European Journal of Molecular & Clinical Medicine

ISSN 2515-8260 Volume 11 Issue 04, 2024

DESCRIPTIVE STUDY TO ASSESS THE ROLE OF MRI IN CHARACTERIZATION OF CNS COMPLICATIONS AMONG DIAGNOSED CASES OF LEUKEMIA IN A TERTIARY CARE CENTRE IN WESTERN INDIA.

Dr Ashish Trivedi[1]*, Dr Mohammed Anas[2], Dr Subhash Bishnoi[3], Dr Anu Bhandari[4], Dr Kuldeep Mendiratta[5]

[1]*Junior Resident, Department of Radiodiagnosis, SMS Medical College, Jaipur.
[2]Junior Resident, Department of Radiodiagnosis, SMS Medical College, Jaipur
[3]Junior Resident, Department of Radiodiagnosis, SMS Medical College, Jaipur
[4]Professor: Department of Radiodiagnosis, SMS Medical College, Jaipur.
[5]Senior Professor and HOD, Department of Radiodiagnosis, SMS Medical College, Jaipur

***Corresponding Author:** Dr Ashish Trivedi
*Junior Resident, Department of Radiodiagnosis, SMS Medical College, Jaipur.

Introduction and Importance of the study-The neurological complications of leukaemia have common presenting symptoms but varying imaging abnormalities. Very few studies till date have been done in leukaemia patients in general regarding its CNS complications, direct as well as treatment related. Leukaemia has a very rapid course, therefore CNS complications are many times missed. Diagnosing CNS lesions in leukaemia is often difficult because there are no pathognomonic imaging features and histological verification is not possible in majority of the patients. CSF analysis has its own limitations and complications but is used for diagnosing because of lack of specific findings in MRI. As many CNS lesions in leukaemia are curable, early diagnosis is important for their proper management.

The purpose of this study was to analyse the MRI imaging features of CNS complications of leukaemia and interpreting these MRI findings in view of clinical data to assess its value in early management.

Results -70 patients were selected for the study MR abnormalities among the studied group were collected and classified according to age, gender, their time of development with respect to treatment and phase of treatment they were in. Various complications noted in our study were Posterior Reversible Encephalopathy Syndrome (PRES), infection, infiltration, infarction, Sino-venous thrombosis, haemorrhage, leukoencephalopathy, brain atrophy, spinal cord compressive myelopathy and cranial nerve involvement.

Conclusion- To reach the correct diagnosis, the presenting signs, symptoms, and laboratory data must be considered along with the radiologic findings. MRI is known for its superior soft-tissue imaging; it was observed that MRI was helpful in the characterization of CNS lesions caused by the leukemic involvement of CNS structures and treatment-associated CNS complications and thus will lead to early management and prevention or minimizing the side effects of the disease.

INTRODUCTION

When blood cell precursors differentiate in the bone marrow, they undergo a neoplastic change that leads to leukaemia, a diverse group of diseases[1]. It accounts for about 30% of all malignancies and is the most common among children, with acute lymphoblastic leukaemia accounting for 75% of cases (ALL). A wide variety of clinical and laboratory findings are used to make the diagnosis[2]. Due to the fast progression of the disease, central nervous system (CNS) complications of leukaemia are uncommon. Acute leukaemia currently has a better prognosis with a 60 percent survival rate because to treatment advancements[3]. Intrathecal methotrexate, high-dose chemotherapy, radiation, or a combination of any of these is used as preventive treatment for the CNS. However, neurological problems may appear in ALL individuals as a result of treatment and effects of the disease itself[4].

Leukemic cells invading the CNS is one category of the neurological side effects of leukaemia, while secondary difficulties brought on by the condition and/or its treatment are another.

The leptomeninges, brain parenchyma, or cerebral vasculature may all be affected by the illness itself. White matter lesions, small-vessel calcifications, cerebrovascular diseases, secondary tumors and infections, brain atrophy, endocrinopathies, and/or neurocognitive impairments brought on by the "late effects" of their therapy are some of the CNS issues connected to treatment. Leukemia's cause is unclear, however some things, such as ionizing radiation, chemicals, and drugs, increase the odds of getting leukaemia. Genetic factors also may predispose to leukaemia as evidenced by increased incidence in siblings of leukaemia, trisomy 21, Fanconi anemia, congenital Agammaglobulinemia, and neurofibromatosis[5].A bone marrow aspiration with more than 55 blasts/mm3 is required for the diagnosis, which is based on a blood count that reveals blast cells[6]. The prognosis has been significantly improved by modern therapeutic methods. Radiotherapy and multimodal chemotherapy are examples of therapeutic strategies used for the treatment. Age, sex, race, nutritional condition, immunologic subtype, platelet count, speed of cytoreduction and the presence of organomegaly or lymphadenopathy are all prognostic variables[6].

Awareness of the effects of treatment approaches is important as improvements in cancer therapy has improved the prognosis of patients with leukaemia[7]. Young individuals who receive certain chemotherapy treatments may experience neurological adverse effects in the short- or long-term. Within three days of dosing, methotrexate may produce neurotoxicity and cognitive impairment[8]. L-asparaginase therapy can cause hemorrhagic or non-hemorrhagic infarcts in up to 2% of individuals, which are seen as Sino-venous occlusion frequently[8]. White matter abnormalities in the brain can occasionally be caused by many drugs, including cisplatin, carmustine, methotrexate, arabinosylcytosine and thiotepal[9]. Many abnormalities identified on the cranial MRI may result from different illness complications as well as preventative therapy for the central nervous system. There is evidence of cortical atrophy, ventricular enlargement, and white matter hyperintensities[10]. Immunosuppression can be caused by both the underlying tumor and the anti-neoplastic treatment, which can then result in infection. The most common causative microorganisms are fungi, which often affect individuals who have had absolute granulocytic counts below 100/mm3 for longer than two weeks[11]. Soft tissue imaging with an MRI is considered superior. Early management and prevention or at least minimization of long-term adverse effects is facilitated by the use of MRI in the early diagnosis of chemotherapy side effects on the paediatric brain[12]. Adults with AML have CNS involvement in 19% of cases, while adults with ALL have CNS involvement in 5% of cases. While CNS involvement in AML recurrence may be as low as less than 1-4 percent [13,14] with current therapy, it can vary from 7 to 15 percent in ALL relapse. Due to the sensitivity and positive predictive value restrictions of CSF cytology, the diagnosis of CNS involvement can be challenging. Sensitivity can be slightly improved with the inclusion of flow cytometry.[15] For patients with acute leukaemia, contrast-enhanced MRI of the brain and spine is frequently done to assess neurologic symptoms.[15] The most important diagnostic procedure for CNS involvement in paediatric leukaemia is cerebral spinal fluid (CSF) cytology. MRI is not commonly prescribed for the evaluation of CNS involvement. While MRI is more typically employed for the evaluation of therapy-related problems, CT without contrast may be utilized to assess acute events (such as cerebral hemorrhage, Dural venous sinus thrombosis, and ischemic stroke).

Complications from the underlying disease (such as hemorrhage or stroke) or from treatment can be observed with MRI (methotrexate toxicity or l-asparaginase toxicity).[16] Asymptomatic paediatric leukaemia survivors frequently have cerebral and cerebellar volume loss, white matter damage and microhemorrhages.[17] After intrathecal dosing, methotrexate toxicity often manifests itself 3–14 days later.[18] Methotrexate toxicity can also be observed after intravenous injection, albeit less frequently.

The patients present with acute neurological deterioration. In order to rule out stroke in leukemic patients, diffusion- weighted images are very helpful in the diagnosis of acute methotrexate toxicity. The lesions associated with methotrexate toxicity are often bilateral, periventricular (including the centrum semiovale and corona radiata), and do not correspond to a single vascular territory, unlike ischemic stroke, which includes a vascular territory. On T2W and FLAIR-weighted MRI sequences, the transitory hyperintense signal is often seen in the white matter at the level of the bilateral centrum semiovale. The subcortical U fibers are spared. On DWI MRI, the identified regions often show reversible signal changes indicative of cytotoxic oedema. These DWI changes are reliable and early manifestations of acute methotrexate-related leukoencephalopathy.

Although it occurs less frequently than acute methotrexate toxicity, Dural venous sinus thrombosis is most usually linked to L-asparaginase treatment. When plasma proteins essential for both coagulation and fibrinolysis are depleted, it might result in cortical infarction, Dural sinus thrombosis, intracerebral hemorrhage or infarctions.[19]Opportunistic infections are more likely to occur during neutropenic times. Leukaemia patients' infections seem the same on imaging as infections found in the general population. As these might be the locations for direct infection extension to the CNS, the Sino nasal areas should be carefully examined.[20]

Brain and spinal MRI can be used to assess bone marrow infiltrates in vertebra and craniofacial bones. Bone marrow signal, cortical expansion, erosions, and soft tissue masses can all be seen on brain MRI and DWI with contrast enhancement.[20] Imaging complications in paediatric leukaemia survivors include mineralizing microangiopathy, one of the side effects of radiation treatment.[21] Hyalinization and fibrinoid necrosis of small arteries and arterioles result from endothelial proliferation and calcium deposition as a side effect of radiation.[22,23] Children who have had radiation therapy and intrathecal methotrexate are generally asymptomatic, although symmetrical calcifications in the basal ganglia and subcortical white matter are seen on CT scans.

AIMS AND OBJECTIVES

Aim: To study the role of MRI in characterization of CNS lesions in diagnosed cases of leukaemia.

Objectives:

Primary: To estimate the quantitative distribution of different CNS findings found on MRI in leukaemia cases.

Secondary:

1.To assess the distribution of leukaemia cases as per age and type.

2.To assess the CNS manifestations as per their time of development (presentation/treatment/relapse) and phase of treatment when they presented (induction/consolidation/maintenance).

3.To assess the site of infiltration in relation to type of leukaemia and treatment phase.

MATERIALS AND METHODS

Study design: Descriptive study
Study type: Observational study
Study period: began after approval of institutional research and review board till september 2022 then it took take another 2-3 months to process the data and write the thesis.
Study universe: department of Radio-diagnosis SMS Medical college, SMS Hospital, JK Loan hospital, State cancer institute, Jaipur, Rajasthan, India

Study population: All leukaemia Patients of medicine and paediatric oncology in SMS Medical college and attached Hospitals.

Inclusion criteria:
1) Proven cases of leukaemia pathologically and referred for MRI
2) Gave consent for the procedure.

Exclusion criteria:
Patients who had pre-existing disease other than leukaemia that might have had CNS complications.

Tool:
Pretested, predesigned, semi structured proforma.

Equipment:
1. MR Imaging was performed using a head coil with the patient in a supine position. All MR Imaging examination were performed on a 3 Tesla Philips ingenia MR system. Slice thickness of 4-5mm with an inter-slice gap of 0.5mm was used.
2. The following MRI sequences were obtained: pre-contrast axial and sagittal T1 weighted, axial and coronal T2 weighted, axial fluid attenuated inversion recovery(FLAIR), diffusion weighted imaging (DWI), susceptibility weighted imaging, gradient recalled echo (SWI/GRE) and post contrast T1 weighted images. b value of 0 and 1000 sec/mm^2 were used for DWI.
3. Water suppressed spectra were acquired from brain localized singles volume of interest (VOIs) by using SE sequence, with TR 1500ms and TE 145ms. The VOI were located within the lesions in focal brain pathologies, and in the centrum semiovale of neurological controls.

Following parameters were used: -

	T1W	T2W	FLAIR	DWI
TR (msec)	400-600	3000-4000	7000-9000	7000-9000
TE (msec)	15-25	100-120	110	110
Matrix	320x320	320x320	320x320	192x192
No of excitations	2	2	2	4
Slice thickness (mm)	5	5	5	5

Methodology-
This study was conducted in department of Radio-Diagnosis SMS Medical College and Hospital in collaboration with department of Pediatrics, Medicine and Oncology. The study comprised of a patient with known case of leukaemia confirmed pathologically After approval of Ethics Committee inclusion and exclusion criteria's were applied.
Written and informed consent was taken in case of an adult and from the Guardian in case of a minor. A thorough history was taken from the patient including all the relevant points and detailed clinical examination was done. MRI was done as per the protocol and films were reviewed by Professor of SMS Radio-Diagnosis department.

Equipment
MR Imaging was performed using a head coil with the patient in a supine position. All MR Imaging examination were performed on a 3 Tesla Philips ingenia MR system. Slice thickness of 4-5mm with an inter-slice gap of 0.5mm was used.
The following MRI sequences were obtained: pre-contrast axial and sagittal T1 weighted, axial and coronal T2 weighted, axial fluid attenuated inversion recovery (FLAIR), diffusion weighted imaging

ISSN 2515-8260 Volume 11 Issue 04, 2024

(DWI), susceptibility weighted imaging, gradient recalled echo (SWI/GRE) and post contrast T1 weighted images. b value of 0 and1000 sec/mm2 were used for DWI.

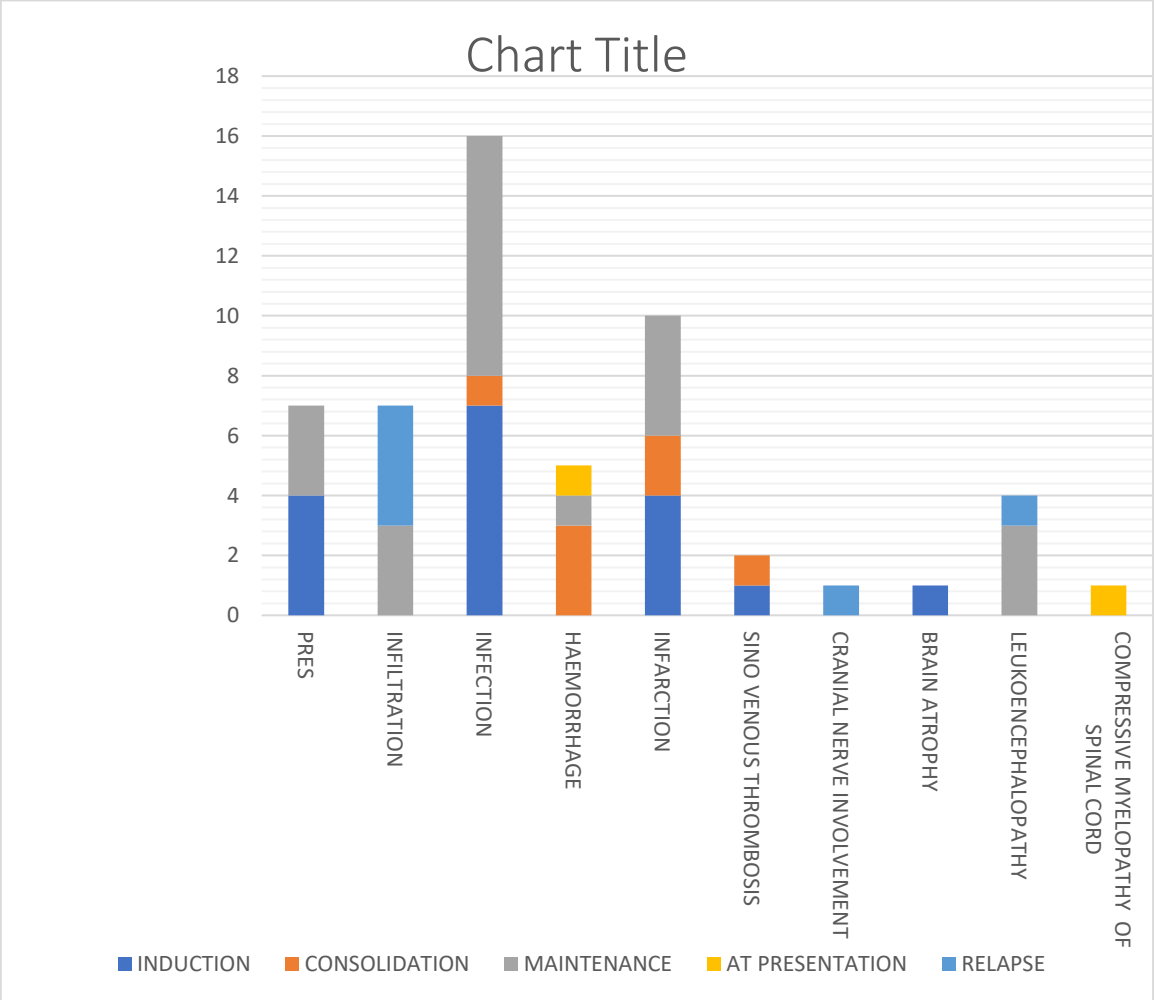
OBSERVATIONS & RESULTS

The study included 70 patients. Their ages at the time of the study ranged from 1 -48 years. Males represented 54 cases (77%), while females represented 16 cases (23%). The patients were classified according to the type of leukaemia into acute lymphocytic leukaemia (ALL), acute myeloid leukaemia (AML), and chronic myeloid leukaemia (CML). There were 64 cases of ALL (91%), 2 cases of AML & 4 cases of CML.

Our patients most frequently experienced headaches, seizures, limb weakness, blurred vision, nausea, vomiting, and fever. Regarding the time of development of CNS manifestations, 60 (87%) of the studied patients had CNS manifestation during treatment phases, 8 patients (12%) were relapsed disease post-end of treatment and 2 patients had CNS symptoms at the time of presentation.

Regarding the phase of treatment at study time, maximum number of cases were seen in induction and maintenance phase. 25 cases (35%) presented at the induction phase, 10 cases (14%), at the consolidation phase while 25 cases (35%) at the maintenance phase.

MR abnormalities among the studied group were collected and classified to posterior reversible encephalopathy syndrome (PRES) 7 cases (10%), infection 16 cases (23%),infiltration 7 cases 10%) ,infarction 10 cases(14%), Sino-venous thrombosis 2 cases, hemorrhage 5 cases,
leukoencephalopathy 5 cases, brain atrophy 1 case, spinal cord compressive myelopathy 1 case and cranial nerve involvement 1 case. (Fig1)



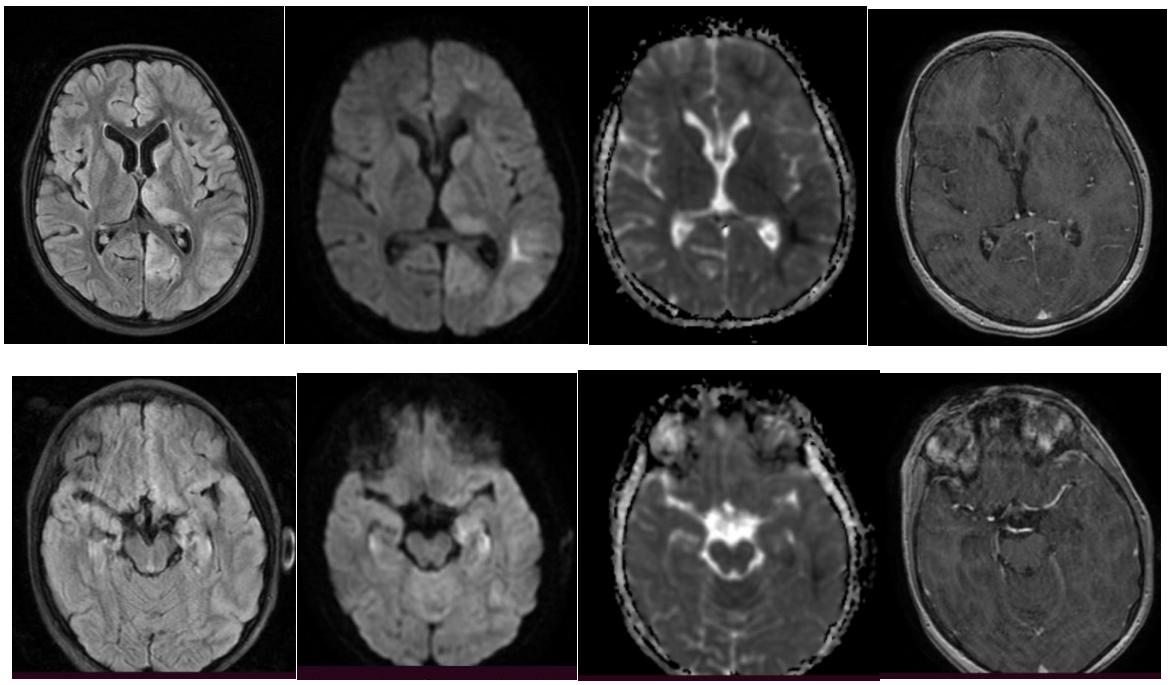
PRES lesions were more commonly seen in induction phase (4 cases,57%) and maintenance phase (3 cases, 43%). PRES lesions were identified in FLAIR images, and their distribution in anatomical regions was made. The most commonly involved typical regions were the occipital lobes, and this was followed by the parietal lobes, frontal lobe.

Hemorrhage was detected in 5 patients; 3 patients were at the consolidation phase, one showed bilateral temporo-parietal hemorrhagic foci, one patient was of PRES with multiple bilateral hemorrhagic foci. One patient was seen in maintenance phase and one patient seen at the time of presentation had multiple parenchymal hemorrhagic foci.
Cerebral venous sinus thrombosis was detected in 2 patients. One case each was seen at the maintenance phase (50%) and at the induction phase (50%). The superior sagittal sinus was transverse sinuses were involved.

Cerebral infection was noted as the most common complication and hence the largest complication among the studied groups. Cerebral infection was seen in 16 cases in form of encephalitis, meningitis and cerebral abscesses, both pyogenic & fungal. 7 cases (43%) were seen in induction phase, 8 cases (50%) in maintenance phase and one case in consolidation phase.
One case in maintenance phase with complaints of fever and altered sensorium presented with status epilepticus. MRI showed hyperintensity on T2/ FLAIR and hypo intensity on T1, mild diffusion restriction and without contrast enhancement seen in left caudate nucleus, thalamus, left posterior parietal region, bilateral para-hippocampal region and cortical region of left temporal lobe suggestive of changes of encephalitis.(Fig 2)

Fig 2

A 7 years old male known case of B-ALL with complaints of fever and altered sensorium presented with status epilepticus



MRI is showing hyperintensity on T2 FLAIR (A,E)and hypo intensity on T1, mild diffusion restriction(B and F are DWI, C and G are corresponding ADC maps) and without contrast enhancement(D and H are T1 weighted post contrast images) seen in left caudate nucleus, thalamus, left posterior parietal region, bilateral para-hippocampal region and cortical region of left temporal lobe suggestive of changes of encephalitis.

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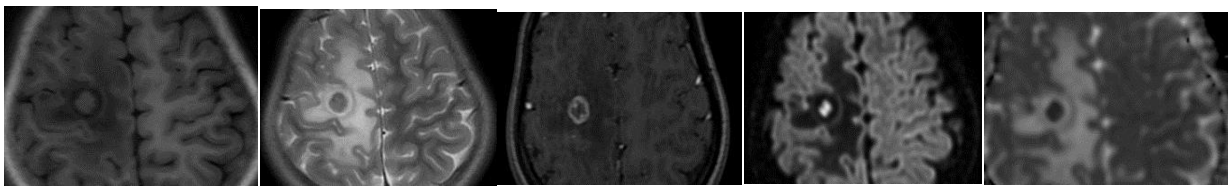
In the current study, two patients developed cerebral abscesses-the first patient a 7 years old male known case of ALL on chemotherapy in induction phase presented with frequent involuntary movements of right upper limb, fever and vomiting. On MRI there was a well- defined, thick-walled lesion in right parietal lobe. The wall was smooth and regular T2 moderately hyperintense, T1 hypointense showing dual rim sign on
FLAIR/T2, ring enhancement on T1 post contrast images, mild blooming on SWI with T2 hypointense center which demonstrated restricted diffusion, no diffusion restriction in peripheral rim on DWI. There was perilesional vasogenic oedema. (Fig 3)

Fig 3

A 7 years old male known case of ALL on chemotherapy in induction phase presented with frequent involuntary movements of right upper limb, fever and vomiting



A B C D E

On MRI there was a well-defined, thick-walled lesion in right parietal lobe. The wall was smooth and regular T2 moderately hyperintense,(B) T1 hypointense (A) ring enhancement is seen on T1 post contrast images (C), which demonstrated restricted diffusion(D is DWI while E is corresponding ADC map) no diffusion restriction in peripheral rim on DWI. There is

perilesional vasogenic oedema. Dual rim sign was seen on T2 WI and SWI, comprising two concentric rims surrounding the abscess cavity, the outer one was hypointense, and the inner one was hyperintense. Histopathologically, the outer T2 hypointense rim is the capsule of abscess in which the production of paramagnetic free radicals by macrophages results in magnetic susceptibility. The granulation tissues between the necrotic center and capsule are responsible for the hyperintense inner rim. Imaging features suggest pyogenic abscess.

Dual rim sign was seen on T2/FLAIR/SWI, comprising two concentric rims surrounding the abscess cavity, the outer one hypointense, and the inner one was hyperintense. Multivoxel MR Spectroscopy with voxel placed in center of the lesion reveals mildly reduced NAA peak, markedly increased choline, lipid-lactate peak, no peak at 3.6mm was noted to suggest fungal etiology. Imaging features were suggestive of pyogenic brain abscess.
In the second case a 12 years old male known case of ALL on chemotherapy, consolidation on hold presented with left hemiparesis, facial palsy, otomycosis, mastoiditis and vomiting. MRI images showed a lesion in right fronto-parietal zone with marked surrounding T2 hyperintense area (perilesional oedema) causing effacement of ipsilateral sulci, cisterns and ventricles with midline shift to left side. The lesion showed T2 isointense, irregular, crenated wall with contrast enhancement and diffusion restriction while the center of the lesion was predominantly T2 hyperintense, T1 hypointense with no diffusion restriction. No blooming was seen on SWI images. Similar lesion was also seen in left basal frontal lobe. Imaging features suggested fungal abscess. Galactomannan test in the serum was positive.
This case improved with antifungal treatment and showed reduction in number and size of abscesses as well as clinical improvement till date.

COMPLICATIONS	INDUCTION	CONSOLIDATION	MAINTENANCE	AT PRESENTATION	RELAPSE
PRES	4	0	3	0	0
INFILTRATION	0	0	3	0	4
INFECTION	7	1	8	0	0
HAEMORRHAGE	0	3	1	1	0
INFARCTION	4	2	4	0	0
SINO VENOUS THROMBOSIS	1	1	0	0	0
CRANIAL NERVE INVOLVEMENT	0	0	0	0	1
BRAIN ATROPHY	1	0	0	0	0
LEUKOENCEPHALOPATHY	0	0	3	0	1
COMPRESSIVE MYELOPATHY OF SPINAL CORD	0	0	0	1	0

Leukemic infiltration was seen in 7 cases. As regards to the site of infiltration, the MRI findings were classified as retinal, meningeal, orbital, skull, and maxillofacial bone infiltration. 3 cases were seen in maintenance phase (43%) while 4 case were seen in relapse phase (57%)
In one case a 5 years old male known case of ALL presented with left proptosis and difficulty in vision. MRI findings showed left proptosis, subacute vitreous hemorrhage and hyphema. Left globe also showed organized hematoma with choroidal detachment and enhancing thickening of left eye coat with heterogeneously enhancing thickening around the globe in posterior aspect and surrounding intra as well as extraconal retro orbital fat stranding. Left optic nerve was thickened with heterogenous perineural as well as intraneural enhancement suggestive of leukemic infiltration.
One case with enhancing bilateral orbital masses at presentation proved by biopsy as leukemic infiltration. Two cases with skull bones and maxillofacial bone infiltration showed enhancement on post contrast images.
Leukoencephalopathy was detected in 5 cases, 3 cases (60%) in maintenance phase while one case each was seen in induction phase and post-relapse. The case in maintenance phase showed a periventricular sheet of a high signal at FLAIR images. Atrophic brain changes were detected in 1 case along with hydrocephalus and had prominent cerebral ventricle, extra axial CSF spaces, and mild volume loss.

One case of compressive myelopathy was seen at presentation in a 20 years old female diagnosed as a case of ALL came with complaints of heaviness and numbness in bilateral lower limbs. MRI images revealed T2 slightly hyperintense posterior epidural lesion from D4-D7 vertebral levels pushing and compressing the spinal cord. The lesion shows homogenous post contrast enhancement. MRI findings were suggestive of compressive myelopathy related to ALL. These were similar to the Findings seen by Elpis Mantadakis et al.[24] and Albert Jang et al.[25] 20 patients, even though they were symptomatic in our study, did not reveal any findings in MRI.

DISCUSSION

Leukaemia is one of the most frequent types of childhood cancer. Because leukaemia is a deadly illness, central nervous system problems were uncommon for a long time. Although breakthroughs in imaging technologies and treatment procedures have boosted survival, the prevalence of CNS problems has grown. CNS problems of leukaemia are divided into those that are caused directly or indirectly by the underlying leukemic process and those that are caused by therapeutic side effects. We prospectively evaluated the Central nervous system (including brain, orbit and spine) MRI of 70 patients proved with leukaemia ranging in age from 1 to 48 years and having CNS manifestations. Male represented 77% in our study, while females represented 23%. ALL represented 91% of our

cases, while AML represented 3% and CML represented 6%. This was consistent with earlier research by Verma et al.[26]and Terwilliger et al. [27] that claimed ALL is the most frequent type of leukaemia.

Cerebral infection was identified as the most prevalent complication among the tested groups. Cerebral infection was found in 16 patients as encephalitis, meningitis, pyogenic and tubercular cerebral abscesses. Seven cases (43 percent) were found during the induction phase, eight cases (50 percent) during the maintenance phase, and one case during the consolidation phase. Pyogenic abscesses go through the stages of early cerebritis, late cerebritis, early capsular, and late capsular development. Pyogenic abscesses are visible as T1 hypointense and T2 hyperintense regions with limited or non-homogenous enhancement during the cerebritis stage.

Tuberculous cerebritis is characterized by an ill-defined, hypoattenuated region characterized by gyral enlargement. Lesions caused by fungal cerebritis are non-enhancing and frequently seen in the basal ganglia and deep white matter. In mature pyogenic and fungal abscesses, peripheral rim enhancement has been described. The etiology of a brain abscess can't be determined using standard MR findings in both the cerebritis and abscess stages of development of an abscess.

In our research, both individuals with brain abscesses also had sinusitis. Previous clinical research by Marzolf et al[28] and Gartner et al[29] advised that doctors should rule out concurrent lung or sinus infections.

In our study, vascular disorders were the most common group of complications (34%), of which 2 patients (2.9%) had Sino-venous thrombosis, 7 patients (10%) had PRES, and 5 patients (7.2%) had a parenchymal hemorrhage, 10 patients (14.3%) showed infarcts.

In both the induction phase (50 percent) and the maintenance phase, cerebral venous sinus thrombosis was seen (50percent). The induction phase was when venous thrombosis was most common, according to Malhotra et al.[30] and Porto et al.[31]. Both studies discovered that the induction and maintenance phases of L -asparaginase therapy were characterized by a high prevalence of venous sinuous thrombosis. Due to the depletion of plasma proteins involved in coagulation and fibrinolysis caused by L-asparaginase therapy, cerebrovascular issues such Dural sinus thrombosis, cortical infarcts, Intra cerebral hemorrhage and hemorrhagic infarcts have been documented to occur. Leukocytosis, thrombocytopenia, sepsis, and coagulopathy are side effects of antileukemic treatment that might result in cerebral vascular thrombosis or haemorrhage.[31] This explains the Sino venous thrombosis that occurred in one of our patients during the consolidation period, which seemed to have very little to do with L-asparaginase treatment. The combination of MR and MRV, according to several studies[32,33] is now the preferred technique because it may detect the lack of cerebral vein flow even in the absence of the classic signs of brain infarcts. When the thrombus is in the acute phase, MRV can show it by the absence of flow, which conventional scans can misinterpret as blood flow.

The clinical symptoms of PRES, which is a clinico-neuro-radiologic condition with specific MR imaging findings. Symptoms include headache, altered mental state, seizures, visual loss, and unconsciousness. In the current study, most cases diagnosed with PRES (4 cases, 57%) were detected early in the induction phase, while 3 cases (43%) in the maintenance phase. This finding was in concordance with reports from Bianca et al. [34] and Raman[35] that incidents of PRES frequently occur early in the induction period. The posterior parts of the brain, specifically the occipital and posterior parietal regions, as well as the frontal regions, were the most often damaged brain regions in the current study, per the MRI studies. This was in line with the results of the study carried out by Appachu et al.[36] and with those of earlier investigations by Raman[35], Kastrup et al.[37], and McKinney[38]. Blood pressure can be normal even though hypertension is a risk factor for PRES, particularly when chemotherapy and immune suppressive treatments are being used[35].

In the present study, we had 5 cases with hemorrhage, 3 patients were at the consolidation phase, one showed bilateral temporo-parietal hemorrhagic foci, one patient was of PRES with multiple bilateral hemorrhagic foci. One patient was seen in maintenance phase and one patient seen at the time of presentation had multiple parenchymal hemorrhagic foci seen on SWI sequences. This was in keeping with research done by Charidimou[39] that found the development of blood-sensitive MRI sequences,

such as T2*-GRE and susceptibility-weighted imaging (SWI), has made it possible to identify brain microbleeds reliably (defined radiologically as small, rounded, homogeneous, hypointense lesions not seen with conventional spin-echo sequences). Additionally, Beavers et al study [40] claimed that GRE scans were the most sensitive for spotting retinal hemorrhages.

Leukemic infiltration was seen in 7 cases. As regards to the site of infiltration, the MRI findings were classified as retinal, meningeal, orbital, and cranio-facial bone infiltration.
3 cases were seen in maintenance phase (43%) while 4 case were seen in relapse phase (57%). In our study, infiltration was seen in cases with ALL. CNS involvement in AML patients is significantly less prevalent than CNS involvement in acute lymphoblastic leukaemia (ALL) in both adults and children, according to studies by Charles et al. [41] and Del Principe et al. [42].
In one case MRI findings showed left proptosis, subacute vitreous hemorrhage and hyphema, left globe organized hematoma with choroidal detachment and enhancing thickening of left eye coat with heterogeneously enhancing thickening around the globe in posterior aspect and surrounding intra as well as extraconal retro orbital fat stranding, Left optic nerve thickening with heterogenous perineural as well as intraneural enhancement suggestive of leukemic infiltration.
One case with enhancing bilateral orbital masses at presentation proved by biopsy as leukemic infiltration. Two cases (18%) with skull bones and maxillofacial bone infiltration showed enhancement on post contrast images and diffusion restriction. This was in line with research done by Eisa [43] and Cao et al. [44] that found that MRI with DWI is an effective and non-invasive method for identifying infiltrations of skull bones in ALL patients before to treatment as well as the diagnosing remission of marrow signal following medications. In one case, meningeal infiltration was found. The patient had enhancement of Dural thickening and subdural collection, which was classified as inflammatory or infiltration. subsequently blast cells were found in the CSF by cytology.

Leukoencephalopathy was detected in 4 cases, 3 cases in the maintenance phase, while one case presented in relapse phase, presented by a periventricular deep white matter sheet of high FLAIR signal. All cases had no history of cranial irradiation.
One case of compressive myelopathy was seen at presentation in a 20 years old female diagnosed as a case of ALL came with complaints of heaviness and numbness in bilateral lower limbs. MRI images revealed T2 slightly hyperintense posterior epidural lesion from D4-D7 vertebral levels pushing and compressing the spinal cord. The lesion showed homogenous post contrast enhancement. MRI findings were suggestive of compressive myelopathy related to ALL. These were similar to the Findings seen by Elpis Mantadakis et al[24]. and Albert Jang et al[25]. Most of the cases of spinal cord compression related to ALL are seen in paediatric population, and as seen in our study this is a rare case. All cases written in literature showed clinical improvement with chemotherapy.
Brain atrophy features with a large cerebral ventricle, extra axial CSF spaces, and a mild volume loss were seen in one case of hydrocephalus. According to research by Porto et al., atrophy of the brain was thought to be a post-irradiation result associated with a diffuse white matter damage [31].

CONCLUSION

The extensive range of CNS complications that can arise during and after leukaemia therapy are linked to both the disease and the therapy. Early diagnosis is crucial because many neurologic manifestations of leukaemia are treatable.
In leukaemia patients, MRI is a helpful modality for the early diagnosis of CNS complications. By identifying treatment-related adverse effects early on, it helps doctors regulate anti-leukaemia therapy. The early identification and characterization of various CNS lesions found in patients with leukaemia and CNS complications related to therapy is greatly aided by the use of diffusion-weighted MRI in conjunction with MR venography, and conventional and post-contrast MRI.

The presenting symptoms of the neurological manifestations of leukaemia are similar, however a wide range of abnormalities are seen on MRI. Along with the radiologic evidence, the proper diagnosis must take into account the patient's presenting symptoms, signs, and laboratory data.

Abbreviations

CNS-central nervous system; ALL-Acute lymphoblastic Leukaemia; AML- Acute myloblastic Leukaemia; MRI- Magnetic Resonance Imaging; DWI: Diffusion-weighted imaging; ADC: Apparent diffusion coefficient; PRES: Posterior reversible encephalopathy syndrome; MTX: Methotrexate

Acknowledgments

We appreciate the help given by all the staff of radiodiagnosis, pediatrics and oncology

Authors' contributions

AT wrote the manuscript and collected the patient data and is responsible for the correspondence to the journal. AB and KM is the author of the research idea. MA participated in the design and review of the study. SB participated in the design and review of the study. AT read and approved the final manuscript.

Funding

Not applicable.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was approved by the Department of Radiology, SMS Medical College, Jaipur, Rajasthan, Medicine Research Ethics Committee, Rajasthan university of health sciences. A written consent was obtained from each child's guardian involved in this research before performing the study.

Consent for publication

Images included in the study are entirely unidentifiable, and there are no details on individuals reported within the manuscript.

Competing interests

The authors declare that they have no competing interests.

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