

Diagnosis of primary meningeal natural killer/T-cell lymphoma of the central nervous system using cerebrospinal fluid cytology: A case report

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Abstract. Primary central nervous system (CNS) lymphoma of the meninges is a rare tumor that originates in the meninges and does not show parenchymal or systemic spread. CNS involvement by natural killer (NK)/T-cell lymphoma accounts for only 2% of all extranodal NK/T-cell lymphomas, and primary NK/T-cell lymphoma of the meninges is even rarer. The present study reports a case of a 55-year-old male patient with primary NK/T-cell lymphoma. The patient presented with intermittent dizziness and headaches for the past 1 month prior to presentation. Magnetic resonance imaging of the head identified no overt abnormalities. However, cytological analysis of a Wright-Giemsa-stained cerebrospinal fluid (CSF) sample, demonstrated numerous atypical lymphocytes and lymphoma cells. Flow cytometry of the CSF was performed as an auxiliary method, and it showed that a large proportion of the cells in the CSF were of the NK/T-cell lineage, to indicating a diagnosis of NK/T-cell lymphoma. Mutations of 14 genes were detected, including JAK3 mutations, upon screening of the CSF for blood system diseases using next-generation sequencing. Therefore, the present study demonstrated that a CSF cytological examination may be an important component of the diagnostic workup for patients suspected to have a primary meningeal CNS lymphoma.

Introduction

Primary lymphoma of the central nervous system (CNS) is a rare and aggressive extranodal type of non-Hodgkin lymphoma

that can originate in the brain, eyes, meninges or spinal cord. The diagnosis of primary CNS lymphoma requires the exclusion of systemic lymphoma. Primary CNS lymphomas account for 3% of all CNS tumors, 4% of all primary brain tumors, 5% of all extranodal lymphomas and <1% of all non-Hodgkin's lymphomas. The tumors can occur in both immunocompromised and immunocompetent hosts, but have a low incidence in the general immunocompetent population, with an incidence rate of 0.4 per 100,000 people per year. The 5-year survival rate of patients with these tumors remains low, with a recent estimate of ~22%. The median survival time is estimated to be 26 months. High-dose methotrexate is the primary treatment (1). The main pathological subtype of these tumors is diffuse large B-cell lymphoma (DLBCL) (2,3). Primary CNS lymphoma originating in the meninges is a rare type of meningioma that is not associated with parenchymal or systemic spread. Natural killer (NK)/T-cell lymphoma of the CNS accounts for only 2% of all extranodal lymphomas, and primary NK/T-cell lymphoma of the meninges is even rarer, with no accurate incidence data available so far (4). The radiological presentation of this rare tumor can be misleading, often mimicking other brain tumors, infections or inflammatory diseases. Hence, the diagnosis of primary NK/T-cell lymphoma of the meninges is challenging and typically requires the identification of lymphoma cells in a brain tissue specimen obtained using stereotactic biopsy. However, lymphoma cells can also be detected in the cerebrospinal fluid (CSF), which can be collected via a lumbar puncture (5). The present study reports the case of a patient who was diagnosed with primary NK/T-cell meningeal lymphoma using CSF cytological examination and flow cytometric analysis. The present study aimed to explore the basis and significance of CSF examination as a type of 'fluid biopsy' for the diagnosis of primary CNS lymphoma of the meninges (5).

Case report

Clinical history. A 55-year-old male patient presented with intermittent dizziness and periodic headaches for the past month and gait instability for 9 days prior to presentation, and

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was admitted to Shaanxi Provincial People's Hospital (Xi'an, China) in October 2023. The patient reported that the episodes of dizziness and headaches began after catching a cold, and that no fever, vomiting or seizures were experienced during this time. A neurological examination demonstrated bilateral hearing loss and left-sided tinnitus. The patient's medical history was unremarkable and there was no evidence of hereditary diseases. A comprehensive medical history, epipharyngoscope examination, magnetic resonance imaging (MRI) and positron-emission tomography/computed tomography (PET/CT) indicated no sinonasal or nasopharyngeal primary lesions. The patient's white blood cell count ($7.54 \times 10^9/\text{liter}$), platelet count ($217 \times 10^9/\text{liter}$) and hemoglobin levels (144 g/l) were within the reference ranges (6,7). A quantitative-PCR assay for circulating Epstein-Barr virus DNA was positive (data not shown).

CSF cytology. Cytological examination of the CSF with Wright-Giemsa staining (Appendix S1) showed that cells with abnormal morphology accounted for ~99% of all cells in the patient's CSF sample. The abnormal cells consisted of a mixture of two main cell types. The first cell type was characterized by an irregular appearance with a slightly serrated border, with long pseudopods, a puffy and large or petal-like nucleus, scant basophilic cytoplasm and a number of cytoplasmic azurophilic granules. The second type of cells appeared round or oval, with flat and coarse granular chromatin, one or two hazy nucleoli in a number of cells, scant dark blue cytoplasm and vacuolar degeneration (Fig. 1A and B). The cells were negatively stained with leukocyte peroxidase, while a few cells were positively stained with periodic acid-Schiff stain (Fig. 1C and D). The results of flow cytometric analysis showed that a large proportion of the cells were of the NK/T-cell lineage. Considering the aforementioned results combined with those of the flow cytometric analysis, a lymphoma was initially suspected. However, to eliminate infection-induced morphological changes in lymphocytes, anti-viral (0.8 g acyclovir orally, daily) and anti-tuberculosis (0.6 g rifampicin, 500 mg pyrazinamide and 0.25 g ethambutol hydrochloride orally, daily) therapies were administered to the patient. To observe the therapeutic effects, a second CSF cytological analysis was conducted after 1 week of anti-infection therapy, but the results were unchanged (Fig. 1E). Furthermore, ink stain and acid-fast stain tests of CSF were negative (data not shown). Hence, chemotherapy was administered, after which, the total number of nucleated cells in the CSF decreased notably, with only 17% lymphoma cells (Fig. 1F-H). The cell morphology also changed; the cells were elliptical, with coarse clumpy nuclear chromatin, vaguely visible nucleoli, light blue cytoplasm, purple-red cytoplasmic granules in a number of cells and almost no pseudopodia.

From our previous clinical experience, it can be suggested that secondary CNS lymphoma, including DLBCL and nasal NK/T-cell lymphoma, is more common than primary CNS lymphoma. The present case is the first time a primary CNS NK/T-cell lymphoma of the meninges was encountered at Shaanxi Provincial People's Hospital. The total number of nucleated cells in the CSF was higher in the present patient than in CSF samples obtained from patients with DLBCL

and nasal NK/T-cell lymphoma (Fig. 2A-C). Moreover, the CSF was almost entirely composed of tumor cells, whereas in the case of DLBCL and nasal NK/T-cell lymphoma, the CSF included a number of normal lymphocytes, monocytes and neutrophils, as well as tumor cells. Statistically significant differences in the protein and glucose, and no significant difference in the CSF concentration of chloride were observed among the three types of lymphomas (Table SI). However, the cell morphology was slightly different among the three tumor types (Fig. 3A-D). In contrast to primary CNS NK/T-cell lymphoma, nasal NK/T-cell lymphoma exhibits regular, round or oval cells, with coarse granular nuclear chromatin and visible nucleoli. The cytoplasmic volume is moderate with a few pseudopod-like protrusions on one side of the cytoplasmic border. DLBCL exhibits cells with notably large cell bodies, irregular hazy nuclei and chromatin condensation. The cytoplasm appears dark blue on Wright-Giemsa staining with medium volume. Most of the cytoplasmic edges are irregular with pseudopods and vacuolar degeneration.

MRI and PET/CT diagnosis. MRI of the brain showed slight bilateral thickening of the trigeminal nerves, and bilateral deep and lobar distribution of lesions in the cerebral white matter, with slightly low-density or equal-density shadows on plain CT and slightly longer signals on T1- and T2-weighted MRI. Multiple patches were visible in the subcortical white matter in the frontal and parietal lobes, with slightly longer signals on T1- and T2-weighted MRI, and hyperintensity on fluid-attenuated inversion/recovery scans (Fig. 4). No sinonasal or nasopharyngeal primary lesions were found by means of medical history, epipharyngoscope examination and PET/CT. Additionally, no significant abnormalities such as a tumor mass were found on whole-body, brain, nasopharynx and spine PET/CT (Fig. 5). Due to the presence of lymphoma cells in the CSF and the absence of extracranial primary lesions, particularly in the nose, sinuses and pharynx, a primary lymphoma of the leptomeninges was suspected; however, no change was detected in the leptomeninges early in the course of the disease.

Flow cytometry and genetic testing. Flow cytometric immunophenotypic analysis of the CSF (Appendix S1) demonstrated that a large proportion of cells was positive for CD2, CD56, CD38, CD30 and CD45, and negative for surface CD3, CD4, CD5, CD8, CD19, CD20, CD16, CD7, CD30, κ and λ light chains, and HLA-DR, which is consistent with the NK/T-cell lineage (Fig. S1). Lymphocytes constituted ~95.33% of nucleated cells, with CD3⁺CD56⁺ NK cells accounting for ~98.96% of the lymphocyte population.

Furthermore, 14 genes with mutations were detected upon screening of the CSF for blood system diseases using next generation sequencing (Appendix S1), including in Janus kinase 3 (JAK3), PTPN11, BCOR, NOTCH2, HLA-A, TRRAP, POT1, SETD1B, CNOT3, BCL11A, IKZF3, TYK2, GNAI2 and FAT1. Among these gene mutations, the JAK3 mutation was closely related to NK/T-cell lymphoma, with a 30% mutation rate. The mutation sites in the JAK3 gene included p.Met511, p.Arg657Gln and p.Ala572Val. All sequencing data are available through the NCBI Sequence Read Archive under the accession no. PRJNA1171089, and the raw reads under accession no. SRR30938159.

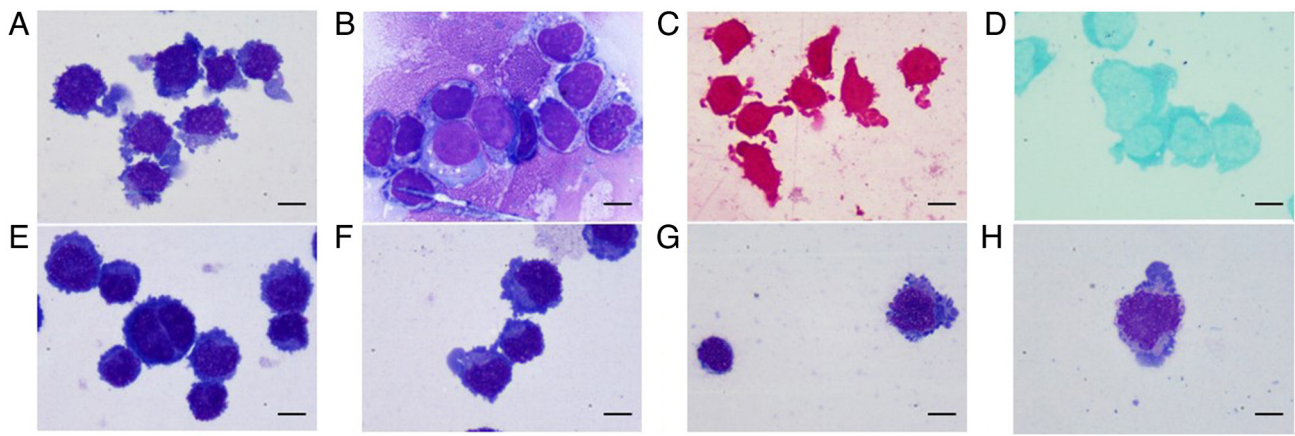


Figure 1. Representative images of CSF cytology and CSF cytochemical staining. (A and B) Numerous lymphocytes with abnormal morphology identified using Wright-Giemsa staining. The abnormal cells are a mixture of two main types. Cytochemical staining using (C) leukocyte peroxidase and (D) periodic acid-Schiff stain. (E) No changes in cellular morphology after anti-infection treatment compared with cellular morphology prior to treatment. (F-H) Notable changes in cellular morphology after chemotherapy compared with cellular morphology prior to chemotherapy. Scale bar, 10 μ m. CSF, cerebrospinal fluid.

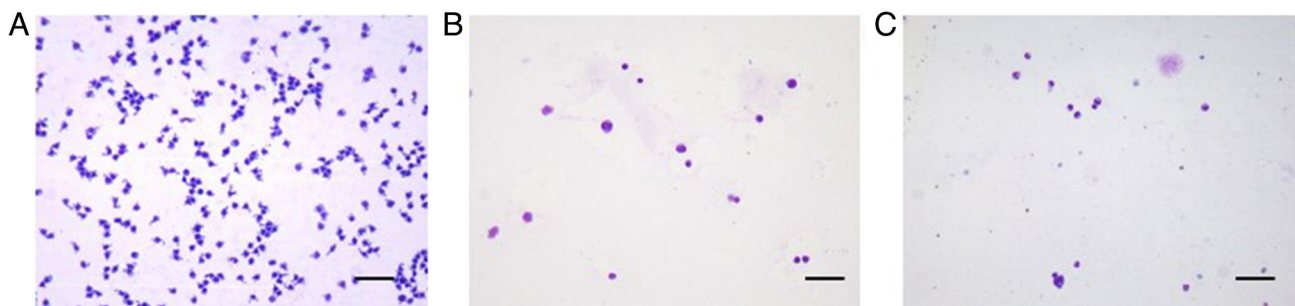


Figure 2. Differences in nucleated leukocyte counts in CSF among three types of lymphomas. Representative images of leukocytes from CSF samples from (A) primary meningeal central nervous system NK/T-cell lymphoma, (B) nasal NK/T-cell lymphoma and (C) diffuse large B-cell lymphoma. CSF, cerebrospinal fluid; NK, natural killer.

Treatment and follow-up. After the diagnosis of a primary CSF NK/T-cell lymphoma was confirmed, a total of 7 rounds of chemotherapy were performed, and the patient was treated with intravenous injections (iv) of high-dose methotrexate (5,000 mg), tislelizumab (200 mg) and cyclophosphamide (2.46 g), combined with an intrathecal injection of methotrexate (15 mg), dexamethasone (10 mg) and cytarabine (25 mg), along with chidamide (30 mg, orally) and supportive treatment, including 5% glucose injection, anti-infective therapy (0.4 g teicoplanin by iv and 0.5 g levofloxacin orally). Subsequently, the patient also underwent autologous stem cell transplantation. After the treatment, the patient showed notable improvement, with symptoms and CSF findings almost normal at first; however, the patient still died of severe pneumonia, cardiac insufficiency, and hypohepatia in October 2024.

Discussion

NK/T-cell lymphoma is a rare type of non-Hodgkin lymphoma originating from activated NK cells or cytotoxic T lymphocytes. In 2008, NK/T-cell lymphomas occurring in the nasal cavity and extranasal region were named extranodal NK/T-cell lymphoma, nasal type, according to the World Health Organization Classification of Tumors of Hematopoietic and Lymphoid Tissues (8). Extranodal NK/T-cell lymphoma of

the nasal type predominantly occurs in middle-aged men, and is associated with Epstein-Barr virus infection and certain ethnicities, environments and genetic variants, for example, most patients show monoclonal rearrangements of the TCR genes (9). NK/T-cell lymphoma tends to invade the midline facial structures such as the nasal cavity and paranasal sinuses, and extranasal sites such as the skin, soft tissues, testes and gastrointestinal tract (10). Previous cases of NK/T-cell lymphoma invading the cauda equina and brain parenchyma have been reported (10,11); however, primary leptomeningeal NK/T-cell lymphoma of the CNS is rare.

In the present case, a 55-year-old male patient was admitted with dizziness and headaches. Routine blood tests yielded normal results, and no lesions in the brain parenchyma or enlarged lymph nodes were detected on PET/CT. Hence, diseases of the hematological system and intracranial mass lesions were preliminarily excluded. Moreover, the absence of extracranial disease confirmed the primary nature of the CNS disease. A CSF examination showed a notable increase in the number of nucleated cells, but negative results for *Mycobacterium tuberculosis* and *Cryptococcus neoformans*, which excluded these specific infections. Numerous abnormal lymphocytes were found on CSF cytomorphological examination, and flow cytometry showed that 98.96% of cells (accounting for all nucleated cells) expressed CD2, CD56,

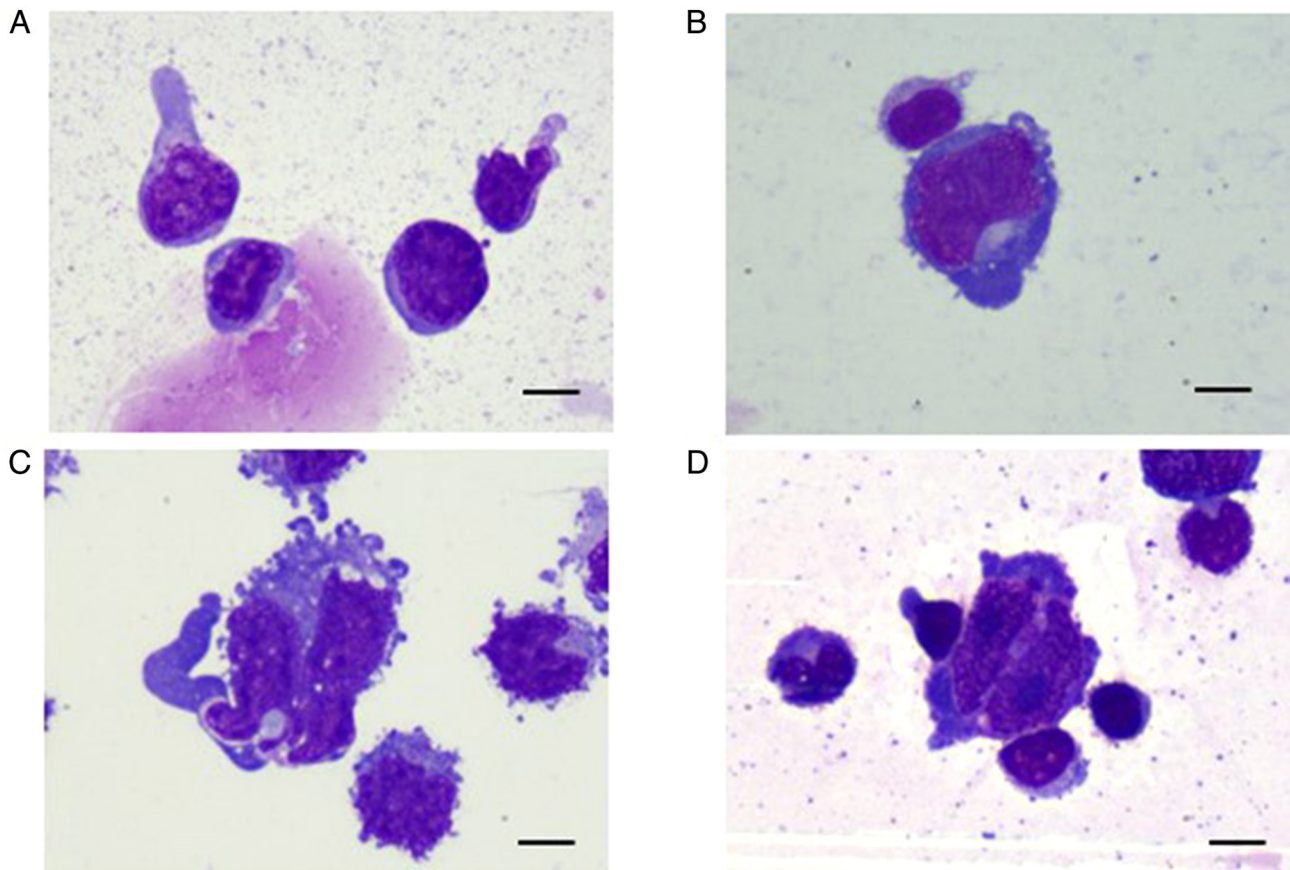


Figure 3. Differences in CSF cellular morphology in nasal NK/T-cell lymphoma and DLBCL lymphoma samples. Representative images of cellular morphology of CSF samples from patients with (A) nasal NK/T-cell lymphoma and (B-D) DLBCL. CSF, cerebrospinal fluid; NK, natural killer; DLBCL, diffuse large B-cell lymphoma.

CD38, CD30 and CD45 on their cell membranes. Since CD2 and CD56 are NK cell-specific antigens, malignant tumors of NK cell origin could be identified by immunophenotyping (4). Moreover, treatment using a combination of chemotherapy with programmed cell death 1 inhibitor (tislelizumab) and chidamide was effective, as indicated by the lack of lymphoma cells in the CSF and the improvement in the patient's CNS symptoms. Considering the aforementioned findings, the patient was diagnosed with primary CNS NK cell meningeal lymphoma.

Contrast-enhanced MRI of the head should be recommended for patients suspected to have meningeal lymphoma. If the lymphoma has invaded the meninges, contrast-enhanced MRI may identify overt meningeal thickening and enhancement at the lesion site (12). However, in the present study, MRI only showed multiple, patchy and slightly long T1 and T2 signals, and hyperintensity on fluid-attenuated inversion recovery images in the subcortical white matter of the frontoparietal lobes. No changes were detected in the meninges. Although CNS lymphomas can have a characteristic CT or MRI appearance, no imaging characteristic unequivocally differentiates CNS lymphomas from other types of tumors. In a number of cases, NK/T-cell lymphoma has been found to invade the leptomeninges, both temporal lobes, the cerebellar folia, and the vermis, and even form a mass in the brain parenchyma (10,13,14). The most common sites of invasion in the case of primary CNS DLBCL are the cerebral hemispheres,

basal ganglia and corpus callosum (11). The present patient had trigeminal nerve thickening, and previous studies suggest that trigeminal nerve thickening can be seen in chronic inflammatory demyelinating polyneuropathy (15-17). It has been reported that trigeminal nerve thickening is associated with primary CSF NK/T-cell lymphoma (18). A previous study has shown that the most frequent locations of primary CNS lymphoma are the cerebral hemispheres, followed by the corpus callosum and basal ganglia (11). Whether trigeminal nerve thickening has significance for the diagnosis of primary CNS NK/T-cell lymphoma needs to be further explored.

A large proportion of primary CNS hematological diseases invade the leptomeninges, but thickened leptomeninges are difficult to detect using CT or MRI in the early stage of the disease. Currently, the diagnosis of primary CNS lymphoma of the meninges is challenging. Pathological examination of a tissue biopsy specimen is considered to be the gold standard for diagnosis, whenever a biopsy is possible. However, as these lesions mainly involve the meninges, a tissue biopsy is often difficult to perform and pathological biopsy specimen of the diseased tissue could not be obtained from the patient. This is a limitation of the present study; however, as the disease process has an impact on the morphology of the cells in the CSF, the accurate identification of the cell types in the CSF may be used for the clinical diagnosis of primary CNS lymphoma. In practice, however, CSF cytology has relatively low sensitivity in the diagnosis of primary CNS lymphoma

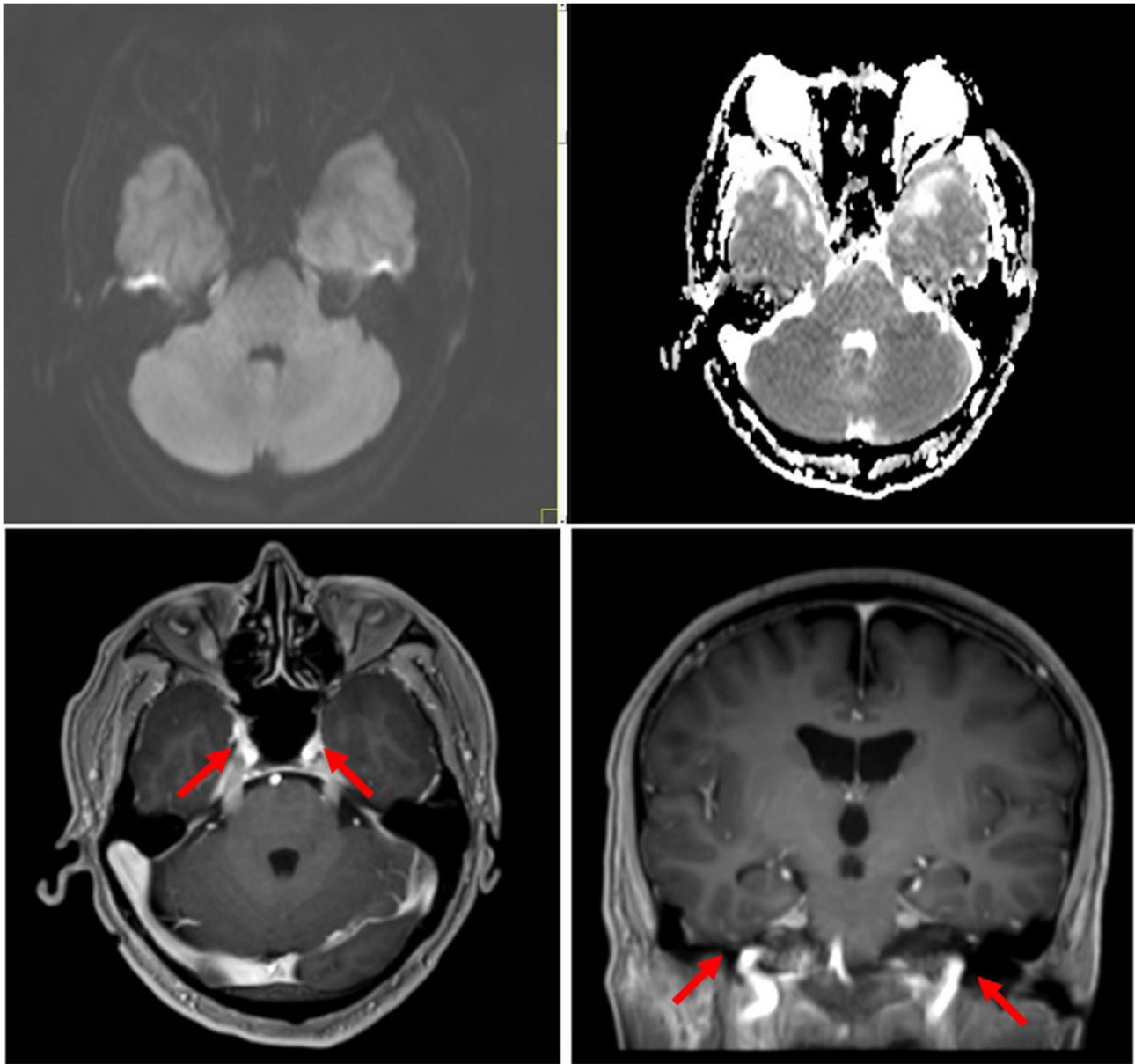


Figure 4. Radiological findings. Brain magnetic resonance imaging shows slight, bilateral thickening of the trigeminal nerves (red arrow).

and only ~20% of diagnoses are made in this way (5). The low sensitivity of CSF cytology is attributable to the morphological similarity between lymphoma cells in the CSF and benign reactive cells. Moreover, morphological variation is observed among different types of lymphomas. Hence, distinguishing these cells on cytomorphological examination is difficult.

In the present case, a large proportion of CSF cells observed were of approximately the same size, and exhibited coarse nuclear chromatin, visible petal-like nuclei, blue cytoplasm, visible granules and numerous pseudopodia at the cell border. In viral meningitis, the total cell count and the proportion of lymphocytes in the CSF are increased, and a number of lymphocytes exhibit the reactive lymphocyte phenotype, whereby they morphologically resemble immature lymphocytes (5). In Shaanxi Provincial People's Hospital, it has been found that although viral infection also stimulates lymphocytes to produce pseudopodia, the number of lymphocytes

with pseudopodia and the number of pseudopodia themselves are few. In contrast to a patient with viral meningitis, the present patient had few normal lymphocytes in the CSF and a markedly increased number of pseudopodia, which is morphologically consistent with malignant lymphoma cells. In our experience, in most primary CNS B-cell lymphomas, the tumor cells in the CSF are large with rough nuclear chromatin, irregular nuclei, basophilic cytoplasm and a dark blue appearance. By contrast, in the present study, the cells were relatively small with petal-like nuclei and overt cytoplasmic granules. Therefore, the cell type was preliminarily determined using cellular morphology, which served an important role in the diagnosis.

Liquid biopsy is a technique that can be used to examine cell-free DNA extracted from body fluids, such as peripheral blood plasma. This technique is currently used to identify genetic mutations in tumor cells in translational research and detect minimal residual disease in various types of

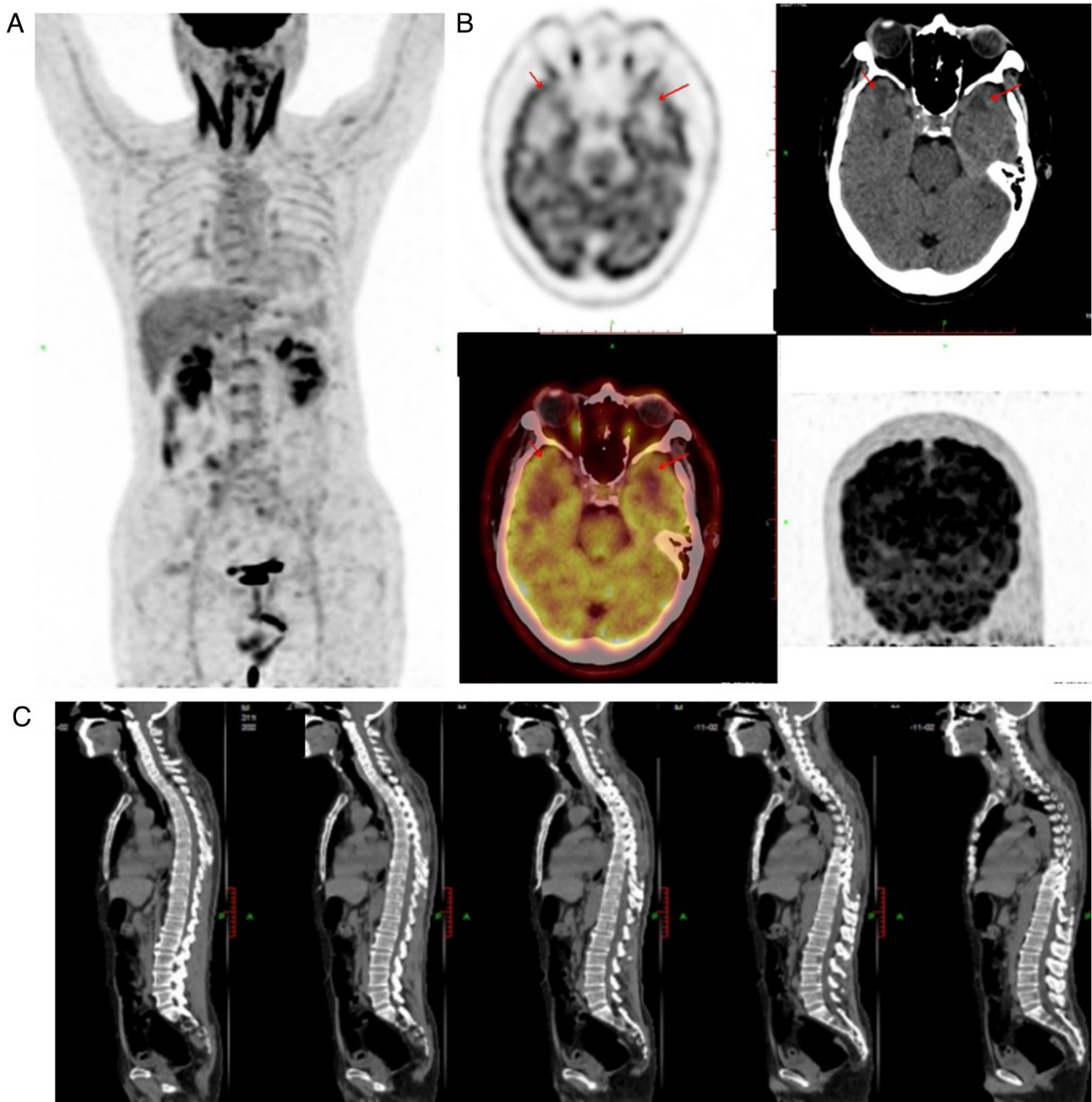


Figure 5. PET/CT imaging. (A) Whole-body, (B) brain and (C) spinal PET/CT showing no significant abnormalities. PET/CT, positron-emission tomography/computed tomography.

tumors (19). In the present study, genetic testing showed three point mutations in the JAK3 gene, which were closely related to NK/T-cell lymphomas. Studies have shown that the activation of JAK3 mutations plays a significant role in the pathogenesis of NK/T-cell lymphoma (20,21). However, ~90% of primary CNS lymphomas are DLBCL, and recent studies have shown an accumulation of mutations in genes such as MYD88 in DLBCL tumors (22,23). The present study also found that chemotherapy was notably associated with alterations in the number and morphology of the lymphoma cells in the patient's CSF. Specifically, the number of lymphoma cells decreased after chemotherapy and the number of pseudopods around the cytoplasm of the lymphoma cells was also reduced.

In summary, the present case of a patient with primary CNS NK/T-cell lymphoma serves to add to the small number of cases reported in the literature thus far. Multimodal analysis of the CSF plays an important role in the diagnosis of primary CNS NK/T-cell lymphoma, and certain imaging methods, such as MRI, can increase the diagnostic accuracy. Furthermore, future work to identify diagnostic biomarkers is necessary to aid in the diagnosis. The morphology of CSF cells plays an important role in the diagnosis of primary CNS NK/T-cell lymphoma in the absence of pathological tissue or imaging diagnosis.

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Availability of data and materials

The data generated in the present study is shown in the National Center for Biotechnology Information Sequence Read Archive when the manuscript published under the accession no. PRJNA1171089, and the raw reads data under the accession no. SRR30938159 (<https://www.ncbi.nlm.nih.gov/sra/?term=SRR30938159>). The remaining data generated in the present study may be requested from the corresponding author.

Authors' contributions

Flow cytometry was performed by WZ. MRI and PET/CT diagnosis were performed by ZM. Collection of information, the analysis of patient data and writing of the original draft was conducted by XC and JF. CSF cytology, review and editing of the manuscript was undertaken by SZ. All authors read and approved the final manuscript. SZ and XC confirm the authenticity of all the raw data.

Ethics approval and consent to participate

The report was approved by the Medical Ethics Committee of Shaanxi Provincial People's Hospital (Xi'an, China; approval no. R017). All patients provided consent for the use of CSF samples.

Patient consent for publication

All patients provided written informed consent for the publication of this report.

Competing interests

The authors declare that they have no competing interests.

References

- Shah T and Venur VA: Central nervous system lymphoma. *Semin Neurol* 43: 825-832, 2023.
- Hernández-Verdin I, Morales-Martínez A, Hoang-Xuan K and Alentorn A: Primary central nervous system lymphoma: Advances in its pathogenesis, molecular markers and targeted therapies. *Curr Opin Neurol* 35: 779-786, 2022.
- Hoang-Xuan K, Deckert M, Ferreri AJM, Furtner J, Gallego Perez-Larraya J, Henriksson R, Hottinger AF, Kasenda B, Lefranc F, Lossos A, *et al*: European association of neuro-oncology (EANO) guidelines for treatment of primary central nervous system lymphoma (PCNSL). *Neuro Oncol* 25: 37-53, 2023.
- Liao B, Kamiya-Matsuoka C, Gong Y, Chen M, Wolf BA and Fowler NH: Primary natural killer/T-cell lymphoma presenting as leptomeningeal disease. *J Neurol Sci* 343: 46-50, 2014.
- Chen X, Huang M, Zhang Z, Jing H, Zou Y and Bu H: Primary meningeal central nervous system lymphoma: A case report and literature review. *Medicine (Baltimore)* 101: e32567, 2022.
- Pietras NM, Gupta N, Justiz Vaillant AA and Pearson-Shaver AL: Immune thrombocytopenia. In: *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing, 2024.
- Guo Y, Liu X, Zihao Z, Zhang Q, Shi Z and Zhang N: Blood routine reference value range should be adjusted according to regional and ethnic characteristics. *Front Public Health* 10: 934101, 2022.
- Sabattini E, Bacci F, Sagromoso C and Pileri SA: WHO classification of tumours of haematopoietic and lymphoid tissues in 2008: An overview. *Pathologica* 102: 83-87, 2010.
- Guan H, Huang Y, Wen W, Xu M, Zan Q and Zhang Z: Primary central nervous system extranodal NK/T-cell lymphoma, nasal type: Case report and review of the literature. *J Neurooncol* 103: 387-391, 2011.
- Li X, Yu H, Fu X, Zhang L, Li X, Li L, Wang X, Sun Z, Zhang X, Li Z, *et al*: Clinical analysis of patients with primary and secondary extranodal natural killer/T-cell lymphoma of central nervous system. *Hematol Oncol* 41: 267-274, 2023.
- Küker W, Nägele T, Korfel A, Heckl S, Thiel E, Bamberg M, Weller M and Herrlinger U: Primary central nervous system lymphomas (PCNSL): MRI features at presentation in 100 patients. *J Neurooncol* 72: 169-177, 2005.
- Capasso R, Negro A, Russo C, Zeccoloni F, Muto G, Caranci F Prof and Pinto A: Conventional and advanced MRI Techniques in the evaluation of primary CNS lymphoma. *Semin Ultrasound CT MR* 44: 126-135, 2023.
- Zing NF, Thais F, Massimo C, Chiattonne C and Ferreri AJM: Diagnosis, prevention and treatment of central nervous system involvement in peripheral t-cell lymphomas. *Crit Rev Oncol Hematol* 167: 103496, 2021.
- Kleinschmidt-DeMasters BK and Gilani A: Secondary parenchymal CNS involvement by lymphoma including rare types: Follicular and EBV-positive NK/T cell lymphoma, nasal type. *Ann Diagn Pathol* 53: 151765, 2021.
- Kajtazi NI, Bafaquh M, Ghamdi JA, AlEissa Z, Shmeikh AA, Alsaeed A, Sulaiman T, Vizcaino MA, Al Hameed M and Raghunathan A: An unusual case of EBV-negative primary CNS lymphoma of natural killer/T-cell lineage. *Clin Pathol* 14: 2632010X211065692, 2021.
- Ball MK, Morris JM, Wood AJ, Meyer FB, Kaszuba MC and Raghunathan A: Ventricle-predominant primary CNS lymphomas: Clinical, radiological and pathological evaluation of five cases and review of the literature. *Brain Tumor Pathol* 37: 22-30, 2020.
- Kan Y, Wang Y, Wang W, Liu J and Yang J: Unexpected corpus callosum involvement of diffuse large B-cell lymphoma on FDG PET/CT. *Clin Nucl Med* 43: 933-935, 2018.
- Guedes BF and Cury RG: Trigeminal nerve thickening in chronic inflammatory demyelinating polyneuropathy. *Arq Neuropsiquiatr* 73: 634-635, 2015.
- Nikanjam M, Kato S and Kurzrock R: Liquid biopsy: Current technology and clinical applications. *J Hematol Oncol* 15: 131, 2022.
- Liu J, Liang L, Li D, Nong L, Zheng Y, Huang S, Zhang B and Li T: JAK3/STAT3 oncogenic pathway and PRDM1 expression stratify clinicopathologic features of extranodal NK/T-cell lymphoma, nasal type. *Oncol Rep* 41: 3219-3232, 2019.
- Koo GC, Tan SY, Tang T, Poon SL, Allen GE, Tan L, Chong SC, Ong WS, Tay K, Tao M, *et al*: Janus kinase 3-activating mutations identified in natural killer/T-cell lymphoma. *Cancer Discov* 2: 591-597, 2012.
- Yamaguchi J, Ohka F, Kitano Y, Maeda S, Motomura K, Aoki K, Takeuchi K, Nagata Y, Hattori H, Tsujiuchi T, *et al*: Rapid detection of the MYD88 L265P mutation for pre- and intra-operative diagnosis of primary central nervous system lymphoma. *Cancer Sci* 114: 2544-2551, 2023.
- Iriyama C, Murate K, Iba S, Okamoto A, Goto N, Yamamoto H, Kato T, Mihara K, Miyama T, Hattori K, *et al*: Utility of cerebrospinal fluid liquid biopsy in distinguishing CNS lymphoma from cerebrospinal infectious/demyelinating diseases. *Cancer Med* 12: 16972-16984, 2023.



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