used to support the diagnosis. MRI can reveal atypical signs such as cord atrophy or intramedullary hyperintensity on T2-weighted images (T2WI).[12] Finally, the diagnosis is confirmed if flexion MRI shows spinal cord compression by the posterior dilated venous plexus and forward shift of the dura.[12] Various treatment options including cervical collar placement for 3–4 years have been partially successful.[13,14] Considering the dynamic nature of the disease, anterior or posterior fusion procedures have been described by many authors.[5,15,16]

To date, there is no general unified consensus regarding the etiology of the disease. This study explores the potential role of venous pathology in the etiopathogenesis of Hirayama disease, a rare cause of cervical myelopathy predominantly affecting younger individuals, thus establishing it as a forefront cause compared to other etiologies. Dilatation of the cervical venous plexus, a potential contributing factor, has been surgically managed with laminectomy and microcoagulation of the dilated epidural veins with or without laminoplasty without fusion. This surgical technique yields similar and consistent neurological outcomes compared to other fusion procedures practiced worldwide while preserving the range of motion which is a major challenge with fusion procedures as this disease affects a very young population. Furthermore, this approach described in the study has fewer complications to the standard fusion procedures.

METHODOLOGY

Study design

This was a prospective descriptive case series of nine cases.

Study population

Patients with a confirmatory diagnosis of Hirayama disease admitted in (Blinded for review) from January 2020 to July 2023 after obtaining informed consent.

Diagnosis

Diagnosis of the Hirayama disease was based on clinical examination and MRI cervical spine flexion and extension, criteria proposed by Tashiro *et al*.[2] and Huashan diagnostic criteria by Wang *et al*.[17] [Table 1].

Salient features described by Tashiro *et al*.[2]

1. Insidious onset between age 10 years and early 20s with gradual progression over 3–5 years and followed by quiescence
2. Weakness and wasting of distal hand and forearm muscles predominantly on the medial or ulnar aspect because of preferential involvement of anterior horn cells that innervate the ulnar aspect and sparing of brachioradialis
3. Irregular and coarse tremors in the hands. Transient worsening of symptoms in cold climate
4. No objective loss of sensation
5. Atypical signs such as pyramidal involvement, proximal upper limb weakness and atrophy, sensory involvement, and long-term disease progression were considered whenever relevant[7,19,20]
6. Conduction studies showing a lesion in the anterior horn cells of the middle and lower cervical spinal cord without involvement of the cranial nerves and dorsal and lumbar spinal cord[21,22]
7. MRI cervical spine in neutral and flexion demonstrating atrophy of the cord, detachment of the dura forms the posterior lamina on neck flexion MRI, engorgement of the posterior epidural venous plexus on flexion and T2WI sequences showing hypersignal intensity and straight or kyphotic alignment of the cervical spine is used for supporting the diagnosis.[2,7,19,20]

Computed tomography venogram

It was found that in some patients, the classical findings of MRI were absent despite the clinical and electrophysiological findings were indicative of Hirayama disease. In these cases, we decided to perform a computed tomography (CT) venogram of the cervical spine with neck flexion which has been rarely used for diagnosis previously. This might be attributed to anatomical differences where patients with long necks might face difficulty in keeping the neck flexed for a long duration of the MRI. The CT venogram demonstrated the engorged venous plexus in the posterior epidural space significantly occupying the canal. We had one case in

Table 1: The Huashan diagnostic criteria for Hirayama disease[17]

	Clinical manifestations	Imaging	Electrophysiology
Features needed for definitive diagnosis	Pubertal onset, more in males Localized wasting and weakness of the upper limbs, especially in the ulnar aspect of forearms and intrinsic hand muscles unilaterally or predominantly on one side No involvement of the cranial nerves and lower limb muscles	Thinning of lower and middle cervical cord on neutral or flexion MRI Loss of dural attachment or crescent-shaped mass at the posterior epidural space on T2WI	Neurogenic changes in the anterior horns and/or roots of the middle and lower cervical cord Normal or mildly abnormal conduction velocity in the upper limb nerves No obvious cranial nerve and thoracic, lumbar, or sacral spinal cord involvement
Other features	Cold-induced paresis and tremors in the fingers Active deep tendon reflex and/or positive pathological signs in the anatomic parts of patients Mild sensory abnormalities in the upper limbs in some	Forward displacement and flattening of the lower cervical spinal cord, narrowing of the anterior spinal space on flexion MRI High-intensity signs in the anterior horn regions on T2WI Straight alignment of the cervical spine in X-rays	
Definite HD	Should meet 1, 2, and 3	Meets 1 or 2	Should meet 2 and 3
Probable HD	Should meet 2 and 3		Should meet 3

HD - Hirayama disease; MRI - Magnetic resonance imaging; T2WI - T2-weighted imaging

which a CT venogram helped to confirm the diagnosis radiologically [Figure 1].

Surgical technique

All patients underwent cervical laminectomy and coagulation of the posterior epidural venous plexus with or without laminoplasty. All patients were operated by the same surgeon. The patient was positioned prone with the head attached to a Mayfield or placed over a horse-shoe headrest in slight cervical flexion. After marking an incision in the midline and subperiosteal muscle dissection, the desired laminas were exposed. Cervical laminectomy was done at the levels identified based on preoperative imaging by drilling the lamina-facet junction on either side and lifting the laminar flap gently to avoid rupture of the large engorged venous channels which could cause huge blood loss.

Engorged epidural venous plexus was found in all the cases and was coagulated until the posterior dura mater was fully exposed and clearly seen. Once the cervical decompression was completed, hemostasis was achieved. In 4/9 patients, laminoplasty was done. No fixation was done in any of the cases, and the incision was closed in layers after drain placement [Figures 2 and 3].

Follow-up

All the patients were followed up regularly. Clinical improvement and neck disability scores (NDI) were assessed. After 6 months of surgery, cervical spine X-rays both in neutral and dynamic positions were done to see for curvature and instability. CT venogram was done to check for recurrence of the posterior epidural venous plexus.

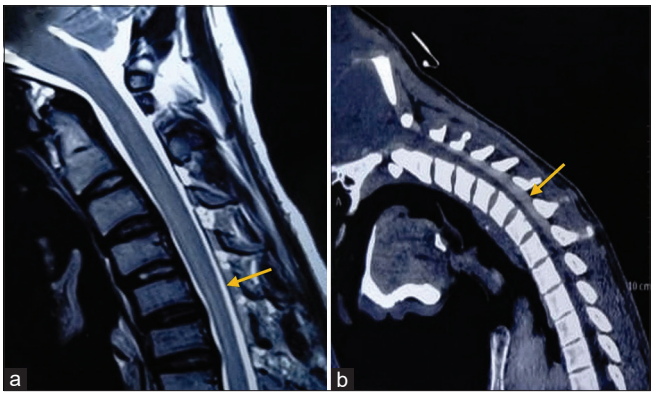

Figure 1: (a) Magnetic resonance imaging with neck flexion not demonstrating significant venous plexus and also the posterior cerebrospinal fluid column is visible as the cord is not displaced anteriorly (yellow arrow). (b) Computed tomography venogram of the cervical spine with neck flexion demonstrating engorged venous plexus with the cord displaced anteriorly (yellow arrow)

RESULTS

Demographic and clinical features

A total of nine patients were included in this series. All patients were male. The age ranges from 18 to 30 years (mean – 21.55). 5/9 patients had involvement of only the left upper limb, one patient had involvement of the right upper limb, whereas 3/9 patients had bilateral involvement. Distal muscle involvement was seen in all patients; however, one patient had involvement of proximal muscles in the form of weakness in bilateral elbow extension (power 3/5) and right shoulder abduction (power 3/5). One patient also reported tightness in both lower limbs [Table 2].

Radiological findings

In our study, 8/9 patients had classical findings on MRI cervical spine with flexion. These findings were engorged epidural venous plexus appearing as flow voids, anterior displacement

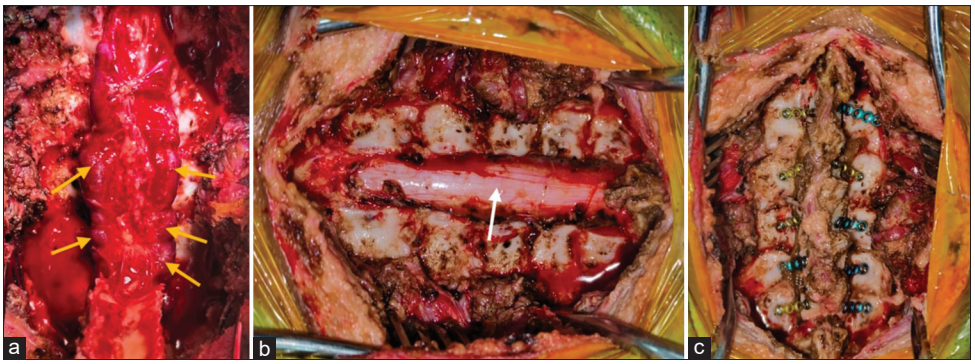

Figure 2: Case Illustration 1: A 19-year-old male patient presented with atrophy of the left hand and distal forearm muscles with decreased grip. A confirmatory diagnosis of Hirayama disease was made. The patient underwent surgery. (a) Shows postlaminectomy engorged epidural venous plexus (yellow arrows). (b) Postcoagulation of the venous plexus and excision of the tissue with coagulated veins leading to visible posterior dura (White arrow). (c) Laminoplasty was done using mini-plates and screws

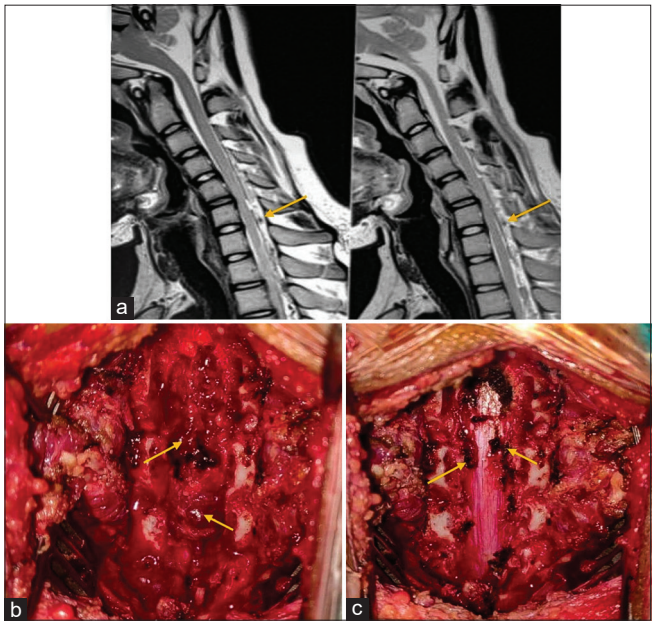

Figure 3: Case Illustration 2: An 18-year-old male presented with atrophy in the left distal forearm and hand muscle and decreased grip. (a) Magnetic resonance imaging neck flexion showing engorged epidural venous plexus (yellow arrow). (b) Shows postlaminectomy engorged epidural venous plexus (yellow arrows). (c) Coagulated venous plexus (yellow arrow) with visibility of the dura postdecompression

of cord with loss of posterior cerebrospinal fluid column, and cord atrophy. One patient's MRI did not correlate with the clinical and electrophysiological findings, for which a CT venogram was done. CT venogram of the cervical spine in flexion demonstrated significant engorged venous plexus in the posterior epidural space with displacement of the cord anteriorly [Table 2].

Electrophysiological findings

All the patients had electrophysiological changes in the form of chronic denervation and reinnervation, decreased Compound muscle action potential (CMAP) in the ulnar or median nerves, or neurogenic lesions. 6/9 patients had involvement of C7-T1 segments which is characteristic of Hirayama disease. Three patients had involvement of upper segments, i.e., C5-T1. Out of these three patients, only one had proximal muscle involvement [Table 2].

Postoperative clinical outcomes

All the patients were evaluated clinically postoperatively, and it was found that 7/9 patients had grip improvement, while the rest two patients had no improvement in grip though one among these two had improvement in performing fine skills. Both of these patients had no further worsening of the grip. The severity of tremors in 7/9 patients had decreased, while rest two had no improvement in severity of tremors. Reversal of atrophy in the form of an increase in girth of the forearm was reported by one patient postsurgery though it could not be confirmed on electrophysiological testing. One patient who had proximal weakness in the form of elbow extension (3/5) and shoulder abduction (3/5) preoperatively had significant improvement after surgery, i.e., elbow extension (4/5) and shoulder abduction (4/5). One patient also complained of tightness in both lower limbs which decreased significantly after surgery [Table 3].

Neck disability index

The Neck Disability Index was assessed in all patients preoperatively and postoperatively. It was observed that 5/9 patients had mild disability preoperatively which improved postoperatively, while the rest 4/9 patients had no disability [Table 4].

Postoperative computed tomography venogram and X-ray

The patients were planned for CT venogram and cervical spine X-ray after 6 months of surgery to look for recurrence or recanalization of the epidural venous plexus as well as instability in the spine [Figure 4]. 6/9 patients underwent CT venogram which demonstrated no engorged epidural venous plexus causing cord compression. 3/9 refused for CT

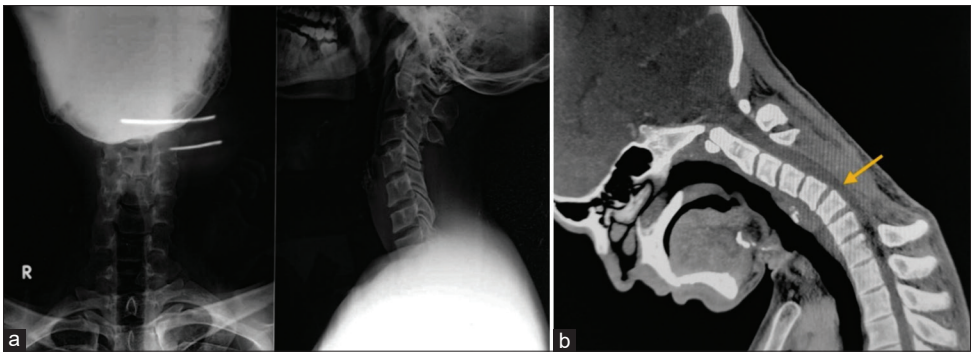

Figure 4: (a) Postoperative X-ray of a patient after 1 year with no significant instability. (b) Postoperative computed tomography venogram with neck flexion with no engorged venous plexus or posterior cord compression (yellow arrow)

Table 2: Preoperative clinical and diagnostic findings

Case	Age/ sex	Side involved	Distal muscle involvement	Proximal muscle involvement	MRI cervical spine with neck flexion	ENMG	Surgery
Case 1	18/male	Left	+	–	C2–7 epidural soft tissue with engorged venous plexus with anterior shift of the posterior dura with cord atrophy	Decreased CMAP in the left ulnar nerve	C2–7 laminectomy with coagulation of the venous plexus
Case 2	24/male	Left	+	–	Cervical epidural venous engorgement C4–D1 with anterior shift of the posterior dura with cord atrophy	Chronic Denervation and reinnervation in the left C8–T1 segments with decreased CMAP in the left ulnar nerve	C4–7 laminectomy with coagulation of the venous plexus
Case 3	19/male	Left	+	–	C4–7 epidural soft tissue with flow voids displacing the posterior dura anteriorly with cord compression and atrophy	Chronic neurogenic lesion in the left C8–T1 segments with decreased CMAP in the left ulnar nerve	C4–7 laminectomy with coagulation of the venous plexus
Case 4	18/male	Left	+	–	Anterior shift of the posterior dura with venous engorgement from C4–D1 with cord atrophy and myelomalacia	Chronic Neurogenic process involving the left C7–T1 segments with decreased CMAP in the left ulnar nerve	C4–7 laminectomy with coagulation of the venous plexus
Case 5	30/male	Bilateral (right > left)	+	–	C3–5 enlarged posterior epidural space with flow voids with anterior shift of the dura with cord atrophy and myelomalacia	Chronic Neurogenic process involving bilateral C7–T1 segments with CMAP in the right ulnar nerve	C3–6 laminectomy with coagulation of the venous plexus
Case 6	20/male	Bilateral (right > left)	+ (with tightness of both lower limbs)	–	C4–7 epidural tissue with flow voids anterior shift of the posterior dura with cord atrophy and myelomalacia changes	Chronic Neurogenic process in the bilateral C7–T1 segments with decreased CMAP in the right ulnar nerve	C4–6 laminectomy with coagulation of the venous plexus with open-door laminoplasty
Case 7	24/male	Bilateral (right > left)	+	+ Bilateral elbow extension (3/5), right shoulder abduction (3/5) weakness	C3–6 engorged epidural venous plexus with anterior shift of the dura with cord atrophy and myelomalacia	Neurogenic lesion involving bilateral C5–T1 segments with evidence of denervation	C3–6 laminectomy with coagulation of the venous plexus and open-door laminoplasty
Case 8	19/male	Left	+	–	C4–7 engorged epidural venous plexus with anterior shift of the cord with atrophy and myelomalacia changes at C5–6	Neurogenic potentials noted from left C5–T1 with evidence of denervation and reinnervation	C4–6 laminectomy with coagulation of the venous plexus and open-door laminoplasty
Case 9	22/male	Right	+	–	C4–T1 engorged epidural venous plexus compressing cord with atrophy	Neurogenic process from C5–T1 with decreased CMAP in the right median and ulnar nerve	C3–7 laminectomy with coagulation of the venous plexus with open-door laminoplasty

ENMG - Electroneuromyography; MRI - Magnetic resonance imaging; CMAP - Compound muscle action potential

venogram due to financial constraints. Cervical spine X-ray in neutral and dynamic position was done in 7/9 patients, in which six patients showed no significant instability, but one patient developed kyphosis but had no neurological

Table 3: Postoperative clinical outcomes with respect to grip improvement, severity of tremors, and reversal of atrophy

Case	Grip improvement	Severity of tremors	Reversal of atrophy
Case 1	Yes	Decreased	No
Case 2	No. But no further worsening	Same	No
Case 3	Yes	Decreased	No
Case 4	Yes	Decreased	No
Case 5	Yes	Decreased	No
Case 6	Yes	Decreased	No
Case 7	Yes	Decreased	No
Case 8	Yes	Same	Yes
Case 9	No. But improvement in performing fine activities	Decreased	No

Table 4: The Neck Disability Index preoperative and postoperative

Case	Preoperative NDI score	Postoperative NDI score
Case 1	8/50 (mild disability)	3/50 (no disability)
Case 2	6/50 (mild disability)	4/50 (no disability)
Case 3	4/50 (no disability)	1/50 (no disability)
Case 4	8/50 (mild disability)	4/50 (no disability)
Case 5	6/50 (mild disability)	3/50 (no disability)
Case 6	6/50 (mild disability)	2/50 (no disability)
Case 7	4/50 (no disability)	2/50 (no disability)
Case 8	4/50 (no disability)	1/50 (no disability)
Case 9	3/50 (no disability)	1/50 (no disability)

NDI - Neck Disability Index

worsening. One patient who had bilateral upper limb involvement (right >left) in whom C4–6 laminoplasty was done also started to experience symptoms in the left hand after surgery. On postoperative CT venogram and X-ray, it was found that the mini-screws were dislodged causing compression on the cord by the lamina, although there was no significant instability. The patient underwent a second surgery in the form of reexploration with the removal of C4–6 lamina and the spinous process, to achieve posterior decompression over the cord, although the patient is being followed up.

DISCUSSION

Etiopathogenesis

Since its first description, several hypotheses have been proposed for the etiopathogenesis of Hirayama disease. One of the earliest hypotheses proposed includes the differential growth of the cervical spine and the spinal cord particularly during puberty leading to the tightness of the dura mater and resulting in dynamic compression over the anterior spinal artery and damage to anterior horn cells.[23]

Brandicourt *et al*.,[5] in their study, observed that sports, such as gymnastics, dance, or the intensive practice of music, with their repeated cervical flexion movements, might contribute to the development of this disease. In their case series which included three patients, one patient was a rugby player, and one was a high-level cellist. In our study, one patient had a history of heavy sports and physical exercises, two were farmers, and one was a software engineer. Thus, these patients may have excessive cervical flexion movements.

At the present time, no genetic predisposition has been highlighted;[24] however, familial cases have been reported.[25] Konno *et al*.,[18] based on the histological studies, proposed the loss of elastin in the dura based on the autopsy findings as the cause.

Some authors proposed that the compression caused by the dilated veins on the posterior aspect is causing the changes in the spinal cord and also the radiological finding of the dura separating from the lamina on flexion MRI. The cause of the venous dilatation as proposed by Brandicourt *et al*.[5] could be because of strenuous activities or repetitive neck movements. Authors in some of the selective cases did a venogram of the proximal veins to look for any stenosis; however, no stenosis has been observed. All the factors leading to the venous dilatation are yet to be identified.

As reported by Brandicourt *et al*.[5] in their case series, the patient had neurological improvement and stabilization of disease postlaminectomy and coagulation of the venous plexus. This one factor stands out in favor of engorged epidural plexus being the potential etiology of Hirayama disease leading to repetitive compression of the cord and trauma with neck movement. A better anatomical understanding of the venous circulatory patterns of the epidural plexus could probably aid in elucidating the etiological factors leading to these venous dilatations of the cervical venous plexus. Pyramidal signs and other clinical characteristics that have been described as atypical symptoms could possibly relate to the length of venous congestion and also the size of the venous dilatation and the extent of compression over the cervical cord.

Imaging

The radiological diagnosis is generally made on the basis of MRI with neck flexion. Ciceri *et al*.[7] demonstrated the venous engorgement on the angiogram. In our study, in addition to the MRI, we performed a CT venogram in neutral and flexion position to get a better visualization of the venous dilatation and compromise of the cervical canal.

It becomes essential to demonstrate venous dilatation as the procedure involves coagulation of the veins to relieve the symptoms. When MRI fails to provide clear visualization

of venous dilatation, utilization of CT venogram has helped to instill the necessary confidence to proceed with the intervention. Furthermore, a CT venogram is also an important diagnostic tool in identifying the precise number of levels requiring decompression.

Treatment

The indications for surgical treatment in Hirayama include:

1. Failure of conservative management
2. Inability to comply with using the cervical collar for longer duration
3. Presence of advanced or rapidly progressive neurological deficits.

Various surgical approaches both anterior and posterior fusions have been used. These surgical approaches include laminectomy, duraplasty, corpectomy, discectomy, decompression, and fusion.[8,15,16] They were able to achieve the results, i.e., prevention of venous congestion and resultant compression over the cord. However, the major drawback of these procedures is the restriction of motion in the neck. As the patients of Hirayama disease are very young, restricted movements become a major challenge. Furthermore, these procedures are associated with more surgical complications.

Laminectomy and coagulation of the venous plexus alone, without fusion, have yielded the same result by preventing the narrowing of the canal and also the compression over the cord by engorged veins. Thus, in the current series, laminectomy and coagulation of the venous plexus with or without laminoplasty have addressed both issues. Hence, consistently in our study, 7/9 patients had improvements in neurological deficits, while rest two patients had stabilization of the disease process. The current series is the largest series which have proven findings and also the outcomes of this surgical modality. The earlier series by Brandicourt *et al*.[5] have shown the outcomes in only three cases.

Hence, considering all the factors, the procedure looks reliable, and with reasonable surety, we can assume that varicosities such as dilatation and venous engorgement seem to play a major role in etiopathogenesis. However, the question that remains unsolved is the exact factors that cause these cervical venous dilatations and also the long-term follow-up after coagulation to look for recurrence and stability of the cervical spine.

CONCLUSION

Hirayama disease predominantly affects young individuals and appears to be linked to varicose-like venous dilatation, leading to compression of the cord, especially during cervical flexion. It is imperative that further research is done to understand the mechanism behind this venous dilatation, which could potentially pave the way for preventive measures. However, surgical management with laminectomy and venous coagulation with or without expansile laminoplasty has delivered consistent improvement in neurological outcomes and long-term disease stabilization. Moreover, this approach preserves the range of motion in the neck which is particularly vital for young patients and is associated with fewer surgical complications. In cases where MRI fails to demonstrate engorged veins, CT venogram in flexion and neutral position can be a valuable diagnostic tool. Overall, this study contributes to the existing literature surrounding this rare neurological disorder and offers promising surgical strategies for its management.

Limitations

First, the small sample size, attributed to the rare nature of the disease, restricts the generalizability. However, collaborating with other medical institutions and extending the study period could help in overcoming this limitation. Second, the short follow-up period of 6 months may be inadequate to elicit recurrence as well as biomechanical changes in the spin, thus calling for the need of longer follow-up.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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