The First Case of Concomitant *Mycobacterium Genavense* Lymphadenitis and EBV-Positive Lymphoproliferative Disorder

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Abstract. This is the first case of concurrent *Mycobacterium genavense* lymphadenitis and Epstein-Barr virus (EBV)-positive lymphoproliferative disorder (LPD) in the same lymph node with no immunocompromised history. *M. genavense* infection is a rare opportunistic infection mainly for human immunodeficiency virus (HIV)-infected patients. Although no immunodeficiency was detected in our patient, our case indicates that the immunodeficiency in the background of EBV latency type III and the immunosuppression by malignant lymphoma itself might induce the *M. genavense* lymphadenitis. This case highly alerts clinicians to the immunosuppressive state of EBV-positive LPD with latency type III even if any immunodeficient serological factors are not detected.

Keywords: *Mycobacterium genavense*; Epstein-Barr virus-positive lymphoproliferative disorder (EBV-LPD); Programmed cell death 1 ligand 1 (PD-L1).

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Introduction. *Mycobacterium genavense* is a non-tuberculous mycobacterium (NTM), first isolated from 18 HIV-infected patients with CD4-positive T cell counts below 100 /μL in 1992.¹ The infection against non-HIV patients is extraordinarily unusual, and only 46 cases have been reported.² Most cases are immunocompromised hosts, and the common underlying complications are solid organ transplantation, sarcoidosis, and hematopoietic stem cell transplantation. As for the relation with malignant lymphoma, three cases have been reported, and all developed the infection under the immunocompromised conditions due to chemotherapy or immunosuppressive agents. Herein, we report the first non-HIV case of concomitant *M. genavense* lymphadenitis and Epstein-Barr virus (EBV)-positive lymphoproliferative disorder (LPD) with no apparent immunocompromised history.

Case Report. The patient was a 53-year-old male with no significant past medical history. Since December 2017, the fever up to 40°C emerged intermittently, followed by weight loss and right inguinal lymphadenopathy. In February 2018, a CT scan...
showed multiple subphrenic lymphadenopathies. A blood culture detected the bloodstream infection of methicillin-resistant *Staphylococcus aureus* (MRSA), and a gastrointestinal endoscopy revealed the widespread esophageal candidiasis. In March, he was complicated by herpes zoster infection. The right inguinal lymph node biopsy showed mycobacterium infection with malignant lymphoma, and he was transferred to our hospital.

On admission, laboratory data showed a white blood cell count of 14,400 /μL (band cell 3.0%, segmented cell 81.0%, monocyte 8.5%, lymphocyte 7.5%), hemoglobin level of 9.0 g/dL, platelet count of 18.3 x 10⁴ /μL, CD4-positive T cell count of 678 /μL (50.3% of T cells), aspartate transaminase (AST) of 16 U/L, alanine aminotransferase (ALT) of 15 U/L, blood urea nitrogen (BUN) of 5.3 mg/dL, creatinine of 0.60 mg/dL, C-reactive protein (CRP) of 26.52 mg/dL, immunoglobulin G of 1764 mg/dL, soluble IL-2R of 16,523 U/mL. HIV antibody, HTLV-1 antibody, mycobacterium avium complex (MAC) antibody, candida antigen, aspergillus antigen and Interferon-Gamma release assay were negative. Polymerase chain reaction (PCR) assays for the detection of clonally rearranged T cell receptors in the peripheral blood showed no clonality, and lymphocyte blastoid transformation test by phytohemagglutinin (PHA) was 29,300 count per minute (cpm) (normal range: 20,500-56,800 cpm), which suggested no apparent T cell dysfunction.

PET-CT demonstrated multiple enlargements of subphrenic lymph nodes (SUVmax 11.1 in the right inguinal lymph node) (Figure 1a-b). The histopathological examination of the right inguinal lymph node biopsy showed the destruction of normal structure and the mixture of the proliferation of abnormal large lymphoma cells and epithelioid cell granuloma. With small T cells and histiocytes as a background, Hodgkin cells, Reed-Sternberg cells and Lacunar cells invaded. These malignant cells were positive for CD30 and PD-L1, partially positive for CD15, and negative for CD3, CD4, CD8, and CD20 in immunohistochemistry. EBER-ISH was positive, and LMP-1 and EBNA-2 were also partially positive, which suggested EBV infection with latency type III (Figure 2a-e). This case showed more atypical and various cell appearance than Hodgkin lymphoma (HL). EBV-associated HL typically shows EBV infection with latency type II. Based on these pathological findings, EBV-positive LPD with Hodgkin lymphoma-like features was diagnosed.

PCR tests of the right inguinal lymph node were negative for *Mycobacterium tuberculosis* and MAC, and culture tests of bacteria, fungi, and mycobacterium species were also negative. However, Ziehl-Neelsen staining of the biopsy specimen showed acid-fast bacilli in granulomas (Figure 2a). In PCR, we revealed 100% sequence identity of both 16s ribosomal RNA and heat shock protein 65 (hsp65) of *M. genavense*, targeting 710 base pair (bp) sequences out of 1500 bp and 361 bp sequences out of 1623 bp respectively. The detection of *M. genavense* infection by culture is troublesome due to its fastidious growth requirements; therefore, negative culture result cannot exclude *M. genavense* infection. Consequently, EBV-positive LPD and *M. genavense* lymphadenitis were concomitantly diagnosed. We treated him with rifampicin, ethambutol and clarithromycin against *M. genavense*, and adriamycin, vinblastine and dacarbazine for EBV-positive LPD. We excluded bleomycin due to emphysema. Although fever and lymphadenopathy promptly subsided with these double therapies, PET-CT after six cycles showed multiple lymphadenopathies. The right inguinal lymph node

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**Figure 1.** PET-CT images on admission. PET-CT on admission shows (a) multiple enlargement of subphrenic lymph nodes and (b) SUVmax 11.1 in the right inguinal lymph node.
re-biopsy demonstrated the relapse of EBV-positive LPD with no signs of mycobacterium infection. We started salvage chemotherapy and continued triplet antibiotics. The optimal treatment duration against *M. genavense* remains unclear, and we continued the triplet therapy for more than one year. We stopped the triplet antibiotics after 17 months’ duration, and subsequently, the patient has had NTM free follow-up for 14 months.

**Discussion.** Our case is the first case with concomitant *M. genavense* lymphadenitis and malignant lymphoma in the same lymph node. *Mycobacterium genavense* is a rare pathogen named after Geneva, which was first reported in a series of 18 patients with acquired immune deficiency syndrome (AIDS). *M. genavense* infection used to be an opportunistic infectious disease for HIV-infected patients with CD4-positive T cell counts less than 100/μL. However, 46 non-HIV cases have been reported. Most of them were immunocompromised hosts, and the common underlying conditions were solid organ transplantation (40%), sarcoidosis (14%), autoimmune diseases (13%) and hematopoietic stem cell transplantation (7%). 60% were on at least two immunosuppressants, and the median CD4-positive T cell counts were 105/μL. The main symptoms were weight loss, fever, lymphadenopathy and hepatosplenomegaly, which were similar to those of malignant lymphoma.

Three cases reported the relation between *M. genavense* infection and lymphoma (Table 1A). An 80-year-old female patient with chronic lymphocytic leukemia, a 51-year-old female patient with peripheral T cell lymphoma, and a 63-year-old male patient with non-Hodgkin lymphoma (NHL) caused *M. genavense* infection. All cases were under chemotherapy or immunosuppressive therapy when *M. genavense* infection was detected; thus, the situation is different from our patient with concurrent *M. genavense* infection and EBV positive LPD with no immunosuppressive therapy.

Meanwhile, a simultaneous diagnosis of NTM infection and malignant lymphoma has been reported in four cases (Table 1B). Two of them were patients with AIDS, a 27-year-old male patient with MAC infection and HL, and a 31-year-old male patient with NTM infection and NHL. Since NTM infection and malignant lymphoma are both included in AIDS-defining diseases, the possibility of simultaneous onset may be relatively high in AIDS patients. The other two cases were a 13-year-old male with *M. avium* infection and HL, and a 5-year-old male with MAC infection and HL. These cases were compatible with the evidence that NTM lymphadenitis has mainly occurred in children, and MAC accounts for 80-90%. Consequently, our patient is the first adult non-HIV
Table 1(A). The summary of patients with M. genavense infection and malignant lymphoma.

| Case | Age/sex | Phenotype of lymphoma | Clinical presentation | Other underlying conditions | Immunosuppressants | CD4 positive T cell count | Biopsy sites for lymphoma | Infection sites of Mycobacterium | Treatment of mycobacterium | Treatment of lymphoma | Outcome |
|------|---------|----------------------|-----------------------|-----------------------------|--------------------|---------------------------|---------------------------|-----------------------------|-----------------------------|--------------------------|---------|
| 1    | 53/M    | EBV-LPD              | Lymphadenopathy, fever, weight loss | None                        | Chlorambucil + predonosine for B-CLL | 678 /μL                  | Right inguinal LN          | Right inguinal LN, Bone marrow, blood | RFP, EB, CAM                  | None                      | Relapse of LPD |
| 2    | 80/F    | B-CLL                | Lymphadenopathy, splenomegaly, anemia | None                        | Methotrexate, lefunomide, steroid for polyarthritis | N/A                      | Bone marrow               | Right supraclavicular LN, subcutaneous nodules | RFP, EB, CAM                  | ICE, auto SCT           | Recurrent infection |
| 3    | 51/F    | PTCL                 | Lymphadenopathy, weight loss | None                        | N/A                 | 346 /μL                  | Inguinal LN                | Bone marrow, disseminated | N/A                        | CR                       | CR |
| 4    | 63/M    | NHL                  | N/A                    | N/A                        | N/A                 | N/A                      | N/A                       | N/A                        | N/A                        | N/A                      | N/A |

Table 1(B). The summary of patients with concomitant NTM infection and malignant lymphoma.

| Case | Age/sex | Phenotype of lymphoma | Mycobacterium species | Clinical presentation | Other underlying conditions | Immunosuppressants | CD4 positive T cell count | Biopsy sites for lymph node | Infection sites of Mycobacterium | Treatment of mycobacterium | Treatment of lymphoma | Outcome |
|------|---------|----------------------|----------------------|-----------------------|-----------------------------|--------------------|---------------------------|-----------------------------|-----------------------------|--------------------------|--------------------------|---------|
| 5    | 27/M    | EBV-associated HL (MC type) | MAC                  | Intermittent fever, lymphadenopathy | AIDS                     | None                | <50                      | Left cervical LN          | Left cervical LN, Intrasanal ulcerating lesion | RFP, EB, CAM | None |
| 6    | 31/M    | NHL (unknown phenotype) | Not identified        | Right facial swelling  | AIDS                      | None                | N/A                      | Intrasanal ulcerating lesion | Supravacular LN            | EB, RFP, INH, PZA       | CR                       | CR |
| 7    | 13/F    | HL (MC type)         | M. avium             | Supravacular mass     | None                      | None                | N/A                      | Supravacular LN            | Lung, left supraclavicular LN | EB, RFP, AZM       | CR                       | CR |
| 8    | 5/M     | NLPHL                | MAC                  | Cervical lymphadenopathy | N/A                      | None                | N/A                      | Lung, gastric aspirates    | Lung, left supraclavicular LN | EB, RFP, AZM       | ABVE/PC       |

AMK, amikacin; auto SCT, autologous stem-cell transplantation; AVD, adriamycin, vinblastine and dacarbazine; B-CLL, B cell chronic lymphocytic leukemia; EB, ethambutol; EBV-LPD, EBV positive lymphoproliferative disorder; CAM, clarithromycin; CR, complete remission; ICE, ifosfamide, cisplatin and etoposide; LN, lymph node; N/A, not available; NHL, non-Hodgkin lymphoma; PTCL, peripheral T cell lymphoma; RFP, rifampicin.

Table 1(A). The summary of patients with M. genavense infection and malignant lymphoma.

Table 1(B). The summary of patients with concomitant NTM infection and malignant lymphoma.

This patient presents with an EBV latency type III. It is typically observed in immunodeficiency-associated LPD and a part of EBV-positive diffuse large B cell lymphoma (DLBCL), not otherwise specified (NOS), which indicates the highly immunodeficient background. Furthermore, this case with concomitant NTM lymphadenitis and lymphoma.
patient suffered from \textit{M. genavense} lymphadenitis, MRSA bacteremia, widespread esophageal candidiasis, and herpes zoster infection. These bacterial, fungal, and viral infections further suggest an immunocompromised condition. However, this case did not have primary immune disorders, HIV infection, or another iatrogenic immunodeficiency, or pathological features of DLBCL. White blood count, CD4-positive T cell count, and immunoglobulin levels were normal. T cell receptors in the peripheral blood were polyclonal, and the lymphocyte blastoid transformation test by phytohemagglutinin (PHA) was normal, which suggested no apparent T cell dysfunction. Mycobacterial, fungal, and viral infections can be caused by monocytopenia and mycobacterial infection (MonoMAC) syndrome.\textsuperscript{15} However, the differential blood count, including the monococyte count of this patient was normal, which exclude the possibility of MonoMAC syndrome. Furthermore, we analyzed the sequence of GATA binding protein 2 (\textit{GATA2}) using DNA extracted from peripheral blood and found a single-nucleotide polymorphism c.490 G>A (p.A164T) and a silent mutation c.15 C>G. In addition, our case did not have the age like suffering from severe immunosenescence, which is critical for the pathogenesis of EBV-positive DLBCL, NOS.\textsuperscript{14} Based on these results, no immunodeficiency could be detected in our patient.

Patients with HL are often complicated with tuberculosis.\textsuperscript{16} HL cells are known to highly express PD-L1 and cause intratumoral T cell exhaustion, leading to T cell dysfunction.\textsuperscript{17} Generally, high PD-L1 expression on malignant lymphoma cells is due to either the amplification of the PD-L1 locus on chromosome 9p24.1, which is a recurrent abnormality seen in HL, or EBV infection.\textsuperscript{18} EBV infection upregulates PD-L1 expression via EBNA2, the characteristic of EBV latency type III.\textsuperscript{18} In our case, EBNA2 induced PD-L1 expression on the lymphoma cells and might activate PD-1/PD-L1 signaling on the surrounding T cells. Immune checkpoint players such as PD-1, cytotoxic T lymphocyte antigen 4 (CTLA-4), and T cell immunoglobulin and mucin domain-containing molecule 3 (TIM-3) have been well known for the role of not only cancer immune escape but also immunosuppression during chronic infection.\textsuperscript{19,20} For example, during chronic \textit{Mycobacterium tuberculosis} infection, T cells express multiple inhibitory receptors, including PD-1 and TIM-3, which cause T cell exhaustion.\textsuperscript{21} It promotes impairment of T cell function and impairs host resistance to \textit{M. tuberculosis}.\textsuperscript{21} These reports suggest that T cell exhaustion may induce the exacerbation of infections against mycobacterium species. Therefore, the immunosuppressive effect through the PD-1/PD-L1 axis might promote the simultaneous \textit{M. genavense} infection in our case. Consequently, our case indicates that the immunodeficiency in the background of EBV latency type III and the immunosuppression by malignant lymphoma itself might induce the \textit{M. genavense} lymphadenitis and other bacterial, fungal, and viral infections. Our case highly alerts clinicians of the immunosuppresssive state of EBV-positive LPD with latency type III even if any immunodeficient serological factors are not detected.

\textbf{Conclusions.} This is the first case of simultaneously diagnosed \textit{M. genavense} lymphadenitis and EBV-positive LPD with no immunocompromised history. As patients with EBV-positive LPD with latency type III may be highly susceptible to mycobacterium species and other opportunistic infections, there should be increased awareness of their marked immunocompromised condition regardless of the existence of any immunodeficient serological findings.

\textbf{References:}

1. Böttger EC, Teske A, Kirschner P, Bost S, Chang HR, Beer V, Hirschel B. Disseminated "Mycobacterium genavense" infection in patients with AIDS. Lancet 1992;340:76-80. https://doi.org/10.1016/0140-6736(92)90397-L
2. Mahmoud M, Ajmal S, Abu Saleh OM, Bryson A, Marcelin JR, Wilson JW. Mycobacterium genavense infections in non-HIV immunocompromised hosts: a systematic review. Infect Dis. 2018;50:329-39. https://doi.org/10.1080/23744235.2017.1404630
3. van Dongen JJ, Langerak AW, Brüggemann M, Evans PA, Hummel M, Lavender FL, Delabesse E, Davi F, Schuuring E, García-Sanz R, van Krieken JH, Droese J, González M, Parreira A, Smith JL, Morgan GJ, Kneba M, Macintyre EA. Design and standardization of PCR primers and protocols for detection of clonal immunoglobulin and T-cell receptor gene recombinations in suspect lymphoproliferations: report of the BIOMED-2 Concerted Action BMH4-CT98-3936. Leukemia 2000;17:2257-2317. https://doi.org/10.1038/sj.leu.2403202
4. Pai S, Esen N, Pan X, Musser JM. Routine rapid Mycobacterium species assignment based on species-specific allelic variation in the 65-kilodalton heat shock protein gene (hsp65). Arch Pathol Lab Med. 1997;121:859-64
5. Ombelet S, Van Wijnjaerden E, Lagrou K, Tousseyn T, Gheysens O, Droogwe W, Doublé P, Kyypers D, Claes KJ. Mycobacterium genavense infection in a solid organ recipient: a diagnostic and therapeutic challenge. Transpl Infect Dis. 2016;18:125-31. https://doi.org/10.1111/tid.12493
6. Krebs T, Zimmert S, Bodmer T, Lämmlle B. Mycobacterium genavense infection in a patient with long-standing chronic lymphocytic leukaemia. J Intern Med.2000;248:343-48. https://doi.org/10.1046/j.1365-2796.2000.00730.x
7. Numbi N, Demeure F, Van Bleyvenbergh P, De Visscher N. Disseminated Mycobacterium genavense infection in a patient with immunosuppressive therapy and lymphoproliferative malignancy. Acta Clin Belg. 2014;69:142-5 https://doi.org/10.1179/0001551213z.0000000016
8. Hoefsloot W, van Ingen J, Peters EJ, Magis-Escuria C, Dekhuijzen PN, Boeree MJ, van Soolingen D. Mycobacterium genavense in the Netherlands: an opportunistic pathogen in HIV and non-HIV patients.
immunocompromised patients. An observational study in 14 cases. Clin Microbiol Infect. 2013;19:432-7
https://doi.org/10.1111/j.1469-0691.2012.03817.x
PMid:22439918

9. Broussset P, Marchou B, Chittal SM, Delsol G. Concomitant Mycobacterium avium complex infection and Epstein-Barr virus associated Hodgkin's disease in a lymph node from a patient with AIDS. Histopathology 1994;24:586-8
https://doi.org/10.1111/j.1365-2559.1994.tb00583.x
PMid:8063299

10. Kenaii MS, Fadzilah I, Maizaton AA, Sani A. Concurrent mycobacterial infection and non-Hodgkin's lymphoma at the same site in an AIDS patient. Med J Malaysia. 2004;59:108-11

11. de Armas Y, Capó V, González I, Mederos L, Díaz R, de Waard JH, Rodríguez A, García Y, Cabanas R. Concomitant Mycobacterium avium Infection and Hodgkin's Disease in a Lymph Node from an HIV-negative Child. Pathol Oncol Res. 2011;17:139-140
https://doi.org/10.1007/s12253-010-9275-5
PMid:20467849

12. Gupta S, Cogbill CH, Gheorghe G, Rao AR, Kumar S, Havens PL, Caminita BM, Warwick AB. Mycobacterium avium intracellular Infection Coexistent With Nodular Lymphocyte Predominant Hodgkin Lymphoma Involving the Lung. J Pediatr Hematol Oncol. 2011;33:e127-31
https://doi.org/10.1097/MPH.0b013e3181f299a
PMid:21399527

13. García-Marcos PW, Plaza-Fornieles M, Menasalvas-Ruiz A, Ruiz-Pruneda R, Paredes-Reyes P, Miguelez SA. Risk factors of non-tuberculous mycobacterial lymphadenitis in children: a case-control study. Eur J Pediatr. 2017;176:607-13
https://doi.org/10.1007/s00431-017-2882-3
PMid:28265761

14. Castillo JJ, Beltran BE, Miranda RN, Young KH, Chavez JC, Sotomayor EM. EBV-positive diffuse large B-cell lymphoma, not otherwise specified: 2018 update on diagnosis, risk-stratification and management. Am J Hematol. 2018;93:953-62
https://doi.org/10.1002/ajh.25112
PMid:29984868

15. Hsu AP, Sampaio EP, Khan J, Calvo KR, Lemieux JE, Patel SY, Frucht DM, Vinh DC, Auth RD, Freeman AF, Olivier KN, Uzel G, Zerbe CS, Spalding C, Pittaluga S, Raffeld M, Kuhns DB, Ding L, Paulson ML, Marciano BE, Gea-Banacloche JC, Orange JS, Cuellar-Rodriguez J, Hickstein DD, Holland SM. Mutations in GATA2 are associated with the autosomal dominant and sporadic monocytopenia and mycobacterial infection (MonoMAC) syndrome. Blood. 2011;118:2653-5
https://doi.org/10.1182/blood-2011-05-356352
PMid:21670465 PMCid:PMC3172785

16. Harris J, Alexanian R, Hersh EM, Leary W. Hodgkin's Disease Complicated by Infection with Mycobacterium kansasii. Can Med Assoc J. 1969;101:231-4

17. Ansell SM, Lesokhin AM, Borrello I, Halwani A, Scott EC, Gutierrez M, Schuster SI, Millenson MM, Catry D, Freeman GI, Rodig SI, Chapuy B, Ligoy AH, Zhu L, Grosso JF, Kim SY, Timnerman JM, Shipp MA, Armand P. PD-1 Blockade with Nivolumab in Relapsed or Refractory Hodgkin's Lymphoma. N Engl J Med. 2014;372:311-9
https://doi.org/10.1056/NEJMoa1411087
PMid:25482239 PMCid:PMC4348009

18. Anastasiadou E, Stroopinsky D, Alimperti S, Jiao AL, Pyzer AR, Cippitelli C, Pepe G, Severa M, Rosenblatt J, Etna MP, Rieger S, Kempkes B, Coccia EM, Sui SJH, Chen CS, Uccini S, Avigan D, Faggioni A, Trivedi P, Slack FJ. Epstein-Barr virus-encoded EBNA2 alters immune checkpoint PD-L1 expression by downregulating miR-34a in B-cell lymphomas. Leukemia 2019;33:132-47
https://doi.org/10.1038/s41375-018-0178-x
PMid:29946193 PMCid:PMC6327052

19. Das M, Zhu C, Kuchroo VK. Tim-3 and its role in regulating anti-tumor immunity. Immunol Rev. 2017;276:97-111
https://doi.org/10.1111/imr.12520
PMid:28258697 PMCid:PMC5512889

20. Jayaraman P, Jacques MK, Zhu C, Stebloken KM, Stowell BL, Madi A, Anderson AC, Kuchroo VK, Behar SM. TIM3 Mediates T Cell Exhaustion during Mycobacterium tuberculosis Infection. PLoS Pathog. 2016;12:e1005490
https://doi.org/10.1371/journal.ppat.1005490
PMid:26967901 PMCid:PMC4788425