

Magnetic Resonance Imaging Spectrum of Cauda Equina and Conus Lymphoma: Keys to Unravel the Differential Diagnosis with a Review of the Literature

Deb K. Boruah¹ Pallavi Gogoi² Bidyut B. Gogoi³ Kalyan Sarma¹ Gautam Sarma⁴
Karuna Hazarika⁵ Augstine A⁶ Halimuddin Ahmed⁵

¹ Department of Radiology, All India Institute of Medical Sciences (AIIMS), Guwahati, Assam, India

² Department of Library and Information Science, Dibrugarh Hanumanbax Surajmall Kanoi (DHSK) College, Dibrugarh, Assam, India

³ Department of Pathology, Assam Medical College, Dibrugarh, Assam, India

⁴ Department of Radiation Oncology, All India Institute of Medical Sciences (AIIMS), Guwahati, Assam, India

Address for correspondence Deb K. Boruah, MD, PDCC, Department of Radiology, All India Institute of Medical Sciences (AIIMS), Guwahati, Assam 780101, India (e-mail: drdeb_rad@yahoo.co.in).

⁵ Department of Radio-diagnosis, Tezpur Medical College, Sonitpur, Assam, India

⁶ Department of Radio-diagnosis, Assam Medical College, Dibrugarh, Assam, India

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Abstract



Deb K. Boruah

Keywords

- ▶ non-Hodgkin lymphoma
- ▶ magnetic resonance imaging (MRI)
- ▶ cauda equina
- ▶ diffusion-weighted imaging
- ▶ chemoradiotherapy

Central nervous system lymphoma is not an uncommon condition, but spinal lymphoma with isolated involvement of the conus medullaris and cauda equina is a rare entity. Our study aims to evaluate the various magnetic resonance imaging (MRI) features of cauda equina and conus lymphoma. This retrospective study was carried out on nine patients with histopathologically proven cauda equina and conus lymphoma, who were presented at a tertiary care hospital between January 2018 and June 2020. All patients underwent lumbar spine MRI scans using a 1.5 Tesla MR scanner. The clinical data and different MRI findings were analyzed with an independent sample *t*-test and paired-samples *t*-test. Among the nine patients with cauda equina and conus lymphoma, three had primary lymphoma and six had secondary lymphoma. Six patients (66.7%) showed a diffuse pattern of involvement of cauda equina and conus medullaris, while three patients (33.3%) showed a focal pattern. T2-weighted imaging (T2WI) hypo to isointense signal intensity lesions were observed in six patients (66.7%) and T2WI iso to slight hyperintensities in three patients (33.3%). Diffuse sheet-like thickening and postcontrast enhancement of the thickened cauda equina nerve roots were observed in two patients of primary and one patient with secondary lymphoma. The diagnosis of cauda equina and conus lymphoma especially primary lymphoma is challenging and requires a high index of clinical suspicion as distinguishing this entity from similar conditions is difficult solely on MRI. Early diagnosis of this entity is important for early institution of treatment for increasing the chances of survival and improvement of symptoms.

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Introduction

The intradural and intramedullary spinal lymphomas, whether primary or secondary, have been an uncommon entity. Central nervous system (CNS) lymphoma is rather common but spinal lymphoma is a rare entity.¹ Primary CNS lymphoma accounts for 1 to 2% of all non-Hodgkin lymphoma.² Of the CNS lymphoma, spinal cord lymphoma occurs in less than 1%.³ Among the spinal cord lymphoma, cauda equina lymphoma is the rarest one.³

The primary cauda equina and conus lymphomas are uncommon extranodal non-Hodgkin lymphoma. Secondary cauda equina and conus lymphomas occur due to secondary involvement of systemic lymphoma, either from hematogenous, direct invasion, venous spread through Batson's plexus, or drop metastasis from brain involvement.⁴

B cell type of lymphoma dominantly affects the cauda equina in both primary and secondary forms.² The aggressive form of B cell lymphoma secondarily affects the CNS in up to 25% of patients. Human immunodeficiency virus (HIV)-infected, organ-transplanted, and congenital immunodeficiency patients are more prone to the development of CNS lymphoma.⁵ There has been an increasing incidence of primary CNS lymphoma in immune-competent individuals also. The frequency of spinal lymphomas in decreasing order are intraosseous, epidural, intradural extramedullary, and intramedullary depending on their location.⁶

Leptomeningeal seeding of lymphoma manifests as abnormal shaggy to nodular enhancement over the spinal cord surface and nerve roots.⁴ The intravascular form of B cell lymphoma presents with progressive cauda equina syndrome, skin lesions, or other systemic features⁷ where nasal mucosal, skin, or bone marrow biopsy helps in its diagnosis.

Intraosseous and epidural lymphomas have a better prognosis than intradural or intramedullary lymphoma,⁴ so

knowledge of various magnetic resonance imaging (MRI) appearances of intradural lymphoma of cauda equina and conus medullaris is of utmost importance for early diagnosis and early treatment for better patient outcomes.

This study aims to evaluate the various MRI features of cauda equina and conus lymphoma.

Materials and Methods

A retrospective study was conducted in our institute on histopathologically proven nine patients of cauda equina and conus lymphoma presented between January 2018 and June 2020. This study was approved by the institutional ethics review committee.

Inclusion Criteria

- Only intradural extramedullary and intramedullary forms of spinal lymphoma affecting cauda equina and conus medullaris.

Exclusion Criteria

1. Isolated spinal epidural lymphoma
2. Lymphoma involving contiguous vertebra and or retroperitoneum

MRI Protocols

All patients underwent an MRI scan of the spine, using a 1.5 Tesla MR scanner, Siemens Magnetom Avanto (Siemens Medical Systems, Erlangen, Germany). The conventional MRI sequences of the spine includes sagittal T1-weighted imaging (T1WI), T2WI, short tau inversion recovery (STIR), diffusion-weighted imaging, coronal STIR, and axial T1WI, T2WI. Postgadolinium T1WI sequences were obtained in all three planes. The parameters of the various sequences used are shown in (→Table 1).

MRI evaluation: The patients were evaluated for the involvement of conus medullaris, cauda equina nerve roots,

Table 1 Parameters used in various conventional MRI sequences of spine protocol

MRI sequence	TE (ms)	TR (ms)	Matrix	Field of view (FOV)	Slice thickness (mm)	Flip angle	Others
T1W sagittal	9–15	450–500	256 × 256	200-220	4	90°	
T2W sagittal	110–120	3400–4600	256 × 256	200-220	4	90°	
STIR sagittal	25–28	4500–4900	256 × 256	200-220	4	90°	TI = 160ms
STIR coronal	25–28	4500–4900	256 × 256	200-220	4	90°	TI = 160ms
DWI sagittal	86–100	2500–3000	128 × 128	200-220	4	90°	b = 1000sec/mm ²
T1W axial	9–15	450–500	256 × 256	200-220	3	90°	
T2W axial	110–120	3400–4600	256 × 256	200-220	3	90°	
Fat-suppressed postcontrast T1WI axial, coronal and sagittal	9–15	450–500	256 × 256	200-220	3	90°	after injecting I.V. Gadopentetate Dimeglumine at a dose of 0.1mmol/kg body weight.

Abbreviations: DWI, diffusion-weighted imaging; MRI, magnetic resonance imaging; STIR, short tau inversion recovery; T1WI, T1-weighted imaging; TE, time of echo; TI, inversion time; TR, repetition time.

superior or inferior extensions, and pattern of contrast enhancement.

Laboratory test and histopathological examination: All patients were evaluated with complete blood count, enzyme-linked immunosorbent assay for HIV, cerebrospinal fluid (CSF) analysis, bone marrow aspiration cytology, and posteroanterior view of chest X-rays. Confirmation of lymphoma was established by histological confirmation of postoperative resected specimen of thickened cauda equina nerve roots in three patients of primary Lymphoma, lymph nodal biopsy in five patients, and associated leg mass biopsy in one patient with secondary lymphoma.

Treatment: Four patients were treated with only multi-drug chemotherapy and five patients with combined chemoradiotherapy. Clinical, hematological, or radiological follow-up was done in all patients.

Statistical analysis: All statistical analysis was performed by using Statistical Package for the Social Science (SPSS programs, version 16). The clinical data and different MRI findings were analyzed with an independent sample *t*-test and paired-samples *t*-test.

Results

Patient and clinical data: In this study sample, nine patients ($n=4$ male, $n=5$ female) of cauda equina and conus lymphoma were included with a male: female ratio of 1:1.25 and mean age of 48.89 ± 1.84 (standard deviation, SD) years (range: 18–80 years). The demography, clinical and MRI findings were summarized in (►Table 2). Primary lymphoma was identified in three patients (33.3%) and secondary lymphoma in six patients (66.7%). Patients with secondary lymphoma had cervical lymphadenopathy in two patients, mediastinal lymphadenopathy in two patients, retroperitoneal lymphadenopathy in one patient, and leg mass with tibial involvement in another one patient.

The most common clinical presentation was chronic paraparesis with bladder and bowel dysfunction in five patients (55.56%), chronic low backache with radiculopathy in two patients (22.2%), and chronic low backache with dissociative anesthesia in one patient (11.1%) and chronic low backache in another 1 patient (11.1%). The mean duration between neurological symptoms onset and MRI examination was 4.78 ± 2.11 (SD) months.

MRI findings: Six patients (66.7%) showed a diffuse pattern (►Figs. 1 and 2) and three patients (33.3%) showed a focal pattern of involvement of cauda equina and conus medullaris (►Figs. 3–5). T2WI hypo to isointense signal intensities were observed in six patients (66.7%) and T2 iso to slight hyperintensities in three patients (33.3%). Diffusion restriction with a low apparent diffusion coefficient value was observed in four patients (44.4%) with the diffuse pattern of lymphoma and two patients (22.2%) with focal lymphoma.

Diffuse sheet-like postcontrast enhancement of the cauda equina fibers and sheet-like thickened nerve roots was observed in two patients (22.2%) of primary

Table 2 Summarized clinical data and MRI findings in nine patients of conus and cauda equina lymphoma

S/N	Age (y)/sex	Clinical presentation	Clinical findings	CSF analysis findings	Blood cell count	MRI appearance of the lesion		Other site involvement	Diagnosis	Treatment	Survival		
						T2WI	DWI						
1.	50/F	LBA with saddle perianal anesthesia	b/l lower limb muscle power 3/5, decreased tone, absent deep tendon reflexes in lower limbs	Elevated protein—68 mg/dL and lymphocytic pleocytosis—92 cells/ μ L with many large-sized atypical lymphoid cells	TLC—5,400, N79, L13	Iso to slight hyperintense	Restricted	Postgadolinium Sheet-like Homogenous enhancing lesions over conus, cauda equina and clumped lumbar and upper sacral nerve roots	D12 to S1 vertebral level	No	Primary lymphoma	Chemotherapy +radiotherapy	Died after 4 months of therapy
2.	53/M	LBA with radicular pain, paraparesis	b/l lower limb muscle power 2/5, decrease tone, absent deep tendon reflexes in lower limbs	Elevated protein—76mg/dL, lymphocytic pleocytosis—143 cells/ μ L with many large atypical lymphoid cells	TLC—5,800, N73, L15	Hypo to isointense	Restricted	Sheet-like homogenous enhancement D12 to L5 vertebral level	D12 to L5 vertebral level	No	Primary lymphoma	Chemotherapy	Died after 7 months of therapy

(Continued)

Table 2 (Continued)

S/N	Age (y)/ sex	Clinical presentation	Clinical findings	CSF analysis findings	Blood cell count	MRI appearance of the lesion			Other site involvement		Diagnosis	Treatment	Survival
						T2WI	DWI	Postgadolinium	Extension of lesion				
3.	50/F	LBA with paraparesis and bladder and bowel dysfunction	b/l lower limb muscle power 1/5, decreased tone, absent deep tendon reflexes in lower limbs	Elevated protein: 102 mg/dL, lymphocytic pleocytosis—178 cells/ μ L with many atypical lymphoid cells	TLC—7,820 N 69, L17	Hypo to isointense with plaque like lesion	Restricted	Segmental plaque-like homogeneously enhancing lesions in conus, cauda equina, and clumped lumbar nerve roots	L1 to S1 vertebral level	Retroperitoneal lymphadenopathy	Secondary lymphoma	Chemotherapy +radiotherapy	Died after 3 months of therapy
4.	60/F	LBA with radicular pain	b/l lower limb muscle power 3/5	Elevated protein—87 mg/dL, lymphocytic pleocytosis—101 cells/ μ L	TLC—6,430, N 71, L16	Hypo to isointense	Restricted	Sheet-like homogeneously enhancing lesions in cauda equina fibers and lumbar nerve roots	L2 to L5 vertebral level	Mediastinal lymphadenopathy	Secondary lymphoma	Chemotherapy +radiotherapy	Died after 8 months of therapy
5.	50/F	Paraparesis and bladder and bowel dysfunction	b/l lower limb muscle power 2/5	Protein—112 mg/dL, lymphocytic pleocytosis—89 cells/ μ L	TLC—5,780 N-67, L14	Hypo to isointense	No restriction	Mild sheet-like homogeneously enhancing lesions over conus with enhancing cauda equina fibers	D6 to D12 vertebral level	Cervical lymphadenopathy	Secondary lymphoma	Chemotherapy	Died after 9 months of therapy
6.	80/M	Paraparesis and bladder and bowel dysfunction	b/l lower limb muscle power 3/5	Protein—77 mg/dL, lymphocytic pleocytosis—89 cells/ μ L	TLC—5,800 N-68, L14	Iso to Slight hyperintense	No restriction	Patchy plaque-like and nodular enhancing lesions within conus medullaris and over surface. No cauda equina fibers affected	D10 to L1 vertebral level	No	Primary lymphoma	Chemotherapy	Died after 6 months therapy
7.	24/M	Paraparesis and Bladder and bowel dysfunction	b/l lower limb muscle power 1/5	Protein—97 mg/dL, lymphocytic pleocytosis—95 cells/ μ L	TLC—6,700 N-71, L 16	Iso to slight hyperintense nodular lesion in conus with dorsal cord T2 hyperintense edema	Restricted	Patchy irregular nodular enhancing lesion in conus medullaris	D11 to D12 vertebral level	Mediastinal lymphadenopathy	Secondary lymphoma	Chemotherapy +radiotherapy	Died after 4 months
8.	18/M	Para paresis and bladder and bowel dysfunction	b/l lower limb muscle power 2/5	Protein—107 mg/dL, lymphocytic pleocytosis—89 cells/ μ L	TLC—6,300 N-69, L19	Hypo to isointense	No restriction	Sheet-like enhancement over conus with enhancing nodules within conus	D2 to L1 vertebral level	Cervical lymphadenopathy	Secondary lymphoma	Chemotherapy +radiotherapy	Died after 9 months
9.	55/F	LBA and paraparesis and bladder and bowel dysfunction	b/l lower limb muscle power 3/5	Protein—123 mg/dL, lymphocytic pleocytosis—108 cells/ μ L	TLC—6,200 N 70, L 17	Iso to slight hyperintense	Restricted	Intradural mass-like enhancement over the conus medullaris with displacement of conus towards left side.	D11 to L2 vertebral level	Right leg mass lesion with tibial involvement with cortical destruction	Secondary lymphoma	Chemotherapy	Died after 10 months of therapy

Abbreviations: CSF, cerebrospinal fluid; DWI, diffusion-weighted imaging; LBA, low back ache; MRI, magnetic resonance imaging; T2WI, T2-weighted imaging; TLC, total leucocyte count.

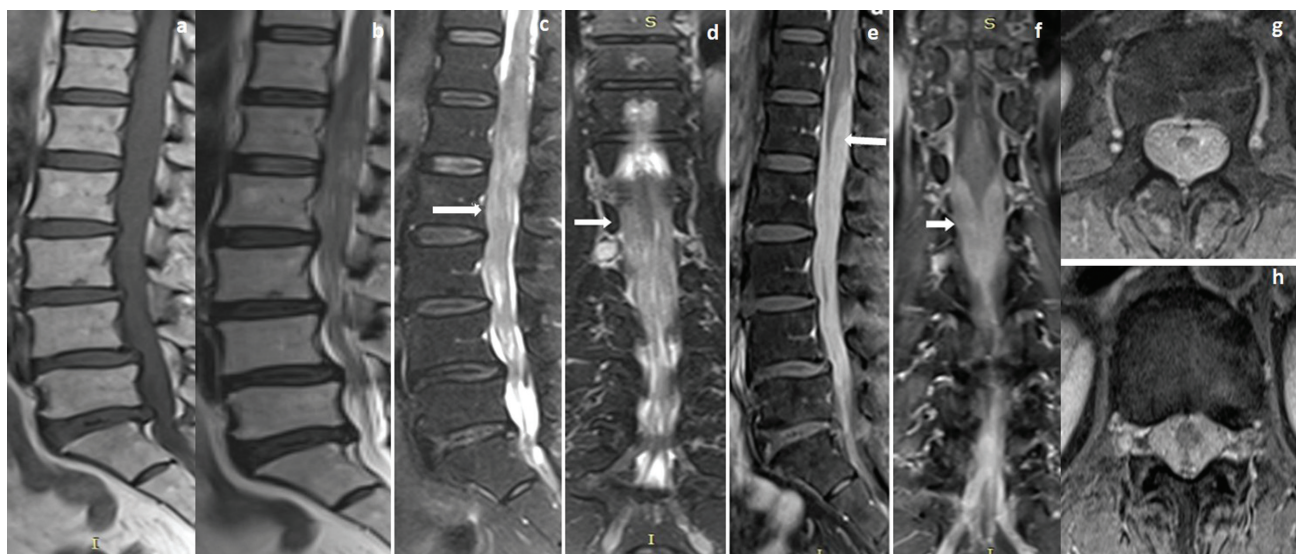


Fig. 1 A 50-year-old female with a diffuse pattern of primary lymphoma presented with chronic low backache with saddle perianal anesthesia. Sagittal T1-weighted (T1W), T2W, and short tau inversion recovery (STIR) images (A–C) showed long segmental T1 iso, T2, and STIR iso to slight hyperintense sheet-like intradural lesions (arrow) extending from D12 to S1 vertebral level. Coronal STIR image (D) showed the sheet-like lesions along the cauda equina nerve fibers. Sagittal, coronal, and axial postgadolinium T1W images (E–H) showed homogenous sheet-like enhancement around the conus medullaris and along the cauda equina fibers.

(→Figs. 1 and 2) and one patient (11.1%) with secondary lymphoma. Plaque to focal mass-like postcontrast enhancement within or around the conus medullaris and cauda equina fibers was found in four patients (44.4%) (→Figs. 3 and 5), focal (intradural mass-like) postcontrast enhancement over conus in one patient (11.1%) (→Fig. 4), and

isolated conus surface enhancement in another one patient (11.1%).

Clumping of cauda equina nerve roots was observed in six patients (66.7%) (→Figs. 1 and 2). Intradurellary enhancing conus lesion observed in one patient (11.1%) (→Fig. 5), sheet-like conus surface enhancement in four

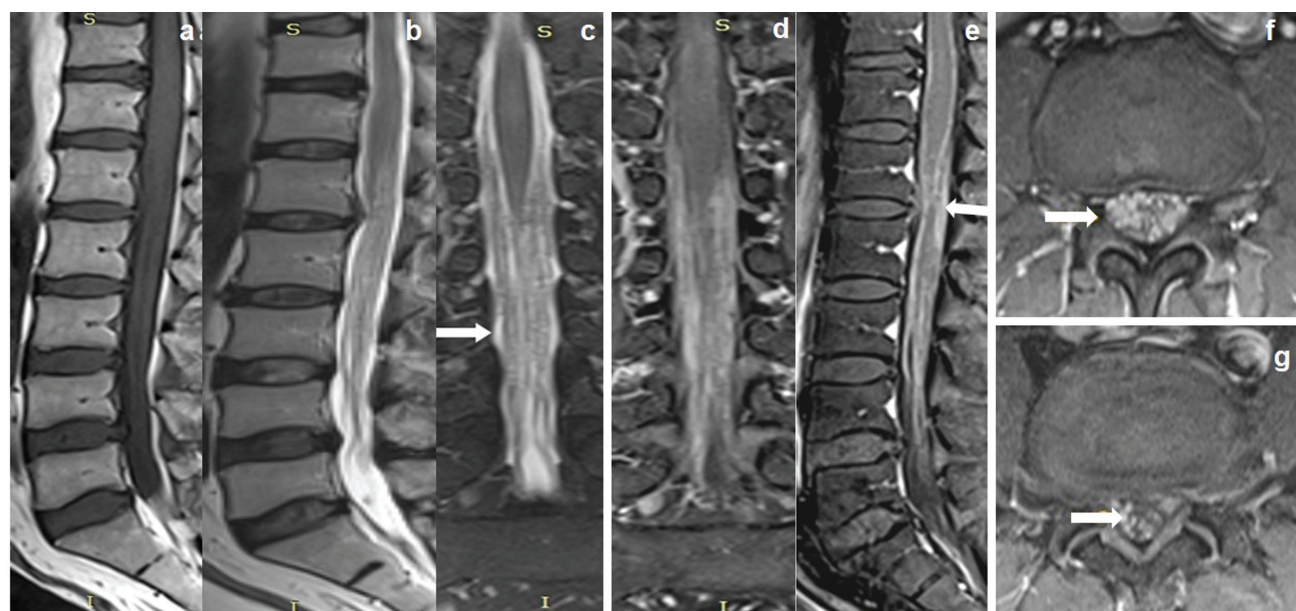


Fig. 2 A 53-year-old male patient with a diffuse pattern of primary lymphoma presented with chronic low backache with radicular pain and paraparesis. Sagittal T1-weighted (T1W), T2W, and coronal short tau inversion recovery images (A–C) showed ill-defined T1W isointense and T2 hypo to isointense sheet-like lesions seen in the intradural location from D12 to L5 vertebral level with inferior extension along the cauda equina fibers (arrow). Coronal, sagittal, and axial postgadolinium T1W images (D–G) showed sheet-like homogenous enhancement over the conus medullaris and along the cauda equina fibers (arrows).



Fig. 3 A 50-year-old female of secondary focal intradural lymphoma with cervical lymphadenopathy presented with chronic low backache with progressive paraparesis and bladder and bowel dysfunction. Sagittal and axial postgadolinium T1-weighted images (A–C) showed homogeneously enhancing lesions noted in the intradural location encircling the conus medullaris (arrow) along with marginal enhancement within the conus medullaris.

patients (44.4%), and both intramedullary lesion and conus surface enhancement in four patients (44.4%) (→Fig. 3). The salient differences between the primary and secondary lymphoma in our study sample were shown in →Table 3.

Four patients of conus and cauda equina lymphoma were treated with only multidrug chemotherapy and five patients with combined chemoradiotherapy. The mean patient survival was 6.67 ± 2.55 (SD) months after the treatment.

Discussion

Previous literature showed various case reports of lymphomatous involvement of conus and cauda equina in the localized⁸ as well as a disseminated form of non-Hodgkin lymphoma. Recurrent lymphoma of spinal cord can cause cauda equina syndrome.⁹ The intramedullary form of lymphoma commonly affects the thoracic cord followed by the conus medullaris and cervical cord.¹⁰

Primary adrenal lymphoma may be presented with cauda equina syndrome with secondary deposits in cauda equina nerve roots.¹¹ Patients with cauda equina lymphoma usually presented with nonspecific symptoms like low backache, radiculopathy, paraparesis, or saddle anesthesia.^{12,13}

Increased CSF protein level, hypoglycemia, or pleocytosis was observed in cauda equina lymphoma.¹¹ Lachance et al¹⁴ found malignant lymphocytes in CSF in 66% of patients with cauda equina lymphoma. Accurate diagnosis of cauda equina lymphoma is usually achievable with surgical resection of the affected nerve root and confirmation on histopathological or immune histopathological examinations.¹⁵

Cauda equina lymphoma on MRI appears as a focal increase in the volume of cauda equina or nerve roots, sheet-like thickening, and homogenous moderate-to-intense postcontrast enhancement of the thickened nerve roots.^{8,12} In our study, sample of 66.7% of patients showed a diffuse pattern and 33.3% showed a focal pattern of involvement of cauda equina

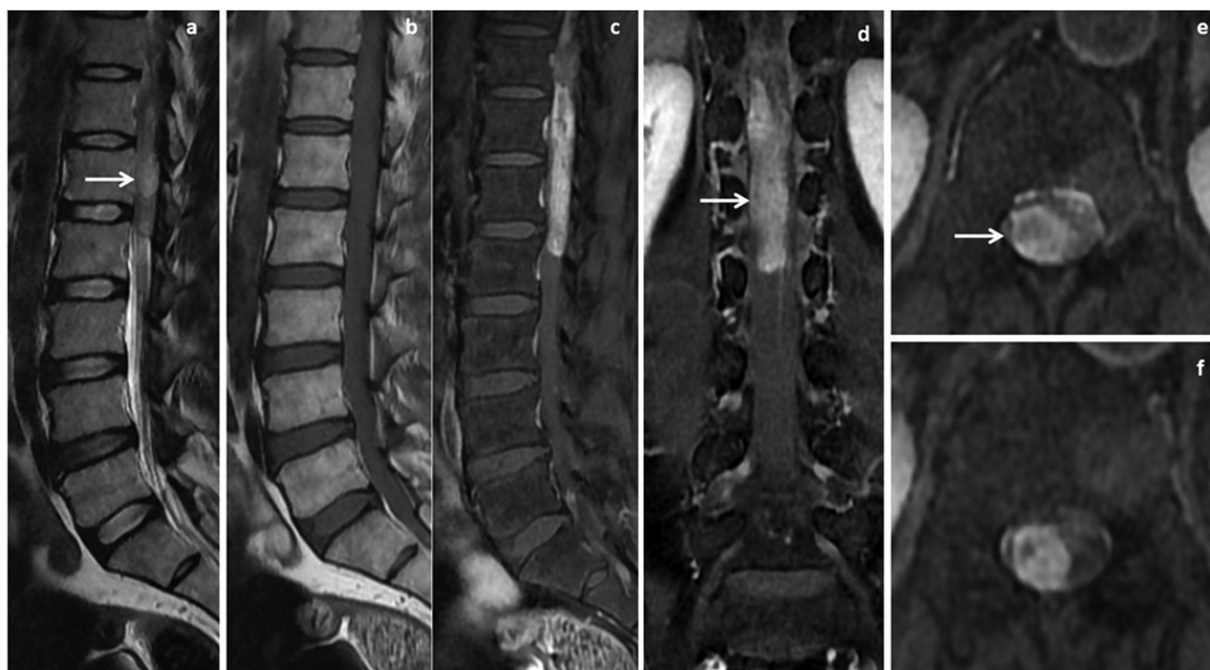


Fig. 4 A 55-year-old female with intradural focal mass-like lymphoma presented with progressive paraparesis. Sagittal T2-weighted (T2W) and T1W (A and B) showed ill-defined T2 iso to slight hyperintense intradural focal mass-like lesion at D12 to L2 vertebral level (arrow). Sagittal, coronal, and axial postgadolinium T1W images (C–F) showed homogeneously enhancing plaque to mass-like lesion noted in intradural location displacing conus medullaris towards the left side (arrow).



Fig. 5 A 24-year-old male with secondary focal intradural lymphoma presented with gradual paraparesis. Sagittal T2-weighted (T2W), short tau inversion recovery, and T1W images (A–C) showed an ill-defined T2 iso to slight hyperintense intramedullary lesion in the conus medullaris with perifocal edema extend into the lower dorsal cord (arrow). Sagittal T1W postgadolinium image (D) showed an oval-shaped nodular enhancing lesion within the conus medullaris (arrow) with less enhancement in the central portion. Axial T2W image (E) showed T2 iso to slight hyperintense intramedullary conus medullaris lesion. Axial postgadolinium T1W image (F) showed the enhancing intramedullary lesion with minimal peripheral irregular margins and less enhancing central area.

Table 3 The salient difference between the primary and secondary cauda equina and conus lymphoma on MRI in nine patients

	Parameters	Primary lymphoma (n = 3)	Secondary lymphoma (n = 6)	p-Value	
	Age (years)	61 ± 16.5 (SD)	42.8 ± 17.4 (SD)	0.178	
	Sex	M: F = 2:1	M: F = 1:2	0.407	
Radiological	T2WI appearance			0.170	
		Hypo to isointense (n = 6)	1 (11.1%)	5 (55.6%)	
		Iso to slight hyperintense (n = 3)	2 (22.2%)	1 (11.1%)	
	DWI characteristics				1.000
		No DWI restriction (n = 3)	1 (11.1%)	2 (22.2%)	
		DWI restriction (n = 6)	2 (22.2%)	4 (44.4%)	
	Form of disease				1.000
		Focal form (n = 3)	1 (11.1%)	2 (22.2%)	
		Diffuse form (n = 6)	2 (22.2%)	4 (44.4%)	
	Pattern of conus involvement on postcontrast images				0.050
Intramedullary enhancing lesion (n = 1)		0	1(11.1%)		
Surface/mass-like enhancement (n = 4)		2(22.2%)	2(22.2%)		
Both intramedullary and conus surface enhancement (n = 4)		1(11.1%)	3(33.3%)		

(Continued)

Table 3 (Continued)

	Parameters	Primary lymphoma (n = 3)	Secondary lymphoma (n = 6)	p-Value	
	Cauda equina nerve roots on postcontrast images			0.111	
		Not thickened	1	2(22.2%)	
		Thickened	0	3(33.3%)	
		Sheet like diffuse thickenings and clumping	2(22.2%)	1(11.1%)	
Extraspinal involvement		No	Yes, lymphadenopathy: cervical 2, mediastinal 2, retroperitoneum 1, 1-right leg mass with tibial involvement		
Prognosis	Survival (months)	5.67 ± 1.53 (SD)	7.17 ± 2.93 (SD)	0.442	

Abbreviations: DWI, diffusion-weighted imaging; MRI, magnetic resonance imaging; SD, standard deviation.

and conus medullaris. In our study sample, diffuse sheet-like postcontrast enhancement of the cauda equina fibers and sheet-like thickened nerve roots was observed in 33.3% of patients, while previous case reports by Broen et al¹³ and Biasi et al¹⁶ showed similar findings of cauda equina lymphoma. A few previous case reports by Teo et al,³ Nakashima et al,¹² and Shin et al¹⁷ showed focal intradural mass lesions around the conus medullaris and cauda equina but in our study sample, only 1 patient showed an intradural mass.

Focal plaque-like enhancing cauda equina mass can be encountered in cauda equina lymphoma and in such a situation tumors like schwannoma, ependymoma, neurofibroma, meningioma, dermoid, epidermoid, paraganglioma, hemangioblastoma and metastasis needed to be differentiated with their characteristics MRI features.¹² Usually, schwannoma shows T1W isointense and T2W hyperintensity with irregular postcontrast enhancement with or without cystic degeneration and commonly having neural exit foraminal extension. Meningioma showed T1W isointense and T2W iso to hypointense signal intensity with moderate to intense homogenous postcontrast enhancement and the presence of a dural tail. Ependymoma showed T1W isointense and T2W hyperintense signal intensity with intense postcontrast enhancement with or without intratumoral hemorrhage and cystic changes. Neurofibroma shows the dumbbell shape of the mass with neural exit foraminal extension.

Sheet-like cauda equina nerve root thickenings can be encountered in acute inflammatory demyelinating polyradiculoneuropathy, chronic inflammatory demyelinating polyradiculoneuropathy, Landry-Guillain-Barre syndrome, hereditary sensory-motor neuropathies (Charcot-Marie Tooth disease), sarcoidosis, arachnoiditis, tuberculous

pachymeningitis, schistosomiasis,^{8,11,18} tumor with CSF drop metastasis (glioblastoma, ependymoma, medulloblastoma, ependymoma, pineal tumor), and extracranial metastasis from breast and lung cancers.^{18,19} There is difficulty in distinguishing these conditions from cauda equina lymphoma on MRI. Even though few salient MRI findings were shown in **Table 4** for their differentiation.

Most of patients with cauda equina lymphoma usually respond to chemotherapy, radiotherapy or combined chemoradiotherapy. In treated cauda equina lymphoma patients, the common symptoms like pain and motor weakness are usually relieved after treatment; however, bladder and bowel incontinence usually remain.^{3,20} Combined chemotherapy and radiotherapy had survival rates ranging from 16 to 44.5 months in cauda equina lymphoma patients³ however, in our study sample, the survival period is less at 6.67 ± 2.55 (SD) months.

However, combined chemoradiotherapy is more effective than isolated radiotherapy or chemotherapy in the management of primary CNS lymphoma.²¹ Isolated radiotherapy is initially effective, but its response is short-lived.²¹ Aggressive surgical resection is not effective in primary CNS lymphoma.²¹ But treatment protocol including initial radiotherapy or chemotherapy with or without surgical intervention is the mainstay of treatment in cauda equina lymphoma presenting with radiculopathy²² **Table 5** shows the literature review of cauda equina and conus lymphoma in the last decade.

In conclusion, the diagnosis of cauda equina lymphoma especially primary lymphoma is challenging and requires a high index of suspicion. Early diagnosis of cauda equina and conus lymphoma is important as early treatment may be beneficial and increase the chances of survival and improvement of symptoms.

Table 4 Salient features of lesions resembling conus and cauda equina lymphoma on magnetic resonance imaging

Parameter	Conus and cauda equina lymphoma	Leptomeningeal metastasis	Chronic inflammatory demyelinating polyradiculoneuropathy (CIDP)	Neurosarcoidosis	Inflammatory arachnoiditis	Guillain–Barre syndrome
Probable etiology	<ul style="list-style-type: none"> - Most commonly non-Hodgkin lymphoma 	<ul style="list-style-type: none"> - Hematogenous metastasis - CSF drop metastasis from brain tumors.²³ - Extracranial metastasis (from breast and lung cancers) 	<ul style="list-style-type: none"> - Neurological disorder of peripheral nerve causing peripheral neuropathy.²⁴ - Demyelination of peripheral nerves 	<ul style="list-style-type: none"> - Systemic granulomatous disease²⁵ - Noncaseating granulomas 	<ul style="list-style-type: none"> - Infectious meningitis - Postoperative failed back - Postirradiation - Hemorrhage - Degenerative spondylosis 	<ul style="list-style-type: none"> - Acute inflammation demyelinating polyradiculoneuropathy - Postinfectious/ postvaccinal demyelination
Salient MRI features	<ul style="list-style-type: none"> - Various MRI patterns can be seen^{11,17,19} - Enlarged cauda equina with iso to slight hyper or hypointensities on T1WI and T2WI - Focal or diffuse homogenous enhancement over conus and cauda equina nerve roots - Diffuse sheet like postcontrast enhancement of the cauda equina nerve roots 	<ul style="list-style-type: none"> - 4 MRI pattern can be seen²⁶ - Solitary focal at bottom of thecal sac or along cord surface - Diffuse sheet-like coating of spinal cord/ nerve roots - Rope-like thickening of cauda equina nerves - Multifocal, discrete nodules along the spinal cord/ nerve roots 	<ul style="list-style-type: none"> - Enhancement of the cauda equina nerve roots - Affected nerve roots are enlarged - Most commonly enlarged in extra- foraminal segment²⁷ 	<ul style="list-style-type: none"> - Smooth postcontrast enhancement over conus surface and cauda equina nerve roots²⁸ 	<ul style="list-style-type: none"> - 3 MRI patterns cauda nerve roots²⁹ - Central clumping - Peripheral clumping with empty sac sign - Central mass-like clumping with decreased thecal sac diameter 	<ul style="list-style-type: none"> - Ventral nerve roots dominantly affected - Normal on T1W and T2W images - Smooth enhancement over conus and cauda equina nerve roots

Abbreviations: CSF, cerebrospinal fluid; MRI, magnetic resonance imaging; T1WI, T1-weighted imaging.

Table 5 Literature review of cauda equina and conus lymphoma in last decade

Series/year	Number	Age/mean age (y)	Sex/sex ratio	Salient MRI findings	Form of lymphoma	Cell type of lymphoma	Treatment	Outcome
Iwasaki et al 2012 ²⁷	1	69	M	Enhancing lesion in conus medullaris and cauda equina with old collapse of L1 vertebra	Primary	DLBCL	Chemotherapy (MTX) + RT	Initially improved but died after 18 months
Biasi et al 2015 ¹⁶	1	67	F	Thickening of cauda equina nerve roots with intense postcontrast enhancement	Primary	DLBCL	Chemotherapy	Improved
Nishida et al 2012 ²⁰	1	47	M	Swelling of cauda equina with marked diffuse enhancement	Primary	DLBCL	Chemotherapy + RT	Improved
Broen et al 2014 ¹³	2	75,71	F:2	Enhancement along cauda equina fibers in first case. Thickening and enhancement of multiple lumbosacral nerves in second case	Primary	DLBCL	First case- steroid second case—chemotherapy	First case –not improved and died Second case improved
Nakashima et al 2014 ¹²	1	59	M	Intradural lesion from D12 to S1 level	Primary	DLBCL	RT and MTX	Improved
Teo et al 2012 ³	1	58	M	Minimally enhancing intradural mass from D12 to L4 level	Primary	DLBCL	Chemotherapy + RT+ steroid	Improved
Shin et al 2015 ¹⁷	1	79	F	Segmental intradural mass from L3 to L5 level with leptomeningeal enhancement over cord and Conus.	Primary	DLBCL	Chemotherapy + RT	Improved
Ogilvie et al 2010 ²⁸	1	58	M	Intraspinial mass from D11 to L4 encasing spinal cord, conus medullaris, and cauda equina	Primary	DLBCL	Laminectomy + chemotherapy	Improved
Piyatanont et al 2010 ²⁹	1	77	M	Cauda equina enhancement	Primary	IVL	ND	ND
Tajima et al 2007 ¹¹	1	67	F	Cauda equina edema, enhancement, mass	Primary	DLBCL	RT +CT	Improved
Present study	9	48.89 ± 1.84 (SD)	M: F = 1:1.25	- Enhancement within and over the conus - Intradural plaque-like or mass-forming type - Thickening and enhancement of the cauda equina nerve roots - Diffuse Sheet like thickenings and clumping of nerve roots, especially in primary lymphoma	Primary—3 Secondary—6	B cell lymphoma	Chemotherapy RT	All patient died up to 10 months of follow-up

Abbreviations: CT, chemotherapy; DLBCL, diffuse large B cell lymphoma; IVL, intravascular lymphoma; ND, not defined; RT, radiotherapy; SD, standard deviation.

Authors' Contributions

Deb K. Boruah, Bidyut B. Gogoi, and Kalyan Sarma conceptualized the study. Deb K. Boruah, Karuna Hazarika, and Gautam Sharma were involved in study design and methodology. Deb K. Boruah, Karuna Hazarika, Halimuddin Ahmed, and Antony Augustine were involved in data collection. Deb K. Boruah and Pallavi Gogoi analyzed the data. Deb K. Boruah, Bidyut B. Gogoi, Kalyan Sarma, and Antony Augustine wrote the manuscript. Deb K. Boruah, Gautam Sharma, Karuna Hazarika, and Halimuddin Ahmed reviewed the manuscript.

Conflict of Interest

None declared.

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