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Original Article

Incremental Role of Spinal Diffusion-Weighted Imaging in the Detection of Leptomeningeal Metastasis for Pediatric Intracranial Malignancies: Results from a Prospective Study

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Abstract

Background Screening for leptomeningeal disease (LMD) in pediatric brain tumors on the magnetic resonance imaging protocol is often limited by artifacts, making diagnosis challenging.

Objectives To prospectively evaluate the incremental role of diffusion-weighted imaging (DWI) in screening of LMD in pediatric brain tumors.

Materials and Methods This prospective study included pediatric patients with primary brain tumors having a propensity for cerebrospinal fluid (CSF) metastasis. The spine was screened with T2-weighted (T2W), DWI, and post-contrast T1W (T1W PC) sequences, and LMD was confirmed with CSF analysis and follow-up.

Results The study included 69 patients. LMD was positive in 27 patients and 105 lesions. Smooth LMD was detected in 18 patients on T1W PC. Out of 85 nodular LMD lesions, 81 were detected on DWI. Six lesions on the T1W PC and 16 on T2W were false positives (artifacts). The sensitivity and specificity were: for T1W PC: 93 and 86%; T2W: 63 and 62%; and for DWI: 63 and 100%. The combined sensitivity, specificity, positive predictive value, and negative predictive value of all three sequences were 93, 100, 100, and 95%.

Conclusion The T1W PC sequence is the most reliable sequence for detecting LMD. Using DWI in conjunction with T1W PC and T2W excludes artifacts, resulting in a higher specificity.

Keywords
- leptomeningeal metastases
- pediatric brain tumors
- diffusion-weighted imaging

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Introduction

Brain tumors are the most common pediatric solid tumors, with an overall incidence being around 6.2 per 100,000 individuals.[1] Many pediatric brain tumors show cerebrospinal fluid (CSF) metastasis. These include medulloblastoma, ependymoma, atypical teratoid rhabdoid tumor (ATRT), embryonal tumor with multilayered rosettes (ETMR), germinoma, pediatric-type diffuse high-grade gliomas, pineoblastoma, choroid plexus carcinoma (CPC), etc.[2,3] Among these, medulloblastoma is the most common pediatric malignant brain tumor, and CSF metastasis is seen in 20 to 35% of patients with medulloblastoma at presentation.[4,5] Detection of spinal metastasis is crucial, as it alters prognosis and leads to more intensive treatment protocols.[6,7] The presence of metastatic disease across all the tumor histologies is generally associated with a dismal prognosis. Also, detecting metastasis in embryonal tumors during initial diagnosis changes the risk stratification, and the patients are treated with more intensive regimens. Currently, spinal metastases are diagnosed using CSF cytology and contrast-enhanced magnetic resonance imaging (MRI). False-negative results are as high as 45% for CSF cytology and 30% for gadolinium-enhanced MRI (particularly in the setting of microscopic disease).[8,9] High-resolution imaging techniques like Constructive interference in steady state (CISS)/ Balanced fast field echo sequence (BFFE)/ Fast imaging employing steady-state acquisition (FIESTA) are also performed; however, they are not a part of the essential protocol.[10–12]

Interpretation of spinal MRI (T1W, T2W, and T1W PC) for the detection of metastatic dissemination can be challenging due to artifacts and equivocal findings, particularly in the postoperative setting.[9,13] Many of the primary brain tumors that show a propensity for spinal metastasis have a hypercellular tumor matrix and hence show diffusion restriction.[14] Diffusion-weighted imaging (DWI) can be used to confirm lesions suspicious on routine imaging sequences. Currently, DWI has a complementary role to play in the detection of recurrence in the brain, particularly in embryonal tumors.[15,16] Metastasis of primary central nervous system tumors may show a matching pattern, a mismatching pattern, or a reverse mismatching pattern.[5] This study aimed to evaluate the additional value of spinal DWI in detecting leptomeningeal metastasis in pediatric brain tumors.

Materials and Methods

Study Design and Setting

This was a prospective observational pilot study conducted at a tertiary cancer center from July 2020 to October 2021. Since it is a pilot study, convenience sampling was done, including all patients fitting the inclusion criteria, for a period of 10 months following ethics committee approval.

Objectives

- Primary: To evaluate if DWI of spine has an incremental value as compared to other routine imaging sequences.
- Secondary: To characterize the patterns of metastatic lesions as match (restricting and enhancing), mismatch (restricting and nonenhancing), or reverse mismatch (no restricting and enhancing).

Inclusion Criteria

- Pediatric brain tumors (<18 years) with a propensity toward CSF dissemination were included in the study: embryonal tumors (like medulloblastoma, ATRT, and ETMR), supratentorial ependymoma, intracranial germ cell tumors, and high-grade gliomas, including diffuse midline gliomas, high-grade pineal tumors, and CPC.

Exclusion Criteria

- Primary pediatric brain tumors that do not show diffusion restriction and are not known to have cranio-spinal metastasis were excluded.
- Patients lost to follow-up.
- Those with no lesion detected on routine sequences and CSF studies.

Expected Outcomes

Primary: Sensitivity and specificity of spinal DWI in detecting leptomeningeal disease (LMD).

Secondary: Evaluate the diagnostic accuracy (positive predictive value [PPV], negative predictive value [NPV]) and characterize lesion patterns on DWI.

Materials and Methods

Imaging was done on the Philips Ingenia 1.5 T MRI (Amsterdam, The Netherlands). For children who were unable to cooperate, MRI was done under general anesthesia. MRI of the brain was performed using T1W, T2W, T1W PC (post-contrast), fluid-attenuated inversion recovery (FLAIR), DWI, and GRE (gradient echo) in various orthogonal planes. Sequences for spine imaging were also obtained: T1W, T2W, T1W PC, and DWI (at *b*-values of 0 and 600) in the sagittal plane, and additional axial images, as applicable on an individual basis, were acquired at the level of the suspicious lesion. The parameters are provided in ►**Supplementary Table S1**.

MRI imaging features of each patient from the hospital Picture Archiving and Communication System (PACS) database were assessed. All the images were initially assessed by a single neuroradiologist with 10 years of experience and later verified by another neuroradiologist (who was not blinded to the interpretation provided by the first person). In case of discrepancies in the findings between the two radiologists, a consensus opinion was obtained by discussion with a separate radiologist. Since it was a prospective study, the clinical status was known and the radiologist was not blinded to it; however, CSF analysis was generally performed after imaging. Lesions were classified as smooth or nodular (►**Figs. 1** and **2**). Leptomeningeal metastasis was categorized as nodular if the measurement was possible in two dimensions. The size of the lesion was measured on the T1W PC image. The location and specific vertebral level of the metastatic lesions were noted. Imaging characteristics of the metastatic lesions were documented and categorized into three groups (match, mismatch, or reverse mismatch group).

The baseline demographic details, including age, clinical symptoms, and previous course of the disease, were recorded

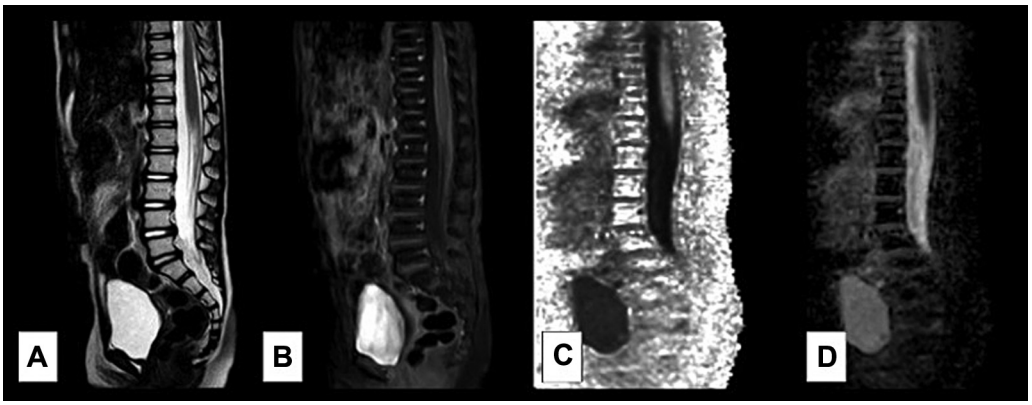

Fig. 1 Smooth leptomeningeal metastasis: case of SHH medulloblastoma in a 5-year-old child shows linear enhancement along the cauda equina on post-contrast image (**B**). This is not appreciated on T2W (**A**) and diffusion images (**C, D**). SHH, Sonic Hedgehog; T2W, T2-weighted.

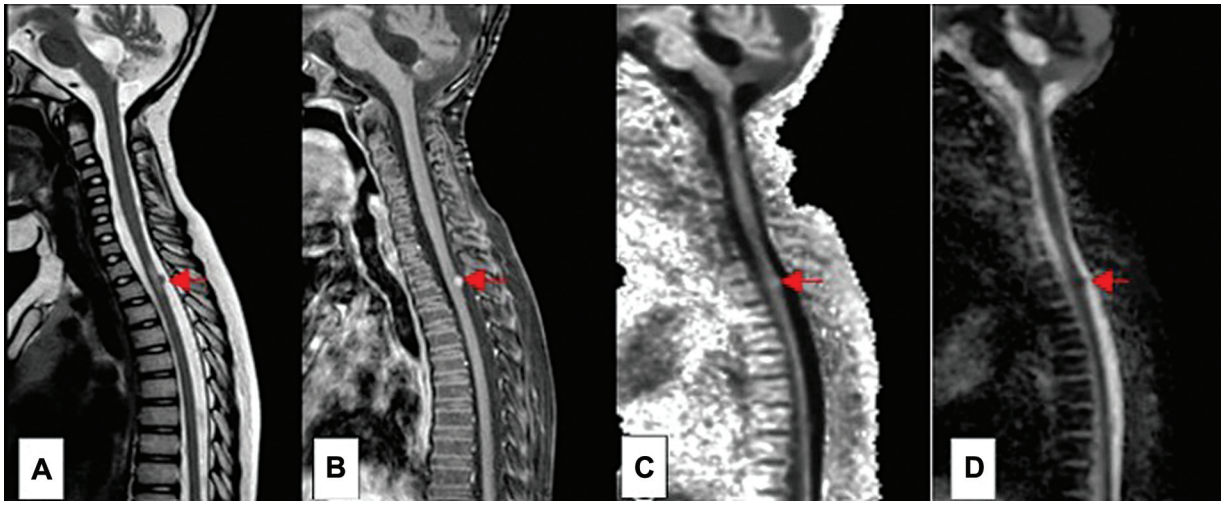

Fig. 2 Nodular leptomeningeal metastases: case of group IV medulloblastoma in an 11-year-old child shows a nodular lesion on the posterior aspect of the spinal cord at the D2 level measuring 7 mm. It is intermediate on T2W (**A**), enhancing on post-contrast image (**B**), and shows diffusion restriction (**C, D**). T2W, T2-weighted.

using electronic medical records. The patients were managed according to the standardized institutional protocols. The status of the lesions was documented on a follow-up MRI (obtained every 6 months, and in case of any new clinical complaints/suspicion, earlier scans were obtained as per the discretion of the treating physician).

Additional lesions were documented separately. Confirmation of spinal metastasis was based on the results of CSF studies, clinical and radiological follow-up, and decisions in JNOM (Joint Neuro-oncology Meetings). In cases where CSF studies were not available, patients with no suspicious findings on index and follow-up MRI scans and no clinical suspicion of spinal metastases on follow-up were categorized as having absent spinal metastases. If suspicious lesions were seen on MRI on any sequence, a follow-up scan (short-term follow-up scan at 6 weeks), CSF studies, and a decision were used to establish the final diagnosis.

To analyze the incremental value of DWI, the sensitivity, specificity, PPV, and NPV of T2W, T1WPC, and DWI were calculated individually and for conventional imaging. The nodular lesions detected were categorized into the match (enhancing and restricting), mismatch (nonenhancing and restricting), and reverse mismatch (enhancing and non-restricting) groups.

Statistical Analysis

Demographic data were analyzed and summarized with descriptive statistics, and categorical data were represented in the form of frequency and percentage. The efficacy of DWI incremental value was analyzed using McNemar's test since the data were paired and categorical. Metastatic lesions were summarized as match (restricting and enhancing), mismatch (restricting and nonenhancing), or reverse mismatch (no restricting and enhancing) using frequency and percentage. A p-value <0.05 was considered to be significant and statistical analysis was performed using SPSS (IBM Corp), version 20.

Ethical Approval

The study was approved by the Institutional Ethics Committee (Project number: 3443) on June 15, 2020. Waiver of consent was approved as the study involves less than minimal risk. All procedures performed in studies involving human participants were in accordance with the ethical standards of the

Table 1 Distribution of leptomeningeal metastases according to histology, disease setting, location, and status of primary disease in the brain

Features	Patients	Lesions
Histology		
Medulloblastoma	38 (55%)	15 (56%)
Ependymoma	12 (17%)	5 (19%)
Atypical teratoid rhabdoid tumor	2 (3%)	1 (4%)
Germinoma	3 (5%)	0 (0)
Glioblastoma	5 (7%)	2 (7%)
Pineoblastoma	8 (12%)	4 (15%)
Choroid plexus carcinoma	1 (1%)	0 (0)
Disease setting		
During adjuvant treatment	27 (39%)	8 (30%)
Immediate postoperative	19 (28%)	10 (37%)
Surveillance	19 (28%)	5 (18%)
Baseline	4 (5%)	4 (15%)
Status of primary disease in brain		
Preoperative	4 (6%)	4 (15%)
Residual or recurrent disease	28 (41%)	16 (60%)
No measurable disease	37 (53%)	7 (37%)

institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Results

Demographic and Clinical Characteristics

The study included 69 patients. The median age of the cohort was 9 years (range 0–18 years). In this study, 38 (55%) patients had medulloblastoma, 12 (18%) patients had ependymoma, 8 (12%) had pineoblastoma, 5 (7%) had pediatric-type diffuse high-grade gliomas, 3 (6%) had germinoma, 2 (3%) had ATRT, and 1 (1%) had CPC (►**Table 1**). There were 27 patients with CSF dissemination (39%), based on cytology and follow-up information, with the most common histology being medulloblastoma (56%), followed by ependymoma (19%), pineoblastoma (15%), and others. Of the total cases with CSF dissemination, 27 (39%) were receiving treatment, 19 (28%) were postoperative, 19 (28%) were on follow-up, and 4 (5%) were at baseline (►**Table 1**). Of the total patients, 19 (28%) had a previous history of recurrence or metastasis. Among the positive cases, eight (30%) had a previous history of recurrence or metastasis. Of the 27 positive cases, only 4% had clinical symptoms indicating spinal metastasis during the time of index MRI. Of the total cases included, 37 (53%) were postoperative and had no gross residual disease in the brain, 28 (41%) were postoperative and had measurable disease in the brain, and 4 (6%) were preoperative (►**Table 1**). Of the total positive cases, 16 (60%) were postoperative and had measurable disease in the brain, 7 (37%) were postoperative and had no gross residual disease in the brain, and 4 (15%) were preoperative (►**Table 1**).

Table 2 Distribution of lesions according to location along the spinal cord

Distribution of lesions according to location	Number of patients
Cervical	22 (26%)
Thoracic	42 (49%)
Lumbar	16 (19%)
Sacral	5 (6%)

Pattern of LMD

At least one follow-up MRI was available in 54 of 69 patients. The total number of lesions was 105, with a median number of lesions of 4 (range: 1–17) per patient. Among the 27 patients with LMD, 7 had only nodular lesions, 7 had only smooth lesions, and 13 had both. Lesion-wise, 20 were classified as smooth LMD, while 85 were nodular. The spinal metastatic disease varied from smooth leptomeningeal enhancement and thicker leptomeningeal coating to nodular extra-medullary deposits. Of the total patients with nodular leptomeningeal metastasis, 22 (26%) were at the cervical level, 42 (49%) at the thoracic level, 16 (19%) at the lumbar level, and 5 (6%) at the sacral level (►**Table 2**).

Imaging Features

Of the patients with LMD, T2W, T1WPC, and DWI were positive in 21, 25, and 21 patients, respectively, representing 98, 121, and 82 lesions. The sensitivity, specificity, PPV, and NPV for various sequences are summarized in ►**Table 3**. Using T2W sequences, the sensitivity and specificity for the detection of spinal metastasis were 63 and 62%, respectively. Using T1W PC, it was 93 and 86%, respectively. Combined use of conventional sequences (T2W and T1W PC) yielded the sensitivity and specificity of 93 and 62%, respectively. Using DWI, it was 63 and 100%.

The sensitivity and specificity for the detection of smooth leptomeningeal metastases with post-contrast imaging were 91 and 96%, respectively. The PPV and NPV were 100 and 96%, respectively. Of the 20 patients with nodular leptomeningeal metastases, there was a total of 85 nodular deposits with a maximum of 17 nodular deposits in a single patient. For conventional sequences, the sensitivity and specificity for the detection of nodular leptomeningeal were 100 and 90%, respectively. The PPV and NPV were 93 and 100%, respectively. For DWI, it was 95 and 100% respectively, and the PPV and NPV were 100 and 94%, respectively.

Summary of Results

A total of 69 patients were included in our study over 14 months. Of these, spinal metastases were seen in 27 patients with 7 showing the smooth type, 7 showing the nodular type, and 13 showing mixed types. Of the total 20 patients with smooth leptomeningeal metastases, only one lesion was detected on T2W and diffusion sequence, indicating that diffusion has a limited role in the detection of smooth leptomeningeal metastases. Of the 20 patients

Table 3 Sensitivity, specificity, and predictive values for each sequence in the detection of leptomeningeal metastases

Sensitivity, specificity, and predictive values of T2W, PC, and DWI for LMD				
Study/sequence	**Sensitivity**	**Specificity**	**PPV**	**NPV**
T2W	63	62	52	72
T1W-PC	93	86	81	95
DWI	63	100	100	81
Combined (T2W + T1W PC + DWI)	93	100	100	95

Abbreviations: DWI, diffusion-weighted imaging; LMD, leptomeningeal disease; NPV, negative predictive value; PC, post-contrast; PPV, positive predictive value; SHH, Sonic Hedgehog; T1W, T1-weighted.

with smooth leptomeningeal enhancement, none of the patients had a recent (within 4 weeks) history of surgery or any form of instrumentation. Of the 85 nodular lesions that were detected on the T1W PC sequence, four lesions were not detected on diffusion-weighted as well as T2W sequence. These four lesions were seen in four separate patients and all four patients had multiple other nodular deposits seen on all three sequences. The sizes of all four lesions were less than 2 mm and they were seen in the cervical, thoracic, and lumbar regions. The smallest lesion detected by diffusion sequence was 2.4 mm in our study.

In our study, 16 patients had suspicious lesions on T2W sequences (►**Fig. 3**). Out of these, lesions were seen on T1W PC imaging in six patients (►**Fig. 4**). The rest of the lesions of the patients were classified as artifacts based on T2W and T1W PC sequences. None of these lesions was seen on DWI. All these patients were discussed in JNOM and their lesions were regarded as artifacts (either vessel-related or flow-related). The details of the patients who were diagnosed as having artifacts are elaborated in ►**Supplementary Table S2**.

Of the 27 patients with CSF dissemination, CSF studies were available in 18 patients at the time of index MRI. Of these 18 patients, CSF cytology was positive in 4 patients only. Of the total 91 nodular lesions detected on T1W PC, 85 showed a match pattern and 6 showed a reverse mismatch pattern. None of the lesions showed a mismatch pattern. The six lesions showing reverse mismatch patterns were classified as artifacts. Thus, all the true metastatic lesions showed a match pattern.

Discussion

DWI of the brain has proved useful in the evaluation of hypercellular brain tumors, which show diffusion restriction.[17,18] Many of the brain tumors that show a propensity for spinal metastases have a hypercellular matrix and thus

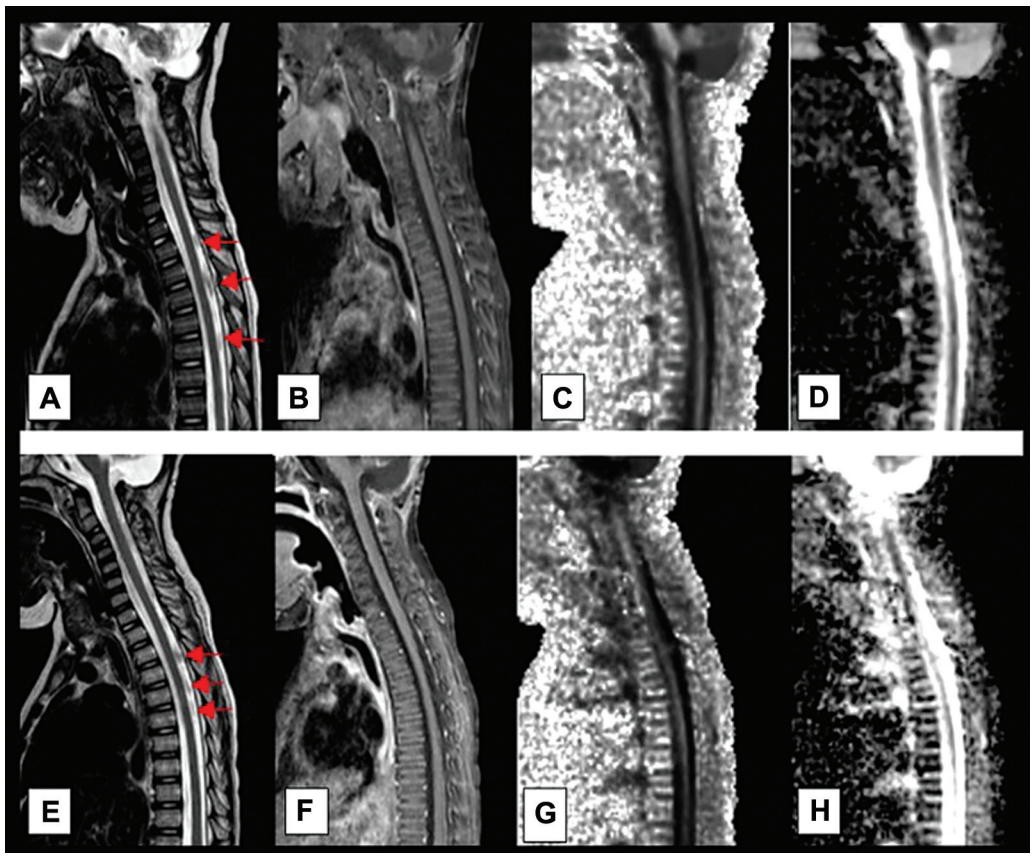

Fig. 3 Artifact seen on T2W: case of group 4 medulloblastoma in an 8-year-old shows T2 hypo-intensities on sagittal T2W sequence (**A**) in the posterior thecal sac at the level of D4–D6 vertebrae, which were not seen on post-contrast (**B**) and diffusion-weighted sequences (**C, D**). These were regarded as flow artifacts and the child received no treatment. Follow-up scan after 9 months shows similar hypo-intensities on T2W (**E**), but in a different location, which were not seen on post-contrast (**F**) and diffusion-weighted sequences (**G, H**). T2W, T2-weighted.

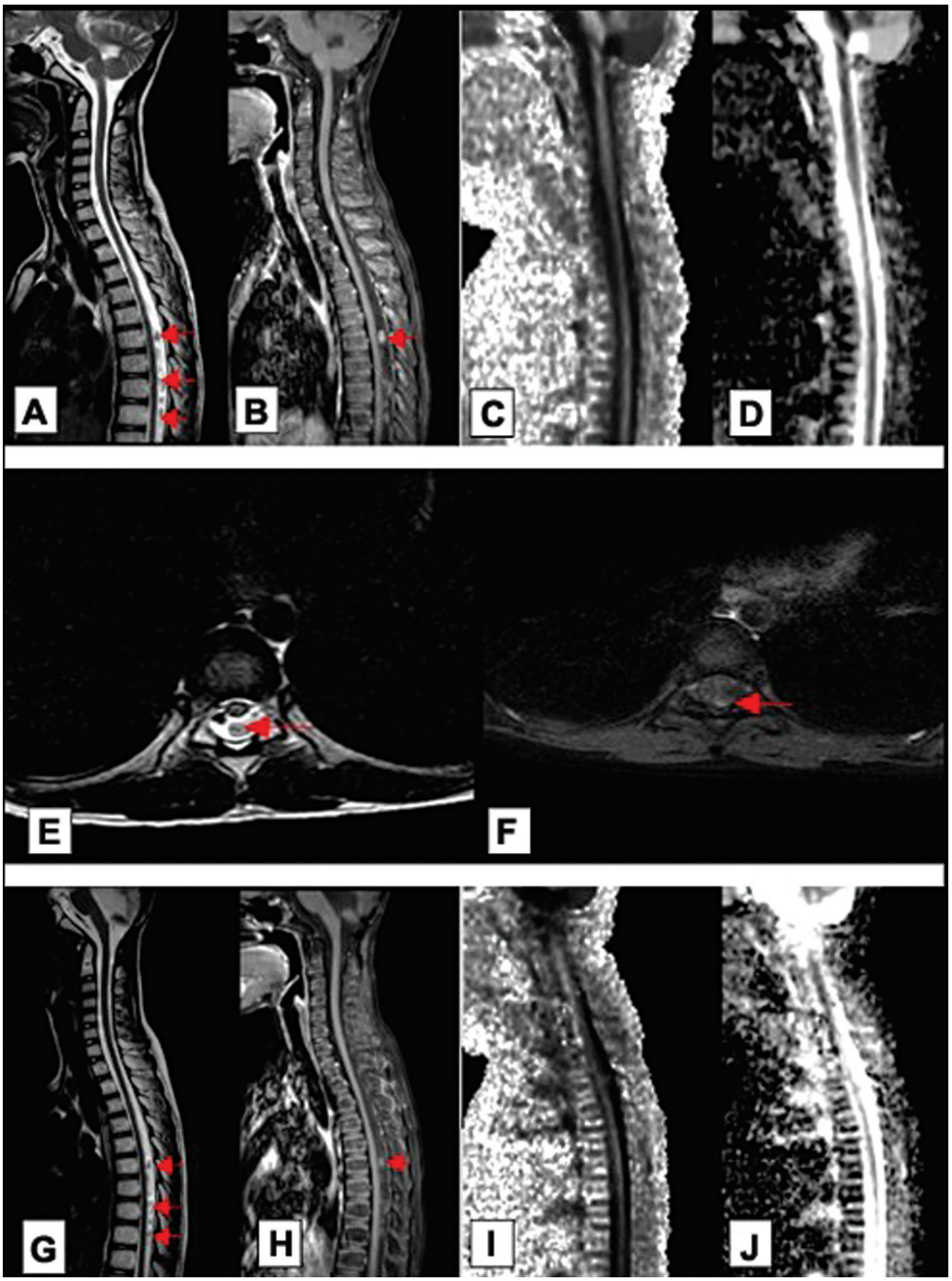

Fig. 4 Artifact seen on T2W and T1w post-contrast sequences: case of SHH medulloblastoma in a 14-year-old child shows T2 hypo-intensities on T2W sequences (**A**) in the posterior thecal sac at the level of the D6–D9 vertebrae, which were also seen on the post-contrast sequence (**B**), and on axial sections on T2W (**E**) and post-contrast sequences (**F**), but not seen on diffusion sequences (**C, D**). Follow-up scan after 3 months shows persistent altered signal intensities on T2W (**G**) and post-contrast scans (**H**), not seen on diffusion (**I, J**). These lesions were considered metastases and the child was given systemic chemotherapy. However, these were persistently seen on follow-up scans done after 2 years and were concluded to be flow-related artifacts.

show diffusion restriction.[14] Our study demonstrates the role of the DWI spine in characterizing the suspicious lesions picked up on other conventional MRI sequences. Currently, imaging and CSF analysis are considered gold standards in the diagnosis of LMD. However, CSF cytology is often falsely negative and imaging findings are often inconclusive.[6,19] International imaging recommendations (RAPNO and COG working group) state that T1W PC spine imaging is required as part of the essential protocol.[10,11] High-resolution imaging techniques like CISS/BFFE/FIESTA are performed only in cases where small metastatic lesions are suspected and are not part of the essential protocol.[10–12]

Historically, DWI of the spine has had very limited uses. It is not used routinely in children due to low spatial resolution and susceptibility artifacts from the surrounding structures. Using moderate *b*-values (400–600) and reducing the

frequency encoding steps can lower the time to echo, which improves the signal-to-noise ratio and reduces distortion. Other techniques such as reducing the field of view can also improve image quality.[20,21] The protocol for DWI of the spine has been optimized in our institution over a period of time and is now being used routinely in children.

There is very limited literature on the use of DWI spine imaging in pediatric brain tumors. In a study carried out by Porto et al, DWI was found to improve the detection of cranial leptomeningeal metastases that were isointense and non-enhancing in patients with medulloblastoma.[22] Hayes et al reported a case of ATRT with drop metastases seen on DWI, which was not seen on post-contrast images on the initial scan. The patient was kept on short-interval follow-up and showed an increase in the drop metastases at 8 weeks.[23] Our study complements the findings of these studies, demonstrating the role of DWI sequences.

In our study, most patients showing metastases had medulloblastoma (69.2%), showing smooth, nodular, and mixed types of metastases. Similar results were found in the study conducted by Zhang et al.[24] The majority of patients (95%) with LMD in our study were on treatment, postoperative, or under surveillance, with only 5% patients undergoing baseline scan. About 37% patients with LMD have isolated relapse in the spine, with 75% having concurrent disease in the brain. In a study evaluating the role of MRI in the surveillance of patients with primary brain tumors, 7% had isolated spinal recurrence, 77% isolated brain recurrence, and 16% had concurrent brain and spinal recurrence.[25]

Our data revealed that contrast-enhanced T1W MRI remains the single most sensitive sequence for detecting LMD, and therefore should be mandatorily included in the MRI protocol for spine screening for LMD. In a study carried out by Singh et al, which compared contrast-enhanced T1W imaging and contrast-enhanced FLAIR imaging for detecting LMD, the sensitivity and specificity of contrast-enhanced T1W imaging were 59 and 93%, respectively.[26]

In the study by Singh et al, combining unenhanced FLAIR imaging, T1W PC imaging, and contrast-enhanced FLAIR imaging, MRI imaging had an overall sensitivity of 65%.[26] In our study, combining all sequences, MR imaging had an overall sensitivity of 93% in detecting LMD. Turbulent flow is seen in the subarachnoid space in the dorsal thoracic spine as a result of cardiac and respiration-related pulsatile CSF flow superimposed on the caudocranial flow of CSF and the turbulent flow of CSF from ventral to dorsal subarachnoid space. These artifacts are seen as hypointense areas on T2W sequences and linear enhancing areas on T1W PC sequences and thus can mimic a lesion as well as obscure a lesion.[27,28] These artifacts occur much more in children due to the greater pulsatility of CSF in children than in adults.[29] In our study, 16 patients had suspicious lesions on T2W sequences. Out of these, lesions were seen on T1W PC imaging in six patients. The rest of the lesions on the patients were classified as artifacts based on T2W and T1W PC sequences. None of these lesions was seen on DWI. All these patients were discussed in JNOM and their lesions were regarded as artifacts as described. Hence, this demonstrates the role of DWI in avoiding overtreatment in such cases. Among the four lesions not detected on T2W and DWI, all lesions were smaller than 2 mm in size. Thus, we concluded that DWI is not able to detect lesions less than 2 mm.

Majority of the patients with nodular LMD had deposits in the thoracic region, followed by cervical, lumbar, and sacral regions. However, no significant difference was seen in the sensitivity of each sequence in the detection of the metastatic lesion according to its location. A maximum of 17 nodular lesions were detected in a single patient, and the smallest lesion detected on DWI measured 2.4 mm. Of the four lesions that were not detected by T2W and DWI, each was in the cervical, thoracic, and lumbar regions; thus, no significant difference was seen in lesion detection by DWI based on location. There were two false-negative cases on index MRI, both cases of medulloblastoma. Both of them developed linear LMD on follow-up MRI. One of them had positive CSF cytology at the time of the index MRI and received craniospinal irradiation (CSI) after the index MRI. Among all the patients with metastases, only one had backache symptoms. However, as our study included pediatric patients, obtaining proper history was difficult.

Smooth LMD was detected in only one patient on T2W and DWI, indicating that diffusion has a limited role in the detection of smooth leptomeningeal metastases. Blood products and abnormal enhancement can significantly limit interpretation of LMD in the immediate postoperative period.[30,31] However, of the 20 patients with smooth leptomeningeal enhancement, none of the patients had a recent (within 4 weeks) history of surgery or any form of instrumentation. In our study, CSF cytology was not available in 33% patients and among the patients with available CSF cytology, it had a high false-negative rate of 78% in our study. In a study carried out by Palmisciano et al, CSF cytology was not available in 31.9% patients and it was false negative in 36.4% patients.[32,33] The sensitivity of CSF cytology is known to increase to 80 to 90% with multiple lumbar punctures.[34,35] However, in all patients with available CSF cytology, only a single CSF cytology evaluation was done.

The primary brain tumors that are nonenhancing and show diffusion restriction will show drop metastases, which are also nonenhancing and show diffusion restriction. We have categorized the metastatic lesions into the match, mismatch, and reverse mismatch groups. However, all the metastatic lesions that we detected were enhancing and restricting and thus belonged to the match category. Furthermore, we postulated that the DWI would play a role in the detection of metastatic lesions that show restriction and are nonenhancing. However, in our study, there were no lesions that were restricting and nonenhancing. We found that the post-contrast T1 sequence is the most reliable sequence for the detection of LMD, but it can have some false-positive results. In such cases, using DWI in conjunction with T1W PC/T2W sequences allows the exclusion of pulsation artifacts and vessels that can masquerade as LMD. This, as mentioned previously, avoids unnecessary interventions and overt treatment. Additionally, if DWI rules out LMD, we can consider focal radiation therapy as opposed

to CSI, as the latter has poorer cognitive outcomes, particularly in the pediatric age group.

Our study is the largest case series so far that evaluates the role of DWI in the detection of drop metastasis in pediatric patients. While it highlights the potential role of spinal DWI in detecting LMD in pediatric brain tumors, particularly medulloblastoma, it faces some limitations. CSF correlation was not available for all the patients, which is a serious limitation. Also, we had a relatively small sample size with only a few patients belonging to the diverse histopathological groups and no formal diffusion metrics correlation was done with primary brain disease. Since the interpretation of MRI findings by the neuroradiologists was not done independently, no formal analysis was done. Additionally, we have not included specific sequences like CISS/BFFE/FIESTA in our study, which otherwise would have provided data on comparative analysis of efficacy across different sequences.

Future multicenter studies with standardized DWI protocols, inclusion of advanced diffusion techniques to better characterize smaller nodules, and comparative analysis with CISS/BFFE/FIESTA sequences are needed to validate these findings and improve reproducibility.

Conclusion

The T1-contrast sequence is the most reliable sequence for the detection of LMD but is known to have false-positive results. Using DWI in conjunction with T1W PC/T2W sequences enables the exclusion of pulsation artifacts and vessels masquerading as lesions, thus resulting in higher specificity.

Patient Consent

Waiver of consent was obtained from the institutional ethics committee as this was a retrospective study with less than minimal risk.

Funding

None.

Conflict of Interest

None declared.

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