

[ CASE REPORT ]

# Intracranial Myeloid Sarcoma Mimicking Hypertensive Intracerebral Hemorrhage

Shuhei Ikeda<sup>1</sup>, Masaomi Tsutsumi<sup>1</sup>, Mai Fujita<sup>2</sup>, Sho Okamoto<sup>2</sup>, Makoto Eriguchi<sup>1</sup> and Hideo Hara<sup>1</sup>

## Abstract:

We herein report a case of intracranial myeloid sarcoma mimicking hypertensive intracerebral hemorrhage. A 71-year-old man with a history of acute myeloid leukemia was admitted with acute-onset dysarthria. A hematoma-like lesion was found on computed tomography in the left putamen. Magnetic resonance imaging (MRI) and cerebrospinal fluid cytology confirmed the diagnosis of intracranial myeloid sarcoma. The patient showed a favorable response to chemotherapy, and follow-up MRI revealed shrinkage of the tumor. Since the computed tomography findings resemble those of intracerebral hemorrhage, it is important to suspect intracranial neoplasm, particularly in cases with a history of hematologic diseases.

**Key words:** Myeloid sarcoma, stroke mimic, extramedullary malignancy, magnetic resonance imaging, cerebrospinal fluid examination

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## Introduction

Myeloid sarcoma (MS) is rarely seen as a solid extramedullary tumor derived from malignant primitive myeloid cells. It is commonly caused by acute myeloid leukemia (AML) or chronic myeloid leukemia (CML) and is mostly a relapse of the primary disease (1, 2). AML relapses usually occur in the bone marrow, whereas extramedullary relapses occur as MS lesions in any part of the body or as leukemic cell infiltration in the body cavity fluid or cerebrospinal fluid (CSF) (3). Besides AML relapses, MS can manifest as extramedullary lesions at the onset of AML or even as an isolated MS (4). It frequently affects the skin (28.2%), lymph nodes (16.3%), testes (6.5%), and intestines (6.5%), and the central nervous system (CNS) (3.3%) only rarely experiences it (1). Its clinical presentation is mostly determined by the mass size and position, as well as the mechanical compression of adjacent structures. Computed tomography (CT) findings demonstrate hyperdensity (5) but are difficult to distinguish from other diseases, such as hematoma, abscess, and meningioma (6-11).

We herein report a case of intracerebral MS mimicking spontaneous hypertensive intracerebral hemorrhage (ICH). Making the distinction is crucial, since a timely diagnosis and treatment are linked to a better survival (12, 13).

## Case Report

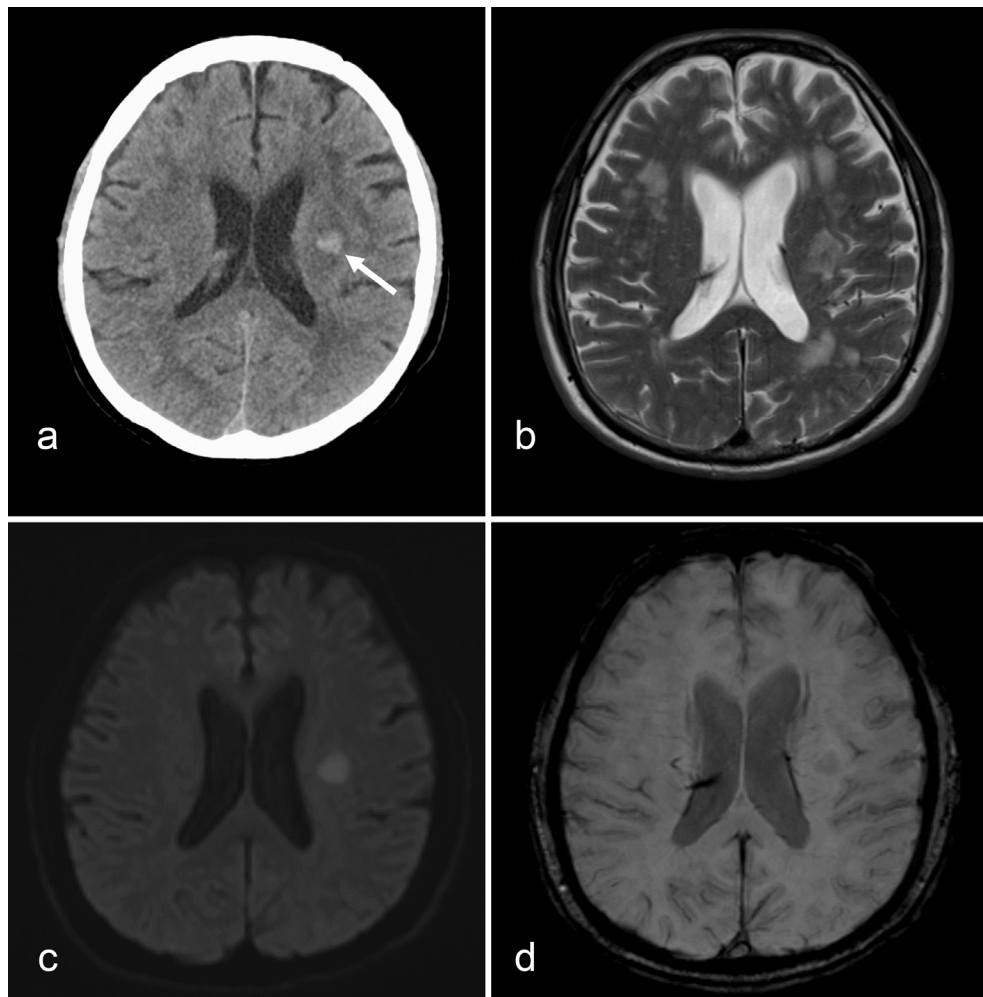
A 70-year-old man presented with pancytopenia. His hemoglobin level was 9.6 g/dL, his platelet count was  $43 \times 10^3/\mu\text{L}$ , and his white blood cell count was  $2.0 \times 10^3/\mu\text{L}$ . A bone marrow biopsy was normocellular with increased numbers of erythroblasts. Micromegakaryocytes, giant neutrophils, and megaloblastic alterations were seen. A diagnosis of myelodysplastic syndromes (MDS) with multi-lineage dysplasia was made based on the World Health Organization 2016 classification (14). His Revised International Prognostic Scoring System score was 5, which is considered to indicate a high risk due to his moderate anemia, severe thrombocytopenia, intermediate karyotype, and low bone marrow blast count.

After receiving supportive therapy without red blood cell infusions for six months following the diagnosis of MDS,

<sup>1</sup>Division of Neurology, Department of Internal Medicine, Faculty of Medicine, Saga University, Japan and <sup>2</sup>Division of Hematology, Respiratory Medicine and Oncology, Department of Internal Medicine, Faculty of Medicine, Saga University, Japan

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Correspondence to Dr. Makoto Eriguchi, eriguchm@cc.saga-u.ac.jp



**Figure 1.** Brain computed tomography and magnetic resonance imaging of myeloid sarcoma. Computed tomography showed a hematoma-like lesion with a mean attenuation of 54 Hounsfield units in the left putamen (a, arrow). The lesion showed hyperintensity on T2-weighted imaging (b). Diffusion-weighted imaging showed a well-defined homogenous hyperintense lesion in the upper putamen (c). Susceptibility-weighted imaging revealed no hemorrhagic changes in the lesion (d).

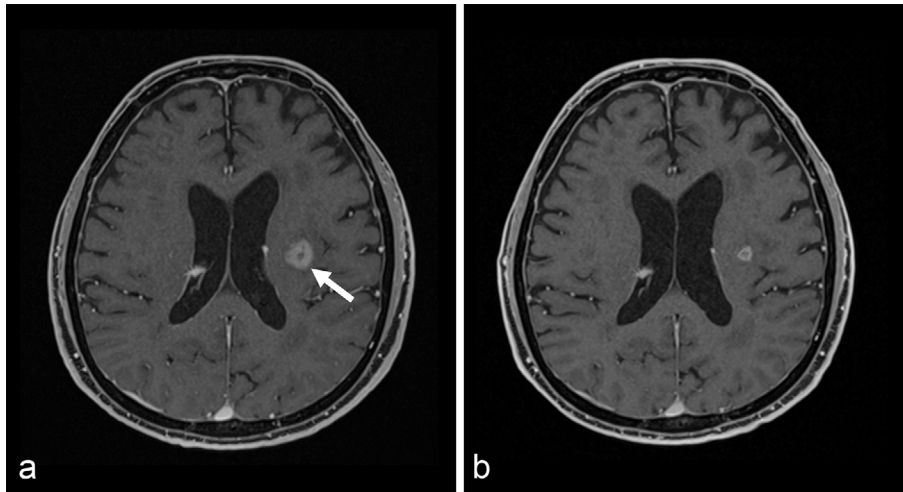
his condition developed into AML with myelodysplasia-related changes. Approximately 30% of the blast forms in the bone marrow were undifferentiated. Blastic cells were positive for CD34, CD13, CD33, CD117, and myeloperoxidase with partial positivity for CD7 and CD64. A G-banding analysis revealed a complex karyotype with additional del 7 q although chimeric fusion gene and FLT3-ITD analyses were negative. Wilms' tumor 1 (WT1) levels in the bone marrow were  $5.1 \times 10^3$  copies/ $\mu$ gRNA.

He was treated with an induction regimen consisting of daunorubicin and a cytarabine-based induction regimen, but induction therapy was a failure. He underwent allogeneic hematopoietic stem cell transplantation (allo-HSCT) from a human leucocyte antigen haploidentical donor after undergoing re-induction mitoxantrone, etoposide, and high-dose cytarabine chemotherapy. The conditioning regimen consisted of fludarabine, busulfan, and melphalan without total body irradiation. A total of  $7.9 \times 10^6$ /kg CD34+ cells were injected. Graft-versus-host disease (GVHD) prophylaxes consisted of PTCy (40 mg/kg on days +3 and +4), continuous infusion

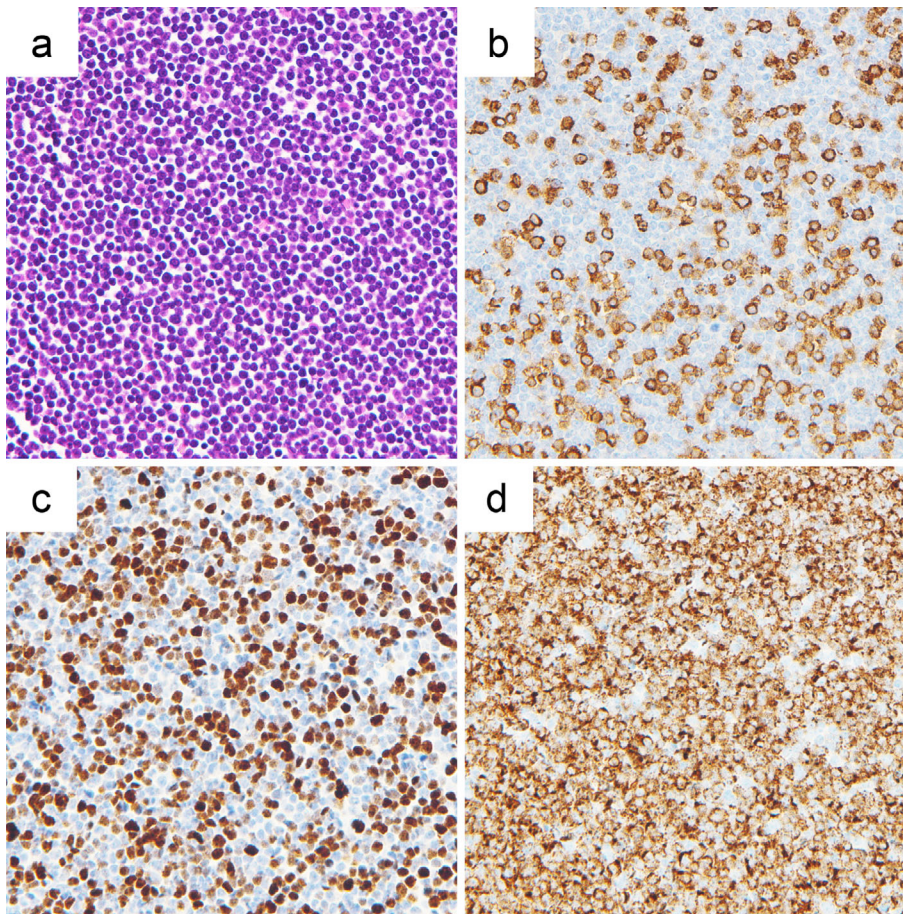
of tacrolimus, and oral mycophenolate mofetil starting on day +5. He had successful engraftment at day +15 and was discharged at day +81 without acute GVHD. While he developed mild chronic GVHD of the skin at day +105, it was resolved with topical steroids.

At day +233 after the stem cell transplant (SCT), he was still in hematological full remission and had stopped immunosuppressive treatment. Magnetic resonance imaging (MRI) screening 10 months after SCT showed no abnormalities. WT1 levels in peripheral blood were monitored monthly and maintained below detection sensitivity.

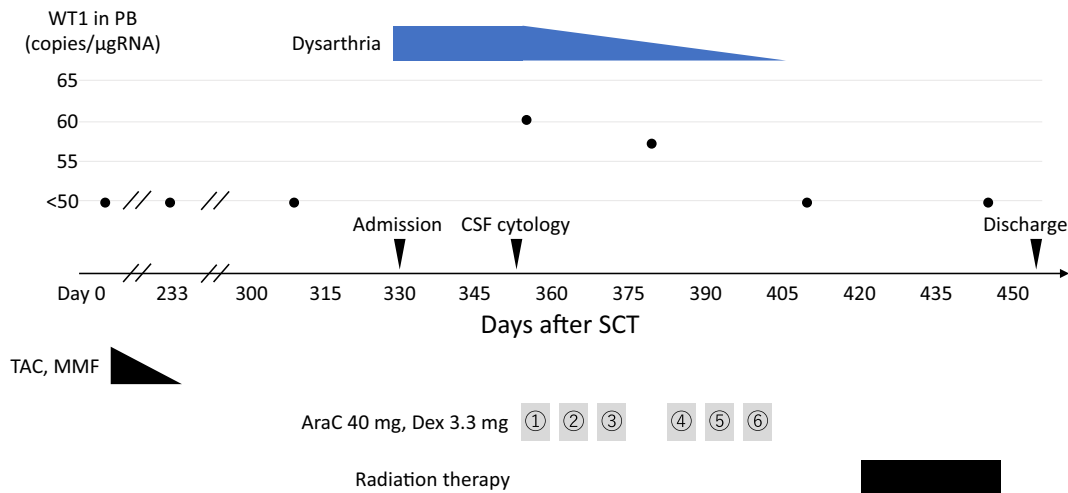
At day +331, he presented to our hospital with acute-onset dysarthria that had started 3 days ago. On admission, vital signs showed a blood pressure of 108/60 mmHg and a pulse rate of 70 beats per minute. A neurological examination revealed mild dysarthria and a National Institutes of Health Stroke Scale score of 1. No symptoms indicative of brain tumor or meningitis, such as headache, nausea, and meningeal irritation signs, were found. Laboratory data showed a white blood cell count of  $13.7 \times 10^3/\mu$ L without



**Figure 2.** Gadolinium-enhanced T1-weighted imaging before and after treatment. A ring-enhancing mass in the left putamen was visible on gadolinium-enhanced T1-weighted imaging performed two weeks after admission (a, arrow). For four months after treatment, the putaminal mass decreased in size (b).



**Figure 3.** Cytology of cerebrospinal fluid. Microscopy with Hematoxylin and Eosin staining of the cerebrospinal fluid demonstrated infiltration of medium-to-large cells with a high nucleocytoplasmic ratio. These immature cells had round-to-oval nuclei with blast-like chromatin and prominent nucleoli (a,  $\times 200$ ). Immunohistochemistry staining demonstrated that tumor cells were positive for myeloperoxidase, CD34 and terminal deoxynucleotidyl transferase (b, c, d  $\times 200$ ).



**Figure 4.** Clinical course of patient. The patient received allogeneic hematopoietic stem cell transplantation (day 0). On day 331, he was admitted with dysarthria, initially considered to be intracerebral hemorrhage. On day 353, the CSF cytology revealed atypical cells positive for a marker of myeloid origin cells. He was diagnosed with intracranial myeloid sarcoma relapse, and systemic chemotherapy was started on day 359. After chemotherapy, he also received radiation therapy. On day 444, he was discharged without any neurological deficits. AraC: cytarabine, CSF: cerebral spinal fluid, Dex: dexamethasone, MMF: mycophenolate mofetil, PB: peripheral blood, SCT: stem cell transplantation, TAC: tacrolimus

blast cells, hemoglobin level of 12.5 g/dL, platelet count of  $229 \times 10^3/\mu\text{L}$ , blood urea nitrogen level of 34.5 mg/dL, serum creatinine level of 1.39 mg/dL, serum sodium level of 138 mEq/L, aspartate transaminase level of 28 U/L, alanine transaminase level of 29 U/L, and lactic dehydrogenase level of 260 U/L. The prothrombin time (PT) international normalized ratio was 1.15, and activated partial thromboplastin time (APTT) was 26.5 s. WT1 levels in peripheral blood were 61 copies/ $\mu\text{gRNA}$ . Brain non-contrast CT showed a high-density area in the left putamen (Fig. 1a). He had multiple ICH risk factors, including hypertension requiring four antihypertensive agents and use of direct oral anticoagulation for venous thromboembolism.

Under an initial diagnosis of spontaneous hypertensive ICH, antihypertensive therapy was started, but the neurological deficit and follow-up CT showed unremarkable changes. MRI performed after eight days of admission showed a lesion in the left putamen with isointensity on T1-weighted imaging (WI), heterogeneous hyperintensity on T2WI (Fig. 1b), and homogenous hyperintensity on diffusion-weighted imaging with corresponding apparent diffusion coefficient hypointensity (Fig. 1c). Susceptibility-WI showed slight hypointensity (Fig. 1d), which differed substantially from the expected findings of a hemorrhagic lesion. Gadolinium-enhanced MRI showed a mass with thick rim enhancement (Fig. 2a).

We suspected that the lesion was most likely neoplastic, e.g. post-transplant lymphoproliferative disorders or recurrence of AML, and performed a lumbar puncture. A CSF examination revealed elevated protein (562 mg/dL) and cell counts (2,249/ $\mu\text{L}$ ). The CSF-to-serum glucose ratio de-

creased to 0.3. The CSF cytology was class V, and hematoxylin-eosin staining showed infiltration of atypical cells with a high nuclear-to-cytoplasmic ratio (Fig. 3a) that were positive on immunohistochemical staining for myeloperoxidase and CD34, regarded as markers of myeloid origin cells (Fig. 3b, c), as well as terminal deoxynucleotidyl transferase (Fig. 3d). Morphologic findings were most consistent with undifferentiated blasts arising in the setting of AML.

Based on the above findings, we diagnosed the patient with CNS relapse of MS after allo-HSCT in AML. Whole-body CT was negative for *de novo* or recurrent tumors. A bone marrow examination showed that complete hematological remission had been maintained. Other laboratory tests were mostly normal. The patient was treated with systemic cytarabine infusion and intrathecal injection of cytarabine and dexamethasone. Four months after admission, he was discharged without any neurological deficits and is currently undergoing radiation therapy (Fig. 4). At day +444, follow-up MRI after treatment showed tumor shrinkage (Fig. 2b).

## Discussion

Our case presented with acute neurological symptoms, and CT showed a homogenous hyperdense lesion in the putamen one year after allo-HSCT for AML. We initially assumed acute ICH, which is frequently encountered in patients with hematological malignancies (15); however, MRI revealed no hemorrhagic changes and instead indicated a tumor-like lesion. CSF cytology ultimately led to a definite diagnosis of intracranial MS.

**Table. Clinical Features of the Thalamus and Basal Ganglia Myeloid Sarcoma Instances That have been Reported.**

Case No	Reference	Age/gender	Primary disease	Onset	Treatment for primary disease	Period from diagnosis of AML or other malignancy (months)	Clinical presentations	Site of lesions	Multiple lesions	Imaging findings	Diagnostic procedure					Clinical outcome (weeks)
											Histological diagnosis	CSF cytology	CSF findings	Pathological findings	Treatment for MS	
1	Pippard (Ref. 23)	63/M	AML	Extramedullary relapse of AML	Chemotherapy	207	Drowsy, memory loss, paresthesia and, ataxia	Right basal ganglia	No	CT: Hyperdensity mass MRI: N/A	N/A	Positive	Presence of blast cells (10/ $\mu$ L)	N/A	CRT	NED (86)
2	Joselson (Ref. 24)	28/F	Renal failure	Primary MS	Renal transplantation		Drowsy, left hemiparesis, left homonymous hemianopsia, and right conjugate eye deviation	Right basal ganglia	No	CT: Hyperdensity mass MRI: N/A	MPO+	N/A	N/A	MPO+	None	Death (7)
3	Simpson (Ref. 25)	35/F	AML	Extramedullary relapse of AML	Chemotherapy	7	Headache	Right frontal, parietal lobes, and right thalamus	Yes	CT: Hyperdensity mass MRI: N/A	Biopsy	N/A	N/A	CD45+, NASDCA+	Radiation therapy	Death (12)
4	Passarin (Ref. 18)	29/M	Pineal germinoma and testicular cancer	Primary MS	Chemotherapy	96	Drowsy, headache	Right caudate nucleus and periventricular site	Yes	CT: No change MRI: Gadolinium enhancing mass	Autopsy	Negative	Mildly increased proteins and absence of atypical cells	MPO+	None	Death (1)
5	Present case	71/M	AML	Extramedullary relapse of AML	Allo-HSCT	12	Dysarthria	Left putamen	No	CT: Hyperdensity mass MRI: Gadolinium enhancing mass	N/A	Positive	Increased proteins and presence of atypical cells (2,249/ $\mu$ L).	MPO+, CD34, TdT	CRT	NED (4)

Allo-HSCT: allogeneic hematopoietic stem cell transplantation, AML: acute myeloid leukemia, CNS: central nervous system, CRT: chemoradiotherapy, MPO: myeloperoxidase, MS: myeloid sarcoma, NASDCA: naphtol AS-D chloroacetate, NED: no evidence of disease, N/A: not available, TdT: terminal deoxynucleotidyl transferase

MS, also called granulocytic sarcoma or chloroma, is a rare solid extramedullary tumor made up of myeloblasts. Clinical symptoms depend on its occurrence site, and nearly half of MS patients are asymptomatic (16). Thus, a previous cross-sectional imaging study reported that 24.5% of cases were incidentally discovered (17).

MS on non-contrast intracranial CT typically presents as a homogeneously hyperdense mass (5) and can thus be mistaken for a subdural hematoma (7, 8), ICH (18), meningioma, or even an abscess (19). It can be challenging to differentiate between MS and these diseases when patients with hematologic diseases present with acute neurological symptoms. MRI can provide useful information for distinguishing these disease lesions. For example, Intracranial MS shows an isointense mass on T1WI and hyperintense mass on T2WI with restricted diffusion and without susceptibility artifacts on MRI (5). However, the time, cost, patient tolerance, clinical status, and MRI availability may preclude emergent MRI (20) in the acute stroke setting, which is why CT is recognized as the “gold standard”. We did not perform emergent MRI in the present case, but our patient had an AML history and did not show any lesion expansion despite receiving anti-thrombotic therapy (21). We should have considered a differential diagnosis including MS.

Spontaneous hypertensive ICH occurs most frequently in the basal ganglia (caudate nucleus/putamen/globus pallidus/subthalamic nucleus/substantia nigra) and thalamus (22). Although uncommon, certain cases of intracranial MS have been described in these locations (Table) (17, 23-27). Three cases, including our own, had an AML history, one received a renal transplant, and another had received chemotherapy for solid cancer. None of the cases presented with hematological relapse at the time of the initial evaluation. All cases were evaluated by CT; four showed a homogeneously hyperdense mass, and one (Case No. 4) had no changes and was undetectable on CT. MRI findings in that case included gadolinium enhancement, similar to our own patient. CSF cytology was performed in three patients, including our case, and two had documented neoplastic cells. There have been few reports on the association between intracranial MS and CSF cytology, but in a small case series, four of five cases showed blast presence (28). Since a brain biopsy is not possible for some lesion sites, CSF cytology may be an alternative evaluation in cases of suspected intracranial MS.

A young age, male gender, and certain biological statuses, such as AML subtype, cytogenetic or chromosomal abnormalities, CD56, and/or T-cell markers, have previously been described as risk factors for the development of extramedullary recurrence after allo-HSCT (29-32). Disease status such as a history of extramedullary lesion, relapse or refractory disease at the time of SCT, and hyperleukocytosis at diagnosis were also related to a high incidence of extramedullary relapse (29-31, 33, 34). Several risk variables for extramedullary relapse, including male gender and refractory disease status at the time of SCT, were present in this instance.

Our case presented with leukemic cells in the CSF, but a

bone marrow examination showed no leukemic involvement, meaning that isolated CNS relapse of AML occurred following allo-HSCT. CNS relapse without bone marrow leukemia is uncommon, with an incidence of about 2% after allo-HSCT (35, 36). Isolated extramedullary MS after allo-HSCT occurred in 9 of 19 (47.4%) cases in a previous MS case series study, while 5 (26.3%) had concurrent bone marrow relapse at the onset of MS, and 3 (15.8%) progressed to bone marrow involvement within 2 years after the MS onset (37). Even in rare cases, if left untreated, it is thought to proceed quickly to systemic recurrence, with a terrible prognosis (38). Although there is no recognized surveillance technique, early identification and systemic treatment are related to an improved survival (12, 13). Radiological studies are not routinely done as a regular follow-up for patients after SCT. Several studies on extramedullary relapse after allo-HSCT have shown the utility of monitoring WT1 levels in peripheral blood (39, 40); however, our patient had low WT1 levels before and after the relapse. It should be emphasized that in cases where WT1 levels are relatively low from the outset, WT1 levels may not be beneficial in checking for relapses, both within and outside the marrow. Importantly, for patients presenting with neurological impairments that do not rule out intracranial MS, CSF cytology and MRI should be conducted.

The pathophysiology of MS in the brain parenchyma is unknown due to its rarity. Diapedesis across endothelium or direct entry with petechial hemorrhaging can allow the migration of leukemic cells into the brain. The perivascular clustering of leukemic blasts on biopsy samples lends weight to this idea (25). In the present case, vascular risk factors, including long-standing hypertension, caused endothelial damage in the deep area, which may have led to the development of MS.

In conclusion, we report the case of a man with intracranial MS relapse following allo-HSCT whose findings closely resembled those of ICH. Although deep cerebral MS is relatively rare, the rigorous distinction should be conducted, even in elderly patients with hematologic disorders. MRI and CSF studies may help diagnose MS.

**The authors state that they have no Conflict of Interest (COI).**

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#### References

1. Pileri SA, Ascani S, Cox MC, et al. Myeloid sarcoma: clinico-

- pathologic, phenotypic and cytogenetic analysis of 92 adult patients. *Leukemia* **21** (2): 340-350, 2007.
2. Neiman RS, Barcos M, Berard C, et al. Granulocytic sarcoma: a clinicopathologic study of 61 biopsied cases. *Cancer* **48** (6): 1426-1437, 1981.
  3. Clark WB, Strickland SA, Barrett AJ, Savani BN. Extramedullary relapses after allogeneic stem cell transplantation for acute myeloid leukemia and myelodysplastic syndrome. *Haematologica* **95** (6): 860-863, 2010.
  4. Shallis RM, Gale RP, Lazarus HM, et al. Myeloid sarcoma, chloroma, or extramedullary acute myeloid leukemia tumor: A tale of misnomers, controversy and the unresolved. *Blood Rev* **47**: 100773, 2021.
  5. Chaudhry AA, Gul M, Chaudhry AA, Dunkin J. Qualitative Assessment of Diffusion Weighted Imaging and Susceptibility Weighted Imaging of Myeloid Sarcoma Involving the Brain. *J Comput Assist Tomogr* **40** (1): 61-66, 2016.
  6. O'Brien CE, Saratsis AM, Voyadzis JM. Granulocytic sarcoma in a patient with blast crisis mimicking a chronic subdural hematoma. *J Clin Oncol* **29** (19): e569-e571, 2011.
  7. Smidt MH, de Bruin HG, van't Veer MB, van den Bent MJ. Intracranial granulocytic sarcoma (chloroma) may mimic a subdural hematoma. *J Neurol* **252** (4): 498-499, 2005.
  8. Gill AS, Gill R, Kaloostian P, et al. Intracranial Myeloid Sarcoma Metastasis Mimicking Acute Subdural Hematoma. *Case Rep Surg* **2017**: 3056285, 2017.
  9. McCabe MG, Broadbent V, Williams DM. Unusual cause of extradural haemorrhage. *Med Pediatr Oncol* **36** (6): 654-656, 2001.
  10. Kabadi K, Anoop P, Sandhya V, Murthy GK. Intracranial granulocytic sarcoma as the first presentation of chronic myeloid leukemia in chronic phase. *J Neurooncol* **134** (2): 473-474, 2017.
  11. Ahn JY, Kwon SO, Shin MS, Kang SH, Kim YR. Meningeal chloroma (granulocytic sarcoma) in acute lymphoblastic leukemia mimicking a falx meningioma. *J Neurooncol* **60** (1): 31-35, 2002.
  12. Yamauchi K, Yasuda M. Comparison in treatments of nonleukemic granulocytic sarcoma: report of two cases and a review of 72 cases in the literature. *Cancer* **94** (6): 1739-1746, 2002.
  13. Tsimberidou AM, Kantarjian HM, Wen S, et al. Myeloid sarcoma is associated with superior event-free survival and overall survival compared with acute myeloid leukemia. *Cancer* **113** (6): 1370-1378, 2008.
  14. Arber DA, Orazi A, Hasserjian R, et al. The 2016 revision to the World Health Organization classification of myeloid neoplasms and acute leukemia. *Blood* **127** (20): 2391-2405, .
  15. Navi BB, Reichman JS, Berlin D, et al. Intracerebral and subarachnoid hemorrhaging in patients with cancer. *Neurology* **74** (6): 494-501, 2010.
  16. Singh A, Kumar P, Chandrashekhara SH, Kumar A. Unravelling chloroma: review of imaging findings. *Br J Radiol* **90** (1075): 20160710, 2017.
  17. Meyer HJ, Ponisch W, Schmidt SA, et al. Clinical and imaging features of myeloid sarcoma: a German multicenter study. *BMC Cancer* **19** (1): 1150, 2019.
  18. Passarin MG, Vattemi E, Musso AM, et al. Intracranial granulocytic sarcoma after chemotherapy for pineal germinoma and testicular cancer. *J Clin Oncol* **26** (27): 4507-4509, 2008.
  19. Vinters HV, Gilbert JJ. Multifocal chloromas of the brain. *Surg Neurol* **17** (1): 47-51, 1982.
  20. Singer OC, Sitzer M, du Mesnil de Rochemont R, Neumann-Haefelin T. Practical limitations of acute stroke MRI due to patient-related problems. *Neurology* **62** (10): 1848-1849, 2004.
  21. Toyoda K, Yasaka M, Nagata K, et al. Antithrombotic therapy influences location, enlargement, and mortality from intracerebral hemorrhaging. The Bleeding with Antithrombotic Therapy (BAT) Retrospective Study. *Cerebrovasc Dis* **27** (2): 151-159, 2009.
  22. Gotoh S, Hata J, Ninomiya T, et al. Trends in the incidence and survival of intracerebral hemorrhaging by its location in a Japanese community. *Circ J* **78** (2): 403-409, 2014.
  23. Pippard MJ, Callender ST, Sheldon PW. Infiltration of central nervous system in adult acute myeloid leukaemia. *Br Med J* **1** (6158): 227-229, 1979.
  24. Joselson RA, Beckstead JH, Davis RL. Granulocytic sarcoma of the brain after renal transplantation. *J Neuropathol Exp Neurol* **41** (6): 580-587, 1982.
  25. Simpson TA, Jr., Anderson ML, Garcia JH, Barton JC. Myeloblastoma of the brain. *Acta Neuropathol* **78** (4): 444-447, 1989.
  26. Voessing R, Berthold F, Richard KE, Thun F, Schroeder R, Krueger GR. Primary myeloblastoma of the pineal region. *Clin Neuropathol* **11** (1): 11-15, 1992.
  27. Kei PL, Kok TY, Linn YC, Padhy AK. Butterfly lesion of the corpus callosum: an unusual case of extramedullary myeloid sarcoma (granulocytic sarcoma). *Clin Nucl Med* **36** (5): 365-366, 2011.
  28. Olar A, Lapadat R, Davidson CJ, et al. Central nervous system involvement by myeloid sarcoma: a report of 12 cases and review of the literature. *Clin Neuropathol* **35** (5): 314-325, 2016.
  29. Lee KH, Lee JH, Choi SJ, et al. Bone marrow vs extramedullary relapse of acute leukemia after allogeneic hematopoietic cell transplantation: risk factors and clinical course. *Bone Marrow Transplant* **32** (8): 835-842, 2003.
  30. Harris AC, Kitko CL, Couriel DR, et al. Extramedullary relapse of acute myeloid leukemia following allogeneic hematopoietic stem cell transplantation: incidence, risk factors and outcomes. *Haematologica* **98** (2): 179-184, 2013.
  31. Ge L, Ye F, Mao X, et al. Extramedullary relapse of acute leukemia after allogeneic hematopoietic stem cell transplantation: different characteristics between acute myelogenous leukemia and acute lymphoblastic leukemia. *Biol Blood Marrow Transplant* **20** (7): 1040-1047, 2014.
  32. Alhashim N, Aljurf M, Hassanein M, et al. Extramedullary relapses after allogeneic stem cell transplantation for acute myeloid leukemia: clinical characteristics, incidence, risk factors and outcomes. *Bone Marrow Transplant* **53** (7): 838-843, 2018.
  33. Yuda S, Fujii S, Onishi A, et al. Extramedullary Relapse of Acute Myelogenous Leukemia after Allogeneic Hematopoietic Stem Cell Transplantation. *Biol Blood Marrow Transplant* **25** (6): 1152-1157, 2019.
  34. Yoshihara S, Ikegame K, Kaida K, et al. Incidence of extramedullary relapse after haploidentical SCT for advanced AML/myelodysplastic syndrome. *Bone Marrow Transplant* **47** (5): 669-676, 2012.
  35. Solh M, DeFor TE, Weisdorf DJ, Kaufman DS. Extramedullary relapse of acute myelogenous leukemia after allogeneic hematopoietic stem cell transplantation: better prognosis than systemic relapse. *Biol Blood Marrow Transplant* **18** (1): 106-112, 2012.
  36. Oshima K, Kanda Y, Yamashita T, et al. Central nervous system relapse of leukemia after allogeneic hematopoietic stem cell transplantation. *Biol Blood Marrow Transplant* **14** (10): 1100-1107, 2008.
  37. Frietsch JJ, Hunstig F, Wittke C, et al. Extra-medullary recurrence of myeloid leukemia as myeloid sarcoma after allogeneic stem cell transplantation: impact of conditioning intensity. *Bone Marrow Transplant* **56** (1): 101-109, 2021.
  38. Almond LM, Charalampakis M, Ford SJ, Gourevitch D, Desai A. Myeloid Sarcoma: Presentation, Diagnosis, and Treatment. *Clin Lymphoma Myeloma Leuk* **17** (5): 263-267, 2017.
  39. Kwon M, Martinez-Laperche C, Infante M, et al. Evaluation of minimal residual disease by real-time quantitative PCR of Wilms' tumor 1 expression in patients with acute myelogenous leukemia after allogeneic stem cell transplantation: correlation with flow cytometry and chimerism. *Biol Blood Marrow Transplant* **18**: 1235-1242, 2012.

40. Ino K, Fuji S, Tajima K, et al. Clinical utility of Wilms' tumor 1 monitoring in patients with myeloid malignancy and prior allogeneic hematopoietic stem cell transplantation. *Biol Blood Marrow Transplant* **23**: 1780-1787, 2017.

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