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Three novel homozygous *ITGB2* mutations among two patients with leukocyte adhesion defect type-1: The first report in Thailand

Suksawat Y *et al.* *ITGB2* mutations LAD-1 in Thailand

Yiwa Suksawat, Punchama Pacharn, Nunthana Siripipattanamongkol, Boonchai Boonyawat

Abstract

BACKGROUND

A leukocyte adhesion defect (LAD) is a rare primary immunodeficiency disorder. LAD type 1 (LAD-1) is the most common, which is caused by *ITGB2* mutation resulting in dysfunction of $\beta 2$ integrin, which impairs leukocyte adherence to the endothelium.

CASE SUMMARY

The first two cases of LAD-1 in Thailand presented with recurrent omphalitis, soft tissue infection, marked leukocytosis, and neutrophilia. One patient experienced delayed umbilical cord separation. Mutation analysis was performed by direct DNA sequencing of the *ITGB2* gene. The results revealed two novel homozygous missense mutations, c.920C>T (p.Leu307Pro) in exon 8 and c.758G>A (p.Arg253His) in exon 7, and one novel homozygous nonsense mutation, c.262C>T (p.Gln88Ter) in exon 4, in the genomic DNA of the first and second patients, respectively. Heterozygous mutations were identified in the parents of both patients, suggesting a carrier status. The patients were administered intravenous antibiotics for infections with good clinical responses. Hematopoietic stem cell transplantation could not be performed due to the

unavailability of matched donors. However, a significant decline in infections was observed after antibiotic prophylaxis. Several follow-up visits were conducted for both patients. They are currently 6 years old.

CONCLUSION

Molecular analysis is essential for definitive diagnosis, early treatment implementation, and prevention of LAD-1 in future pregnancy.

Key Words: Leukocyte adhesion defect; *ITGB2*; Omphalitis; Bacterial soft tissue infection; Molecular investigation; Case report

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Core Tip: Leukocyte adhesion defect (LAD) is a rare autosomal recessive primary immunodeficiency disorder characterized by defects in the leukocyte recruitment cascade. LAD type 1, caused by a mutation in *ITGB2*, is the most common form. Here, we report the first two cases of LAD type 1 with a molecularly confirmed *ITGB2* mutation in Thailand. At the time of initial presentation, both patients had recurrent omphalitis, bacterial soft tissue infection, and marked leukocytosis. Molecular analysis revealed two missense variants and one nonsense mutation. Early identification of these patients by molecular analysis was proven essential for definitive diagnosis, proper antibiotic prophylaxis, and initiation of matched donor hematopoietic ⁴ stem cell transplantation.

INTRODUCTION

Leukocyte adhesion defect (LAD) is a rare autosomal recessive primary immunodeficiency disorder affecting one in every 100000 individuals. A deficiency in

the leukocyte adhesion cascade to the blood vessel wall is the pathogenesis of LAD and is classified into three types. LAD type 1 (LAD-1) (OMIM#116920), which is caused by a mutation in the *ITGB2* gene, is the most common form. The *ITGB2* gene (OMIM*600065) is located on 21q22.3 and encoded the common β subunit of the β 2 integrin protein (CD18). Dysfunctional β 2 integrin is the main defect in LAD-1 and is attributable to impaired neutrophil firm adhesion^[1]. The hallmark characteristics are recurrent bacterial skin and soft tissue infections, omphalitis, and delayed umbilical cord separation. In addition, the absence of pus formation is a distinctive feature^[2]. LAD-1 diagnosis can be confirmed by flow cytometric expression of CD18 and CD11 on leukocytes or *ITGB2* mutation analysis^[2,3]. To date, more than 110 mutations have been identified^[3]. Here, we report the first two cases of LAD-1 with molecularly confirmed *ITGB2* mutation in Thailand. The study protocol was approved by the Institutional Review Board of the Royal Thai Army.

CASE PRESENTATION

Chief complaints

Case 1: A 21-mo-old Burmese boy presented with prolonged fever and multiple whitish ulcers in the oropharynx (Patient #1, P1).

Case 2: A 9-d-old Thai girl presented with redness around the umbilical stump (Patient #2, P2).

History of present illness

P1: The patient had fever and dyspnea for 3 wk. Additionally, he had been previously treated in Myanmar and Laos; however, his clinical condition had deteriorated, and he was referred from a rural hospital near the Thai border. He was on the verge of respiratory failure due to acute upper airway obstruction. Emergency tracheostomy was performed, and pus with debris extending to the oropharynx, larynx, and epiglottis was discovered intraoperatively. *Streptococcus viridans* and *Staphylococcus epidermidis* were identified in the pus cultures. Although intravenous antibiotics were

administered, healing of the wound was difficult. He was re-admitted several times with chronic wound infections around the tracheostomy site, *Pseudomonas aeruginosa* pneumonia, oral candidiasis, and cellulitis. Several organisms, including *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, *Salmonella gr.B*, and carbapenem-resistant Enterobacteriaceae *Klebsiella pneumoniae* were identified in pus cultures.

P2: At 9 d of age, she presented with fever and abdominal distension. Physical examination revealed minimal pus with redness around the umbilical stump (Figure 1). The patient was then diagnosed with omphalitis. Intravenous cloxacillin and metronidazole were administered; however, her clinical condition worsened. Omphalitis persisted until 4 wk of age. Pus culture revealed *Staphylococcus epidermidis*, *Escherichia coli*, and extended-spectrum beta-lactamase-producing *Klebsiella pneumoniae*. The intravenous antibiotics were switched to carbapenems, with some clinical improvement. She was re-admitted because of recurrent omphalitis at 6 wk of age. After administration of intravenous antibiotics for 3 d, her symptoms subsided. At 2 mo of age, she was referred to our university hospital for assessment of recurrent omphalitis.

History of past illness

P1: The patient had a delayed umbilical cord detachment 30 d after birth and delayed wound healing, resulting in difficult-to-treat omphalitis.

P2: The patient's umbilical cord was separated 20 d after birth.

Personal and family history

P1: The patient was born at term with an uneventful pregnancy and delivery history. The patient completed an extended immunization program based on his age. His sister had no health issues despite being the second child of consanguineous parents.

P2: The patient was born at term with an uneventful pregnancy and perinatal history. Her birth weight was 2650 g. BCG and HBV vaccines were administered after birth. She was the first child of a couple who had denied consanguinity.

Physical examination

Physical examination of P1 revealed a weight of 9.5 kg (3rd percentile) and a height of 82 cm (25th–50th percentile). Multiple whitish ulcers were present on both lips and the oral cavity, and a BCG scar was observed on the left shoulder. Mild hepatosplenomegaly was observed.

Physical examination of P2 revealed normal growth parameters. Periumbilical redness with a lack of pus formation was observed, and a BCG scar was observed on the left shoulder.

Laboratory examinations

P1: Complete blood count revealed leukocytosis (WBC 94600/mm³) and neutrophil predominance (67166/mm³), while anti-HIV was negative. Bone marrow aspiration revealed no evidence of hematological malignancy. His parents were asked for permission to conduct immunologic tests, but they denied due to financial concerns.

P2: Complete blood count showed significant leukocytosis (65300/mm³) and neutrophilia (46800/mm³). The lymphocyte populations determined using flow cytometry, serum immunoglobulin levels, and dihydrorhodamine 123 assays were normal.

Imaging examinations

P1: Chest radiography showed patchy infiltration in both lower lungs. Computed tomography of the neck showed obstruction of the upper airway due to an infection involving the mucosa of the oropharynx, hypopharynx, glottic, and subglottic levels.

P2: Anatomical abnormalities of the umbilicus were excluded by abdominal ultrasound, which revealed neither a patent urachus nor an omphalomesenteric cyst.

The diagnosis of LAD-1 was suspected in both patients.

FINAL DIAGNOSIS

The final diagnosis for both patients was LAD-1 with the carrier status in the parents.

TREATMENT

P1: Intravenous cloxacillin, ceftazidime, and amikacin were administered for chronic wound and soft tissue infections, resulting in good clinical responses.

P2: The use of intravenous gentamycin and ciprofloxacin for recurrent omphalitis improved her clinical outcome. She has not presented with omphalitis since that time.

OUTCOME AND FOLLOW-UP

Currently, hematopoietic stem cell transplantation cannot be performed because of the unavailability of matched donors. Sulfamethoxazole-trimethoprim with itraconazole prophylaxis was initiated and a significant decline in infection was noted. P1 developed a soft tissue infection around the tracheostomy, and P2 had occasional gastroenteritis and chronic otitis media in response to antibiotics. Several follow-up visits were conducted for both patients. They are currently six years old.

DISCUSSION

LAD-1 was first identified in 1979^[6]. To date, more than 400 LAD-1 cases have been reported with the highest prevalence in Iran, the United States, and India in over 100 publications^[7,8]. Our report is the first case series of LAD-1 diagnosed in Thailand. Patients with LAD-1 usually present in infancy with delayed umbilical cord separation, omphalitis, and skin infection in both mucosal and subcutaneous tissues. LAD-1 is classified as mild (LAD-1⁺), moderate (LAD-1⁻), or severe (LAD-1⁰) depending on CD18 expression in neutrophils. Although the CD18 expression study remains unavailable at our institution, our patients were suspected of having LAD-1⁰ due to the early age of onset^[3,7-9]. Both patients experienced omphalitis at the first presentation, which was also the most common initial manifestation among patients with LAD-1⁰ in related studies^[8,10,11]. However, delayed cord separation after three weeks was only observed in

P1, suggesting that this clinical feature may not be an essential characteristic of LAD-1⁰[8-10,12].

Other common infections that have been widely reported in related studies, including respiratory tract infection and sepsis^[5-8,10], were not identified in P2, which could possibly be explained by early diagnosis and antibiotic prophylaxis in this patient. The spectra of infectious organisms in our patients were similar to those of other reported cohorts in which bacterial infections, including gram-positive cocci (Staphylococci or Streptococci) and gram-negative bacteria (*Pseudomonas aeruginosa* or *Klebsiella pneumoniae*) were predominantly identified^[8,9,11]. Marked neutrophilic leukocytosis, which is the hallmark of LAD-1, was found in both patients.

The BCG vaccine is routinely prescribed for newborns as part of the national immunization program in Thailand. Vaccine-associated serious BCG infection has been reported among people with immunodeficiency, particularly severe combined immunodeficiency and chronic granulomatous disease (CGD)^[13]. Furthermore, we previously described a case of X-linked CGD with disseminated BCG infection^[14]. According to the recent vaccination recommendations for primary immunodeficiency disease, live bacterial vaccines, such as BCG vaccine, are not recommended for patients with LAD^[15]. Nevertheless, no BCG vaccine-related complications were reported among patients with LAD in the most recent systematic review^[13], except for one reported Japanese girl with LAD-1 who had necrotizing ulcers after BCG vaccination^[16]. This phenomenon is explained by a study in mice with abnormal integrins, CD11a and CD18, which were susceptible to *Mycobacterium tuberculosis* infection, indicating that adhesion molecules are essential for mycobacterial immunity^[17]. Because BCG vaccination was administered to both patients at birth, BCG-related complications were monitored. To date, BCG-related complications have not been observed.

The diagnosis of LAD-1 is based on either the flow cytometric expression study of CD18 on leukocytes or molecular confirmation. Due to the unavailability of the CD18 expression study at our institution, molecular analysis by direct DNA sequencing of *ITGB2* was performed. Mutations in the *ITGB2* gene are heterogeneous, and missense

mutations are the main cause of LAD-1 deficiency. Most mutations ²are located in the highly conserved domain, Von Willebrand Factor type A (VWFA), which consists of 240 amino acids encoded by exons 5 to 9 of the *ITGB2* gene. This domain is required for the enzymatic activity of the $\beta 2$ integrin (CD18). Other mutations are scattered throughout the gene^[3,4,7,8,10].

This study identified three novel mutations: two likely deleterious missense mutations and one deleterious nonsense mutation. The two missense variants, c.920C>T (p.Leu307Pro) in exon 8 and c.758G>A (p.Arg253His) in exon 7, which were identified in P1, are located in the VWFA domain, which is highly conserved in the $\beta 2$ integrin protein. The c.920C>T variant has never been identified in either the Exome Aggregation Consortium (ExAC) or the 1000 Genomes Project population databases. c.758G>A is a rare variant identified in approximately 4 of 8632 individuals of East Asian ancestry according to the ExAC database and was identified only in the heterozygous state. Additionally, these two homozygous missense mutations were not identified in the Thai Reference Exome variant database (1092 unrelated Thai individuals; T-Rex, <https://trex.nbt.or.th/>).

Most of the *in silico* analysis tools consistently predicted these two variants that may damage protein function (Table 2). Many missense pathogenic variants in nearby residues in the *ITGB2* gene have been reported to be associated with LAD-1^[3]. These reasons support the possibility of “likely pathogenic” for both missense variants in Myanmar patients with LAD-1. ²Further *in vitro* studies may address the possible impact of amino acid substitutions on the function of $\beta 2$ integrin. Unfortunately, functional studies cannot be performed at our institution. Two mutations were detected simultaneously in some of the previously reported patients^[4]. One nonsense mutation, c.262C>T (p.Gln88Ter) in exon 4, which was identified in P2, leads to a premature stop at codon 88 which normally encodes for glutamine and results in loss of both active VWFA and cysteine rich domains of $\beta 2$ integrin protein. This nonsense mutation has never been reported in the ExAC or 1000 Genomes Project databases. The VWFA domain is crucial for the ¹structural association of a β -integrin subunits for heterodimer

formation on the cell surface and functional activity. Any significant alterations in this region will definitely have a deleterious effect on the expression and function of $\beta 2$ integrin and result in the LAD-1⁰ phenotype among most patients with LAD-1^[8,10]. Even though consanguineous marriage was denied by the parents of P2, consanguinity could not be excluded based on the identification of a novel nonsense mutation in the homozygous state in the patient and the heterozygous state in both parents.

LAD-1⁰ has an extremely poor prognosis, with the majority of patients dying within two years of life^[7,12]. Early hematopoietic stem cell transplantation remains the treatment of choice, but this is unavailable for the majority of affected children in developing countries, including our patients. Thus, antibiotics used for prophylaxis and treatment of infections are the mainstay of treatment, while waiting for matched donors.

CONCLUSION

Herein, we report two classic cases of severe LAD-1. Early onset and recurrent omphalitis were common pathognomonic signs in our patients. A significant increase in white blood cell counts combined with neutrophilia should increase the awareness of LAD-1. Mutation analysis of the *ITGB2* gene remains the gold standard for the diagnosis of LAD-1. Three novel homozygous *ITGB2* mutations were identified in these patients. Molecular investigation is essential for definitive diagnosis, early treatment implementation, and prenatal diagnosis in future pregnancies.

ACKNOWLEDGEMENTS

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REFERENCES

- 1 Hanna S, Etzioni A. Leukocyte adhesion deficiencies. *Ann N Y Acad Sci* 2012; **1250**: 50-55 [PMID: 22276660 DOI: 10.1111/j.1749-6632.2011.06389.x]

- 2 **van de Vijver E**, van den Berg TK, Kuijpers TW. Leukocyte adhesion deficiencies. *Hematol Oncol Clin North Am* 2013; **27**: 101-116, viii [PMID: 23351991 DOI: 10.1016/j.hoc.2012.10.001]
- 3 **van de Vijver E**, Maddalena A, Sanal Ö, Holland SM, Uzel G, Madkaikar M, de Boer M, van Leeuwen K, Köker MY, Parvaneh N, Fischer A, Law SK, Klein N, Tezcan FI, Unal E, Patiroglu T, Belohradsky BH, Schwartz K, Somech R, Kuijpers TW, Roos D. Hematologically important mutations: leukocyte adhesion deficiency (first update). *Blood Cells Mol Dis* 2012; **48**: 53-61 [PMID: 22134107 DOI: 10.1016/j.bcmd.2011.10.004]
- 4 **Yassaee VR**, Hashemi-Gorji F, Boosaliki S, Parvaneh N. Mutation spectra of the ITGB2 gene in Iranian families with leukocyte adhesion deficiency type 1. *Hum Immunol* 2016; **77**: 191-195 [PMID: 26639818 DOI: 10.1016/j.humimm.2015.11.019]
- 5 **Taghizade Mortezaee F**, Esmaeli B, Badalzadeh M, Ghadami M, Fazlollahi MR, Alizade Z, Hamidieh AA, Chavoshzadeh Z, Movahedi M, Heydarzadeh M, Sadeghi Shabestari M, Tavassoli M, Nabavi M, Nasiri Kalmarzi R, Pourpak Z. Investigation of ITGB2 gene in 12 new cases of leukocyte adhesion deficiency-type I revealed four novel mutations from Iran. *Arch Iran Med* 2015; **18**: 760-764 [PMID: 26497373]
- 6 **Hayward AR**, Harvey BA, Leonard J, Greenwood MC, Wood CB, Soothill JF. Delayed separation of the umbilical cord, widespread infections, and defective neutrophil mobility. *Lancet* 1979; **1**: 1099-1101 [PMID: 86829 DOI: 10.1016/s0140-6736(79)91786-0]
- 7 **Almarza Novoa E**, Kasbekar S, Thrasher AJ, Kohn DB, Sevilla J, Nguyen T, Schwartz JD, Bueren JA. Leukocyte adhesion deficiency-I: A comprehensive review of all published cases. *J Allergy Clin Immunol Pract* 2018; **6**: 1418-1420.e10 [PMID: 29371071 DOI: 10.1016/j.jaip.2017.12.008]
- 8 **Kambli PM**, Bargir UA, Yadav RM, Gupta MR, Dalvi AD, Hule G, Kelkar M, Sawant-Desai S, Setia P, Jodhawat N, Nambiar N, Dhawale A, Gaikwad P, Shinde S, Taur P, Gowri V, Pandrowala A, Gupta A, Joshi V, Sharma M, Arora K, Pilania RK, Chaudhary H, Agarwal A, Katiyar S, Bhattad S, Ramprakash S, Cp R, Jayaram A, Gornale V, Raj R, Uppuluri R, Sivasankaran M, Munirathnam D, Lashkari HP, Kalra M, Sachdeva A, Sharma A, Balaji S, Govindraj GM, Karande S, Nanavati R, Manglani M, Subramanyam

G, Sampagar A, Ck I, Gutha P, Kanakia S, Mundada SP, Krishna V, Nampoothiri S, Nemani S, Rawat A, Desai M, Madkaikar M. Clinical and Genetic Spectrum of a Large Cohort of Patients With Leukocyte Adhesion Deficiency Type 1 and 3: A Multicentric Study From India. *Front Immunol* 2020; **11**: 612703 [PMID: 33391282 DOI: 10.3389/fimmu.2020.612703]

9 **Shaw JM**, Al-Shamkhani A, Boxer LA, Buckley CD, Dodds AW, Klein N, Nolan SM, Roberts I, Roos D, Scarth SL, Simmons DL, Tan SM, Law SK. Characterization of four CD18 mutants in leucocyte adhesion deficient (LAD) patients with differential capacities to support expression and function of the CD11/CD18 integrins LFA-1, Mac-1 and p150,95. *Clin Exp Immunol* 2001; **126**: 311-318 [PMID: 11703376 DOI: 10.1046/j.1365-2249.2001.01661.x]

10 **Madkaikar M**, Italia K, Gupta M, Chavan S, Mishra A, Rao M, Mhatre S, Desai M, Manglani M, Singh S, Suri D, Agrawal A, Ghosh K. Molecular characterization of leukocyte adhesion deficiency-I in Indian patients: identification of 9 novel mutations. *Blood Cells Mol Dis* 2015; **54**: 217-223 [PMID: 25703682 DOI: 10.1016/j.bcmd.2015.01.012]

11 **Parvaneh N**, Mamishi S, Rezaei A, Rezaei N, Tamizifar B, Parvaneh L, Sherkat R, Ghalehbaghi B, Kashef S, Chavoshzadeh Z, Isaeian A, Ashrafi F, Aghamohammadi A. Characterization of 11 new cases of leukocyte adhesion deficiency type 1 with seven novel mutations in the ITGB2 gene. *J Clin Immunol* 2010; **30**: 756-760 [PMID: 20549317 DOI: 10.1007/s10875-010-9433-2]

12 **Wolach B**, Gavrieli R, Wolach O, Stauber T, Abuzaitoun O, Kuperman A, Amir Y, Stepensky P, Somech R, Etzioni A. Leucocyte adhesion deficiency-A multicentre national experience. *Eur J Clin Invest* 2019; **49**: e13047 [PMID: 30412664 DOI: 10.1111/eci.13047]

13 **Fekrvand S**, Yazdani R, Olbrich P, Gennery A, Rosenzweig SD, Condino-Neto A, Azizi G, Rafiemanesh H, Hassanpour G, Rezaei N, Abolhassani H, Aghamohammadi A. Primary Immunodeficiency Diseases and Bacillus Calmette-Guérin (BCG)-Vaccine-Derived Complications: A Systematic Review. *J Allergy Clin Immunol Pract* 2020; **8**: 1371-1386 [PMID: 32006723 DOI: 10.1016/j.jaip.2020.01.038]

- 14 **Boonyawat B**, Suksawat Y, Pacharn P, Suwanpakdee P, Traivaree C. X-Linked Chronic Granulomatous Disease: Initial Presentation with Intracranial Hemorrhage from Vitamin K Deficiency in Infant. *Case Rep Pediatr* 2018; **2018**: 7041204 [PMID: 30034904 DOI: 10.1155/2018/7041204]
- 15 **Sobh A**, Bonilla FA. Vaccination in Primary Immunodeficiency Disorders. *J Allergy Clin Immunol Pract* 2016; **4**: 1066-1075 [PMID: 27836056 DOI: 10.1016/j.jaip.2016.09.012]
- 16 **Kurosawa H**, Mizukami T, Nunoi H, Kato M, Sato Y, Okuya M, Fukushima K, Katsuyama Y, Arisaka O. Necrotizing Ulcer After BCG Vaccination in a Girl With Leukocyte-adhesion Deficiency Type 1. *J Pediatr Hematol Oncol* 2018; **40**: 63-66 [PMID: 28538512 DOI: 10.1097/MPH.0000000000000853]
- 17 **Ghosh S**, Chackerian AA, Parker CM, Ballantyne CM, Behar SM. The LFA-1 adhesion molecule is required for protective immunity during pulmonary Mycobacterium tuberculosis infection. *J Immunol* 2006; **176**: 4914-4922 [PMID: 16585587 DOI: 10.4049/jimmunol.176.8.4914]

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| 1 | Manisha Madkaikar, Khushnooma Italia, Maya Gupta, Sushant Chavan et al. "Molecular characterization of leukocyte adhesion deficiency-I in Indian patients: Identification of 9 novel mutations", Blood Cells, Molecules, and Diseases, 2015
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| 2 | Vahid Reza Yassaee, Feyzollah Hashemi-Gorji, Sara Boosaliki, Nima Parvaneh. "Mutation spectra of the ITGB2 gene in Iranian families with leukocyte adhesion deficiency type 1", Human Immunology, 2016
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