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CASE BASED REVIEW

Epidural myeloid sarcoma as the presenting symptom of chronic myeloid leukemia blast crisis

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Abstract

Epidural myeloid sarcoma revealing chronic myeloid leukemia is scarce. Herein, we describe a patient that presented with back pain and bilateral sciatica secondary to root compression due to epidural deposition of leukemic cells. The magnetic resonance imaging showed epidural masses, causing a slight restriction of the spinal canal with bilateral L5 root compression. Laboratory examinations showed hyperleukocytosis (white blood cell count: 83 × 109/L, absolute neutrophil count: 60 × 109/L). The bone marrow cytology and immunophenotypic findings confirmed the diagnosis of myeloid leukemia. The diagnosis of spinal myeloid sarcoma revealing chronic myeloid leukemia during the blast phase was established. The patient underwent induction chemotherapy. Then, bone marrow cytology revealed less than 3% of blasts, which correspond to cytological remission. Three months later, MRI showed complete disappearance of the epidural masses. A literature review was conducted by searching PubMed using these terms: "Leukemia, Myeloid" AND "Spine" AND "Sarcoma, Myeloid". We emphasize clinical and radiological findings of spinal myeloid sarcoma. This diagnosis should be considered when the MRI reveals epidural mass lesion. The early management of this disease is necessary, and the treatment of myeloid sarcoma is not codified. Our case highlighted that chemotherapy treatment could be sufficient to lead to the disappearance of myeloid sarcoma and the remission of leukemia.

Keywords Leukemia · Myeloid sarcoma · Spine

Introduction

Myeloid sarcoma (MS) or granulocytic sarcomas is an extramedullary proliferation of myeloblasts or immature myeloid cells. It is usually associated with acute myelogenous leukemia (AML) occurring in approximately 3% of these patients [1]. It can also occur in patients with chronic myelogenous leukemia (CML), reflecting the onset of accelerated phase.

It can affect the skin, the bone, the soft tissue of the head and neck, the lymph nodes, and rarely the spine [2]. Epidural involvement is even scarce, occurring in 0.2% of patients with AML [3].

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MS can reveal leukemia or occur during the remission or relapse period. It may also precede leukemic manifestations in the peripheral blood or bone marrow.

We present a rare case of an epidural MS revealing chronic myeloid leukemia during the blast phase. We also conducted a literature review on published spinal MS associated with myeloid leukemia in adult patients.

Search strategy

We presented a case report along with the relevant literature regarding spinal myeloid sarcoma in adults. We performed a literature search in PubMed using the terms: "Leukemia, Myeloid" AND "Spine" AND "Sarcoma, Myeloid". We only included cases with associated leukemia.

We did not include case reports and case series covering MS in children (< 16 years old).

The identified cases are shown in Table 1.

Written informed consent for the case to be published was obtained from the patient for publication of this case report.

Table 1 Literature review from 1988 to 2020: characterization of spinal myeloid sarcoma associated with leukemia

Reference (year)	Location in spine (*n*)	Sex (Age (years))	Delay between MS and ML	Clinical signs (*n*)	Spinal level (*n*)	Biopsy of the mass	Treatment (*n*)	Outcome
[4] (1988)	Epidural (2)	M (19)	Revealing	Back pain, RD	Epidural/thoracic	No	Intrathecal MTX, CT, RT	Died (6 months)
		M (17)	Relapse AML (1 year)	Back pain, weakness, RD	Thoracic	Yes	LaminectomyRT, CT	NS
[5] (1988)	Epidural (1)	M (58)	Preceded AML (7 weeks)	Back pain, neurological deficit	Thoracolumbar	No	CT, RT	Died (6 weeks)
[6] (1990)	Epidural (1)	M (20)	Preceded AML (3 months)	Coccygeal pain, RD	Lumbar sacral	Yes	LaminectomyCT	Remission
[7] (1990)	Epidural (1)	M (24)	Relapse of AML	Neurological deficit	Lumber	No[a]	Intrathecal MTX, CT, RT	MS remission
[8] (1991)	Epidural (1)	M (36)	NS	Low back pain	Thoracic	No	RT	Remission
[9] (1992)	Epidural (1)	M (77)	Revealing AML	Low back pain	Thoracic L2	No[b]	No treatment	Died
[10] (1995)	Epidural (1)	M (27)	Preceded AML (25 days)	RD, neurological deficit	Lumbar	Yes	Laminectomy CT	AML remission, neurological recovery
[11] (1996)	Epidural (1)	M (28)	Preceded AML (10 months)	low back pain, neurological deficit	Thoracic	Yes	LaminectomyCT, intrathecal MTX, RT	MS persistence, died (14 months)
[12] (1996)	Epidural (1)	M (19)	Revealing AML	Low back pain, paraplegia, RD	Thoracic	Yes	LaminectomyCT	AML remission, neurological recovery
[13] (1998)	Epidural (1)	F (45)	Revealing AML	Low back pain, paraplegia	Sacral	No	CT	MS resolution AML remission
[14] (2000)	Epidural (1)	M (58)	Revealing AML	Low back pain, neurological deficit	Thoracic	Yes	LaminectomyCT	AML remission, neurological recovery
[15] (2010)	Epidural (16), prevertebral (13), along nerve root (9), thickening of nerve (6)	21 M/11F (32 [13–66])	Revealing (9 Case) Relapse (23 cases) AML (27 cases) CML (5 cases)	Back pain (9), paraplegia (2), numbness and weakness (12) Others (9)	Lumbo-sacral (23) Thoracic (16) Cervical (5)	Yes (5 from 32 cases)	Laminectomy (4) RT + CT (32)	Died (17 cases) MS resolution (9 cases)
[16] (2011)	Epidural (1)	M (53)	Revealing APM	Weakness	Thoracic	No	CT, RT	Died
[17] (2012)	Epidural (1)	F (28)	Relapse AML (5 years)	Low back pain, numbness	Lumbar	Yes	NS	NS
[18] (2013)	Epidural (1)	M (26)	Revealing APM	Back pain, paraparesis	Thoracic Lumbar	Yes	Laminectomy RT	ALM remission, regression of MS
[19] (2013)	Epidural (1)	M (23)	Relapse of AML	Buttock pain, paresthesia	Sacral	Yes	CT, RT, allogenic transplant	AML remission, neurological recovery
[20] (2014)	Epidural (1)	M (35)	Revealing CML	Neck pain, weakness	Cervical	Yes	Laminectomy	Died (after laminectomy)
[21] (2014)	Epidural (1)	M (59)	Revealing AML	Paraplegia, RD	Thoracic	Yes	Laminectomy CT (intrathecal + systemic)	AML remission, partial regression of MS
[22] (2015)	Epidural (1)	M (20)	Relapse AML	Numbness, weakness	Thoracic	Yes	Laminectomy RT	Partial regression of MS, died (5 months)

Table 1 (continued)

Reference (year)	Location in spine (*n*)	Sex (Age (years))	Delay between MS and ML	Clinical signs (*n*)	Spinal level (*n*)	Biopsy of the mass	Treatment (*n*)	Outcome
[23] (2019)	Epidural (1)	M (68)	Relapse CML (6 months)	Back pain, weakness, RD	Thoracic	Yes	LaminectomyRT, CT	Partial recovery
[24] (2019)	Epidural (3)	M (16)	Revealing AML	Back pain, weakness	Thoracic	Yes	LaminectomyCT	Remission
		M (63)	AML relapse	Back pain, weakness, RD	Thoracic	Yes	Laminectomy	Died (3 months)
		M (53)	Revealing AML	Back pain, weakness, RD	Lumbar	Yes	LaminectomyCT	Died (9 months)

N number of cases, *M* male, *F* female, *RD* rectocystic disturbance, *AML* acute myeloid leukemia, *CML* chronic myeloid leukemia, *APL* acute promyelocytic leukemia, *CT* chemotherapy, *RT* radiotherapy, NS: not specified

[a] Cytology

[b] Postmortem biopsy was performed

Case

A 51-year-old man, with no significant medical history, presented with a 2-month history of progressive back pain and bilateral sciatica. He reported a 6-kg weight loss in 2 months.

Physical examination revealed pallor, hepatomegaly, and splenomegaly. His body temperature was 37.1 °C. He had restricted back movement and a positive straight leg raising test. The neurological examination was unremarkable.

The patient underwent magnetic resonance imaging (MRI) of the spine using a 3 Tesla MRI scanner with 3 mm slices.

MRI showed diffuse low signal intensity of spinal bone marrow on T1-weighted images. Epidural masses were also found extending in front of T2, T11, L3, L4, and L5 and were responsible for a slight restriction of the spinal canal with root compression without cord compression (Fig. 1).

Laboratory examinations showed anemia (8.7 g/dl), thrombocytopenia (89 × 109/L), and hyperleukocytosis (white blood cell count:83 × 109/L, absolute neutrophil count:60 × 109/L). The serum lactate dehydrogenase and uric acid levels were increased (1897 U/L and 736 μmol/L, respectively). The blast count in the peripheral blood represented 45% of the white blood cells.

The percentage of myeloperoxidase-positive blast cells at the bone marrow cytology was 40%. These blasts were positive for CD13, CD33, CD14, CD4, and CD46.

The cytogenetic study revealed a Philadelphia chromosome.

The blast count in the peripheral blood represented 45% of the white blood cells.

The diagnosis of spinal myeloid sarcoma revealing chronic myeloid leukemia (CML) during the blast phase was established.

The patient underwent induction therapy based on idarubicin (20 mg/day) for 3 consecutive days and cytarabine continuously for 7 days (380 mg/day).

Then, bone marrow cytology revealed less than 3% of blasts which corresponded to a cytological remission. Nilotinib therapy was subsequently initiated.

Three months later, the follow-up MRI showed a complete regression of the epidural masses (Fig. 2). The patient reported a significant improvement in pain.

Discussion

Myeloid sarcoma is the result of an extramedullary proliferation of myeloblasts or immature myeloid cells. It can affect 2.4 to 9.1% of patients with acute myeloid leukemia [1, 25]. It may also occur in patients with chronic myelogenous leukemia, especially those with blast crisis and less commonly, in patients with myeloproliferative disorders.

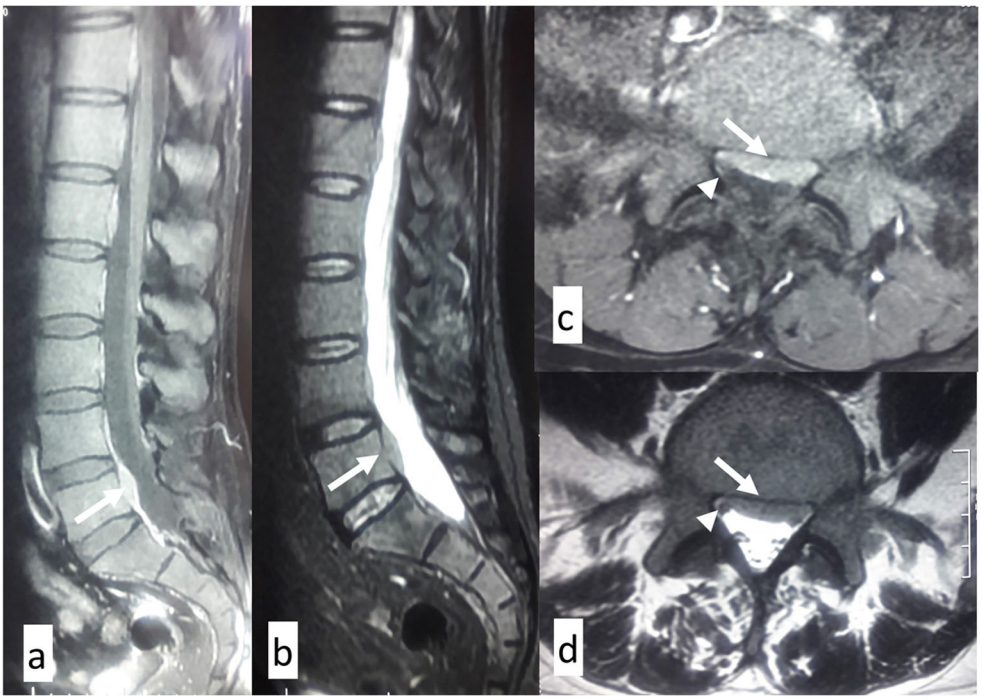

Fig. 1 Spine MRI showing epidural mass at the L5 level with homogeneous enhancement after the intravenous injection of gadolinium (white arrow) on sagittal fat-suppressed T1-weighted image (**a**) and iso-intensity (white arrow) on sagittal fat-suppressed T2-weighted image (**b**). Axial MRI revealing an epidural mass with iso-intensity on T1 (**c**) and T2 (**d**) weighted images responsible for bilateral compression of L5 root (arrow head) and a slight restriction of the spinal canal without cord compression

Isolated MS had been reported in patients without underlying hematological disease. These cases may progress to AML within weeks, months, or years. Therefore, these patients require a long-term follow-up.

Myeloid sarcoma may reveal or occur during these diseases, even in patients in clinical remission. Rarely, they can precede the hematological manifestations. The delay between the diagnosis of MS and the onset of leukemia ranged from a few weeks to 16 years [5, 26].

Myeloid sarcomas can affect several sites such as the skin, lymph nodes, paranasal sinuses, orbits, soft tissue, and bone [1, 8]. Spinal involvement is rare, and epidural involvement is even rarer. The cumulative prevalence was about 1% of patients with myeloid leukemia [15]. In a study including 15 patients with spinal epidural masses, only four patients had spinal MS. It was an isolated MS in one case and MS-related to AML in the three other cases [24].

MS is more frequent in children with AML occurring in up to 40% of cases [27, 28]. Interestingly, the male predominance was striking with a male-to-female ratio at 7.8:1 [27]. This difference may be explained by the higher incidence of leukemia in men than in women.

The thoracic and the lumbar spine are the levels frequently affected [29]. Multiple non-contiguous area involvement, as reported in our patient, was also described [27].

Spinal MS can occur as an epidural mass in the central spinal canal, prevertebral mass, along the nerve root course, or as thickening of the nerve root itself. Table 1 summarized cases of spinal MS-related to myeloid leukemia [4–24]. Among 55 patients with spinal MS, 39 patients had epidural MS. Spinal involvement can cause cord compression or root compression. In our patient, MS was responsible for root compression.

The clinical presentation depends on the level of involvement. It can associate back pain, radicular pain [30], urinary incontinence, numbness weakness, or even acute paraplegia.

Regarding imaging findings, the MRI is the gold standard to assess the epidural involvement. It shows typically epidural mass with iso-intensity on T1-weighted images and isointense or slightly hyperintense signal on T2-weighted images. The enhancement after the injection of gadolinium is usually homogeneous [31, 32].

Diffuse bone marrow infiltration on the MRI suggests the presence of a hematological disorder.

Therefore, the diagnosis of myeloid sarcoma related to leukemia should be considered when MRI shows a diffuse bone marrow signal infiltration associated with multiple epidural masses.

Without evidence of hematological disease, the diagnosis of MS can be challenging. Differential diagnoses include large-cell lymphoma, histiocytic lymphoma, rhabdomyosarcoma, schwannoma, and Ewing sarcoma [5, 33, 34].

Histological findings of MS provide better diagnostic accuracy. However, histological confirmation is not always necessary in patients with Leukemia.

As shown in Table 1, among 55 patients, only 21 patients had histological confirmation of MS.

The pathological study can be carried out on a piece of laminectomy indicated for surgical decompression, an open

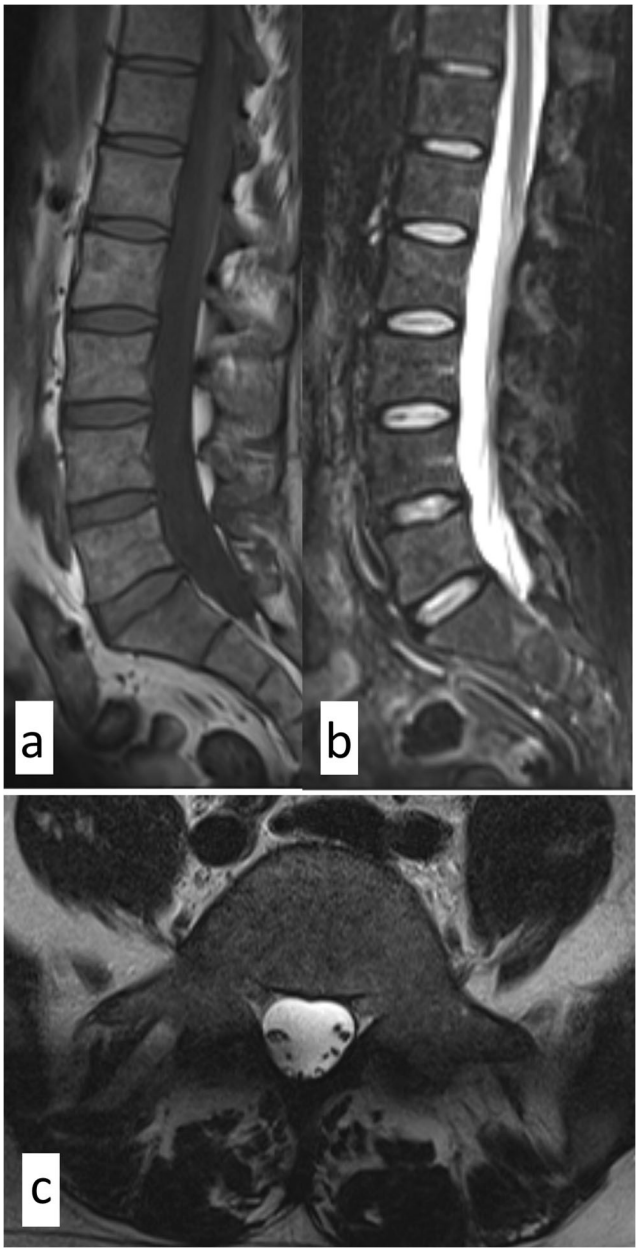

Fig. 2 Spine MRI after 3 months of follow-up showing complete regression of the epidural masses on fat-suppressed T1-weighted image (**a**) and T2-weighted image (**b**, **c**)

biopsy, or a computed tomography-guided needle biopsy. However, the biopsy is associated with a risk of dissemination and should be followed by radiation therapy [22].

There are similarities between the cytogenetical findings of MS tissue and the bone marrow, emphasizing that MS derives from the leukemic clone [4].

Moreover, an immunohistochemical panel, including CD34, CD43, CD45, CD117, CD68, lysozyme, and myeloperoxidase, are useful in differentiating MS from other epidural tumors.

Indeed, CD43, lysozyme, myeloperoxidase, and CD68 are the most sensitive markers for MS [35].

Tumor cells can also be detected in the cerebrospinal fluid [11, 21]. However, a lumbar puncture may be dangerous because it can aggravate a neurological deficit and induce paraplegia [27, 36].

In our case, the biopsy was not performed. The MRI findings and the evidence of CML with blast crisis were sufficient to make the diagnosis.

The management of epidural MS is still controversial given the small number of cases. MS should be treated as acute myelogenous leukemia, even if MS is not associated with leukemia [37].

MS is known to be sensitive to both radiation and chemotherapy, but relapses are not rare [38]. The treatment may also include surgical decompression, intrathecal chemotherapy, and allogeneic stem cell transplantation [39].

Surgical treatment, such as laminectomy, is often indicated in patients with neurological deficit. Nevertheless, this treatment can be tricky and may worsen the neurological deficit, notably when MS is located in the cervical spine [20]. The authors suggested that chemotherapy alone is likely insufficient in patients with cord compression [4, 11].

In the absence of cord compression, the treatment may include high doses of steroids followed by radiotherapy and chemotherapy [4]. Indeed, under chemotherapy alone, the epidural mass may progress on the MRI [11], and neurological damage may persist even if hematological remission was obtained [12].

Radiation therapy can be indicated in several situations such as an isolated MS, the inefficiency of chemotherapy, and relapse after hematopoietic cell transplantation [40]. The stereotactic radiosurgery may be indicated for radioresistant spinal tumors, or oligometastatic disease [41]. This treatment requires pathologic confirmation and should be avoided in case of high-grade spinal cord compression. Furthermore, allogeneic stem cell transplantation may improve the survival of patients with MS [42].

In our case, chemotherapy alone leads to MS disappearance on MRI and cytological remission of leukemia.

Despite the regression of the spinal granulocytic sarcoma, the overall survival rate remains low. It depends on the patient's general status and underlying hematologic disorder [15].

MS is associated with a poor outcome because it represents a sign of CML progression [43].

As shown in Table 1, among 55 patients, 26 patients died (47%). The complete remission of MS was noted in 19 patients.

An early diagnosis may contribute to the improvement of prognosis, mainly neurological damage [23].

In summary, the diagnosis of spinal MS can be very challenging. However, this rare entity should be considered in case of an epidural mass lesion. Bone marrow cytology is required

to diagnose the underlying hematological disorder. An early diagnosis is necessary to improve survival rates.

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Compliance with ethical standards

Disclosures None.

References

1. Neiman RS, Barcos M, Berard C, Bonner H, Mann R, Rydell RE, Bennett JM (1981) Granulocytic sarcoma: a clinicopathologic study of 61 biopsied cases. Cancer. 48(6):1426–1437
2. Sato C, Miyakoshi N, Hongo M, Kasukawa Y, Ishikawa Y, Kudo D, Shimada Y (2019) Spinal epidural myeloid sarcoma with paraplegia in acute myeloid leukemia treated with radiation and chemotherapy: a case report. Open J Orthop 09:131–136
3. Swirsky DM, Li YS, Matthews JG, Flemans RJ, Rees JK, Hayhoe FG (1984) 8;21 translocation in acute granulocytic leukaemia: cytological, cytochemical and clinical features. Br J Haematol 56(2): 199–213
4. Wodzinski MA, Collin R, Winfield DA, Dalton A, Lawrence AC (1988) Epidural granulocytic sarcoma in acute myeloid leukemia with 8;21 translocation. Cancer. 62(7):1299–1300
5. Ripp DJ, Davis JW, Rengachary SS, Lotuaco LG, Watanabe IS (1989) Granulocytic sarcoma presenting as an epidural mass with cord compression. Neurosurgery. 24(1):125–128
6. Watanabe M, Sashikata T, Kizaki T, Fujiwara T, Ugai K, Nakagawa T (1990) A case of epidural granulocytic sarcoma preceding acute leukemia. Acta Pathol Jpn 40(12):922–926
7. Ang P, Virapongse C (1990) Magnetic resonance imaging of spinal intradural granulocytic sarcoma. Magn Reson Imaging 8(1):95–100
8. Freedy RM, Miller KD (1991) Granulocytic sarcoma (chloroma): sphenoidal sinus and paraspinal involvement as evaluated by CT and MR. AJNR Am J Neuroradiol 12(2):259–262
9. Frohna BJ, Quint DJ (1993) Granulocytic sarcoma (chloroma) causing spinal cord compression. Neuroradiology. 35(7):509–511
10. Tosi A, De Paoli A, Fava S, Luoni M, Sironi M, Tocci A et al (1995) Undifferentiated granulocytic sarcoma: a case with epidural onset preceding acute promyelocytic leukemia. Haematologica. 80(1):44–46
11. Fickers M, Theunissen P (1996) Granulocytic sarcoma with expression of CD30. J Clin Pathol 49(9):762–763
12. Aizawa T, Kokubun S, Hatori M, Kashimoto O, Ichinohasama R (1996) Extradural granulocytic sarcoma of the thoracic spine in acute myelogenous leukemia with 8; 21 chromosome translocation. Tohoku J Exp Med 178(4):431–436
13. Novick SL, Nicol TL (1998) Granulocytic sarcoma (chloroma) of the sacrum: initial manifestation of leukemia. Skelet Radiol 27(2): 112–114
14. Niedermayer I, Schmitt-Graeff A, Kölbel CB, Hertel F, Feiden W (2000) Granulocytic sarcoma (so-called chloroma) as a possible cause of spinal cord compression. Case report and differential diagnosis. Pathol. 21(1):82–85
15. Seok JH, Park J, Kim SK, Choi JE, Kim C-C (2010) Granulocytic sarcoma of the spine: MRI and clinical review. Am J Roentgenol 194(2):485–489
16. Bittencourt H, Teixeira Junior AL, Glória ABF, Ribeiro AFLT, Fagundes EM (2011) Acute promyelocytic leukemia presenting as an extradural mass. Rev Bras Hematol E Hemoter 33(6):478–480
17. Smith TR, Slimack N, McClendon J, Wong A, Fessler RG (2012) Low back pain and lumbar radiculopathy as harbingers of acute myeloid leukemia recurrence in a patient with myeloid sarcoma. J Clin Neurosci Off J Neurosurg Soc Australas 19(7):1040–1041
18. Kyaw TZ, Maniam JAS, Bee PC, Chin EF, Nadarajan VS, Shanmugam H et al (2012) Myeloid sarcoma: an unusual presentation of acute promyelocytic leukemia causing spinal cord compression. Turk J Hematol 29(3):278–282
19. Chamberlain MC, Tredway TL, Born D, Fink J (2013) Teaching NeuroImages: sacral spine chloroma. Neurology. 81(11):e87
20. Gupta A, Chanduka A, Sundar IV, Verma J, Chopra S (2014) Granulocytic sarcoma presenting as presenting as monoparesis: a rare case report. Asian J Neurosurg 9(4):241
21. Isshiki Y, Ohwada C, Togasaki E, Shimizu R, Hasegawa N, Yamazaki A, Sugita Y, Kawaguchi T, Tsukamoto S, Sakai S, Takeda Y, Takeuchi M, Sakaida E, Shimizu N, Ota S, Yokote K, Iseki T, Nakaseko C (2014) Acute myeloid leukemia concurrent with spinal epidural extramedullary myeloid sarcoma accompanied by a high CD25 expression and the FLT3-ITD mutation. Intern Med Tokyo Jpn 53(11):1159–1164
22. Joseph JR, Wilkinson DA, Bailey NG, Lieberman AP, Tsien CI, Orringer DA (2015) Aggressive myeloid sarcoma causing recurrent spinal cord compression. World Neurosurg 84(3):866.e7–866.10
23. Koh HJ, Baek J, Lee MS, Park HJ (2019) Epidural chloroma and spinal cord compression. Chin Med J 132(7):853–855
24. Pandey S, Gokden M, Kazemi NJ, Post GR (2019) Hematolymphoid malignancies presenting with spinal epidural mass and spinal cord compression: a case series with rare entities. Ann Clin Lab Sci 49(6):818–828
25. Liu PI, Ishimaru T, McGregor DH, Okada H, Steer A (1973) Autopsy study of granulocytic sarcoma (chloroma) in patients with myelogenous leukemia, Hiroshima-Nagasaki 1949-1969. Cancer. 31(4):948–955
26. Meis JM, Butler JJ, Osborne BM, Manning JT (1986) Granulocytic sarcoma in nonleukemic patients. Cancer. 58(12):2697–2709
27. Mostafavi H, Lennarson PJ, Traynelis VC (2000) Granulocytic sarcoma of the spine. Neurosurgery. 46(1):78–83 discussion 83-84
28. Samborska M, Derwich K, Skalska-Sadowska J, Kurzawa P, Wachowiak J (2016) Myeloid sarcoma in children – diagnostic and therapeutic difficulties. Contemp Oncol 20(6):444–448
29. Petursson SR, Boggs DR (1981) Spinal cord involvement in leukemia: a review of the literature and a case of Ph1+ acute myeloid leukemia presenting with a conus medullaris syndrome. Cancer. 47(2):346–350
30. Kook H, Hwang TJ, Choe K, Yang DW, Nam JH, Park CS (1992) Spinal epidural granulocytic sarcoma preceding acute myelogenous leukemia. J Korean Med Sci 7(3):291–296
31. Ooi GC, Chim CS, Khong PL, Au WY, Lie AK, Tsang KW et al (2001) Radiologic manifestations of granulocytic sarcoma in adult leukemia. AJR Am J Roentgenol 176(6):1427–1431
32. Shinagare AB, Krajewski KM, Hornick JL, Zukotynski K, Kurra V, Jagannathan JP, Ramaiya NH (2012) MRI for evaluation of myeloid sarcoma in adults: a single-institution 10-year experience. Am J Roentgenol 199(6):1193–1198
33. Byrd JC, Weiss RB, Arthur DC, Lawrence D, Baer MR, Davey F, Trikha ES, Carroll AJ, Tantravahi R, Qumsiyeh M, Patil SR, Moore JO, Mayer RJ, Schiffer CA, Bloomfield CD (1997) Extramedullary leukemia adversely affects hematologic complete remission rate and overall survival in patients with t(8;21)(q22;q22): results from cancer and leukemia group B 8461. J Clin Oncol Off J Am Soc Clin Oncol 15(2):466–475
34. Breccia M, Mandelli F, Petti MC, D'Andrea M, Pescarmona E, Pileri SA, Carmosino I, Russo E, Fabritiis PD, Alimena G (2004) Clinico-pathological characteristics of myeloid sarcoma at

diagnosis and during follow-up: report of 12 cases from a single institution. Leuk Res 28(11):1165–1169
35. Alexiev BA, Wang W, Ning Y, Chumsri S, Gojo I, Rodgers WH, Stass SA, Zhao XF (2007) Myeloid sarcomas: a histologic, immunohistochemical, and cytogenetic study. Diagn Pathol 2:42
36. Wong MC, Krol G, Rosenblum MK (1992) Occult epidural chloroma complicated by acute paraplegia following lumbar puncture. Ann Neurol 31(1):110–112
37. Antic D, Verstovsek S, Elezovic I, Grujicic D, Gotic M, Bila J, Perunicic M, Jakovic L (2009) Spinal epidural granulocytic sarcoma in non-leukemic patient. Int J Hematol 89(1):95–97
38. Pui MH, Fletcher BD, Langston JW (1994) Granulocytic sarcoma in childhood leukemia: imaging features. Radiology. 190(3):698–702
39. Lazzarotto D, Candoni A, Filì C, Forghieri F, Pagano L, Busca A, Spinosa G, Zannier ME, Simeone E, Isola M, Borlenghi E, Melillo L, Mosna F, Lessi F, Fanin R (2017) Clinical outcome of myeloid sarcoma in adult patients and effect of allogeneic stem cell transplantation. Results from a multicenter survey. Leuk Res 53:74–81
40. Tsimberidou A-M, Kantarjian HM, Estey E, Cortes JE, Verstovsek S, Faderl S, Thomas DA, Garcia-Manero G, Ferrajoli A, Manning JT, Keating MJ, Albitar M, O'Brien S, Giles FJ (2003) Outcome in patients with nonleukemic granulocytic sarcoma treated with chemotherapy with or without radiotherapy. Leukemia. 17(6):1100–1103
41. Purvis TE, Goodwin CR, Lubelski D, Laufer I, Sciubba DM (2017) Review of stereotactic radiosurgery for intradural spine tumors. CNS Oncol 6(2):131–138
42. Chevallier P, Mohty M, Lioure B, Michel G, Contentin N, Deconinck E, Bordigoni P, Vernant JP, Hunault M, Vigouroux S, Blaise D, Tabrizi R, Buzyn A, Socie G, Michallet M, Volteau C, Harousseau JL (2008) Allogeneic hematopoietic stem-cell transplantation for myeloid sarcoma: a retrospective study from the SFGM-TC. J Clin Oncol Off J Am Soc Clin Oncol 26(30):4940–4943
43. Szymczyk A, Podhorecka M, Tomczak W, Szumiło J, Hus M (2016) Myeloid sarcoma associated with blast crisis in chronic myelogenous leukemia – case report. J Pre-Clin Clin Res 10(2):136–139

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