Renal Replacement Therapy

CASE REPORT

Open Access

Successful renal transplantation following hemodialysis as bridging therapy in a patient with Fechtner syndrome: a case report and literature review

Eriko Yoshida Hama[1], Shintaro Yamaguchi[1*], Kiyotaka Uchiyama[1], Daiki Kojima[1], Tomoki Nagasaka[1], Norifumi Yoshimoto[1], Takaya Tajima[1], Takeshi Kanda[1], Kohkichi Morimoto[2], Tadashi Yoshida[2], Kenjiro Kosaki[3], Hiroshi Itoh[1] and Kaori Hayashi[1]

Abstract

Background Fechtner syndrome, also referred to as nonmuscle myosin heavy chain 9-related disease (MYH9-RD), is an autosomal-dominant genetic disorder. It is caused by abnormalities in the MYH9 gene, which encodes the nonmuscle conventional (class II) myosin heavy chain A (NMMHC-IIA). Its clinical manifestations include mild macrothrombocytopenia with leukocyte inclusions, hearing loss, cataracts, and renal failure.

Case presentation We present the case of a 34-year-old female patient with Fechtner syndrome in whom end-stage renal disease (ESRD) developed. During childhood, she presented with the typical symptoms of MYH9-RD, including thrombocytopenia, leukocyte inclusion bodies, onset of nephropathy, sensorineural hearing loss, and cataracts, wherein a clinical diagnosis of Fechtner syndrome was established. Her renal function deteriorated during adolescence. Furthermore, the patient underwent renal biopsy at the age of 18 years, which revealed focal segmental glomerulosclerosis. She was started on hemodialysis at the age of 33 years, followed by a living-donor renal transplantation after 5 months. She achieved a target platelet count of 50×10^9/L for arteriovenous fistula creation and 100×10^9/L for renal transplantation via platelet transfusions. Heparin use was avoided as an anticoagulant during hemodialysis. Since the patient expressed a desire for childbearing, genetic testing was performed, revealing an in-frame deletion of 21 nucleotides at 3195–3215 in exon 25 (A1065_A1072 del) of *NMMHC-IIA*, which has been reported to correlate with mild renal dysfunction. Our patient's condition progressed into ESRD. Although genetic testing techniques have made great strides in recent years, our case clearly presents the difficulty in assuming an association between genetic abnormalities and clinical manifestations.

Conclusions Our case may provide further understanding of the management of ESRD in patients with MYH9-RD-related thrombocytopenia based on the results of genetic testing.

Keywords Fechtner syndrome, Epstein syndrome, MYH9-related disease, Thrombocytopenia, Renal transplantation, Hemodialysis

*Correspondence:
Shintaro Yamaguchi
yama1005@a6.keio.jp
Full list of author information is available at the end of the article

Background

Variants of the MYH9 gene on the long arm of chromosome 22, which encodes the heavy chain A of nonmuscle myosin of class II (NMMHC-IIA), causes a May–Hegglin anomaly with giant thrombocytopenia, hearing loss, cataracts, and nephropathy due to structural abnormalities of the actin cytoskeleton in podocytes, triggering focal segmental glomerulosclerosis (FSGS). Importantly, the May–Hegglin anomaly, Fechtner syndrome, Sebastian syndrome, and Epstein syndrome constitute a single group with a continuous clinical spectrum, varying from mild macrothrombocytopenia with leukocyte inclusions (Döhle-like bodies) to a severe form complicated by hearing loss, cataracts, and renal failure. Therefore, these four diseases have been grouped together and referred to as MYH9-related diseases (MYH9-RD) [1]. These are autosomal-dominant genetic disorder, with approximately 20% of cases caused by de novo mutations [2].

Although genetic testing has advanced markedly in recent decades, the correlations between genotype and phenotype in patients with MYH9-RD, such as renal functional prognosis and bleeding tendency, remain unclear. In addition, there is no consensus regarding the choice of renal replacement therapy or perioperative target platelet levels in patients with MYH9-RD.

Herein, we report a case of Fechtner syndrome in which hemodialysis (HD) and renal transplantation were performed safely. We describe the selection of renal replacement therapy, management of thrombocytopenia during the perioperative period, and the association of mutations in MYH9 with prognosis of renal disease in a case of MYH9-RD.

Case presentation

A 34-year-old woman was diagnosed with Fechtner syndrome after presenting with thrombocytopenia, glaucoma, cataracts, and hearing loss at the age of 2 years. No family history of thrombocytopenia or nephropathy was noted, and the patient's condition was considered sporadic. The patient had bilateral mixed hearing loss, cataracts, and glaucoma. Urinary protein was detected since the age of three. In addition, renal failure progressed during adolescence. At the age of 18, a renal biopsy was performed, which revealed FSGS with mesangial proliferation, glomerular basement thickening, and splitting. Histological findings were in line with those of a previous report [3]. Therefore, the patient was diagnosed with Fechtner syndrome-associated nephropathy. She continued renal-protective therapy with oral renin-angiotensin system inhibitors. At the age of 30, she visited our hospital. Her serum creatinine level and estimated glomerular filtration rate (eGFR) were 2.42 mg/dL and 21 mL/min/1.73 m^2, respectively. Her urinary protein-to-creatinine ratio (UPCR) was 2.65 g/gCr. Her renal dysfunction progressed to a serum creatinine level of 5.73 mg/dL, eGFR of 8 mL/min/1.73 m^2, and UPCR of 2.48 g/gCr over 2 years. She selected renal transplantation as a renal replacement therapy from her mother as a donor. She was admitted for pre-transplant testing at the age of 33. On admission, renal impairment with a serum creatinine level of 8.48 mg/dL and eGFR of 5 mL/min/1.73 m^2 was observed, and thrombocytopenia (39×10^9/L platelets) with giant platelets and Döhle-like bodies was detected (Table 1). The UPCR was 2.0 g/gCr (Table 1). ABO-compatible living-donor renal transplantation was scheduled with her mother as donor. However, due to the rapid progression of renal failure, dialysis therapy before kidney transplantation was necessary. Based on the findings in previous reports, we considered that her thrombocytopenia might not limit the choice of renal replacement therapy. After a shared decision-making process for dialysis as bridging therapy, the patient chose to undergo HD. Eight months before renal transplantation, an arteriovenous fistula (AVF) was created on the left forearm. The preoperative platelet count was 30×10^9/L–40×10^9/L, and ten units of platelets were transfused to maintain a platelet count of 50×10^9/L during the operation. Five months before renal transplantation, uremic symptoms, such as nausea and anorexia, appeared, for which HD was initiated. Heparin was switched to nafamostat mesylate as an anticoagulant during HD to minimize the risk of bleeding.

Finally, the patient underwent living-donor renal transplantation. Since the patient was at a high risk of bleeding, the platelet count was maintained above 100×10^9/L from the perioperative period until day 10 after renal transplantation, with a total of 120 units of platelet transfusion. She was discharged 22 days after renal transplantation without any postoperative bleeding episodes. The patient received four immunosuppressive drugs: methylprednisolone, cyclosporine A, mycophenolate mofetil (MMF), and everolimus. Her renal function has remained stable, with a serum creatinine level of approximately 1.4 mg/dL, and urinary protein has not been detected for 1.5 years following transplantation.

Considering that the patient wanted to have a baby and preimplantation genetic diagnosis of MYH9-RD is not available in Japan, we provided genetic counseling, noting that patients with MYH9-RD have a 50% chance of passing the variant to their offspring. She further underwent genetic testing, which revealed an MYH9 gene 25 exon c.3195_c.3215 deletion mutation (delCGAGCT CCAGGCCCAGATCGC, p. A1065_A1072 del).

Table 1 Clinical laboratory data of the patient on admission

Blood analysis			
WBC,/μL	4800	Serum creatinine, mg/dL	8.48
Döhle-like bodies	Positive	Serum uric acid, mg/dL	11
RBC,/μL	271×10^4	Serum sodium, mEq/L	141.6
Hemoglobin, g/dL	8.2	Serum potassium, mEqL	5.1
Platelet,/L	39×10^9	Serum chloride, mEq/L	111
giant platelet	Positive	C-reactive protein, mg/dL	0.03
bleeding time	5 min 30 s	PT-INR	0.91
Serum total protein, g/dL	6.4	APTT, sec	21.2
Serum albumin, g/dL	3.7	D-dimer, μg/mL	< 0.5
SUN, mg/dL	61.8		
Urine analysis			
Specific gravity	1.008	WBCs per PHF	Negative
Blood	Negative	Granular casts	Positive
Protein, g/gCr	2	Fatty casts	Positive
RBCs per PHF	5–9		

WBC white blood cell, *RBC* red blood cell, *SUN* serum urea nitrogen, *PT-INR* prothrombin time/international normalized ratio, *APTT* activated partial thromboplastin time

Discussion and conclusions

MYH9-RD, including Fechtner syndrome, is an autosomal-dominant disorder associated with macrothrombocytopenia and leukocyte inclusion bodies at birth, with a risk of developing nephropathy, deafness, and cataracts during infancy or adulthood.

Nephropathy is present in approximately 30% of patients with MYH9-RD, proteinuria usually develops before the age of 30, and 70% of affected patients develop renal failure within a few years [3]. The renal replacement therapies selected by patients with MYH9-RD are summarized in Table 2, which also focuses on the association between bleeding episodes and management of thrombocytopenia due to genetic mutations. In the case of MYH9-RD, HD, peritoneal dialysis (PD) and renal transplantation have been reported [4–21]. Since the patient hoped to conceive after renal transplantation in this case, we explained the rare complication of PD catheter obstruction due to fallopian tube wrapping [20]. The patient requested HD as bridging therapy. A few reports have discussed the type of anticoagulant used during HD, with two cases avoiding heparin [8, 13] and one requiring biweekly platelet transfusion due to an incident of bleeding during HD [6]. Therefore, we selected nafamostat mesylate as it is less likely to cause bleeding [22].

Approximately 28% of patients with MYH9-RD exhibit spontaneous mucosal bleeding, including hypermenorrhea and nose/oral bleeding [23]. Therefore, maintaining optimal platelet targets is essential, particularly during the perioperative period. In general, for major elective non-neuraxial surgery, platelet transfusion targeting a level of 50×10^9/L is recommended [24]. For major surgical interventions, platelet counts of $>100\times10^9$/L are recommended [25]. In the largest review of MYH9-RD, severe bleeding complications requiring blood transfusion occurred in 16 of 183 patients (9%). The mean platelet count was 38×10^9/L [23]. A cohort study of patients with MYH9-RD in France also reported a higher incidence of bleeding with platelet counts $<50\times10^9$/L [26]. These reports indicated that maintaining a minimum of 50×10^9/L, particularly during the perioperative period, is important. Consistently, patients with platelet levels of at least 50×10^9/L underwent successful AVF creation without platelet transfusion [4]. According to previous reports regarding renal transplantation in patients with MYH9-RD, platelet counts of $50–115\times10^9$/L were maintained by transfusions [4, 7, 10, 14, 16, 19]. Importantly, a case report pointed out that achieving 50×10^9/L by transfusion for renal transplantation would not be sufficient to prevent bleeding complications such as intracranial hemorrhage and postoperative intra-abdominal hematoma [19]. These case reports led us to conclude that targeting a platelet count of 50×10^9/L for AVF formation and 100×10^9/L for renal transplantation might be reasonable. Ten units of platelets were transfused almost daily for 10 days postoperatively. In total, 120 units of platelets were transfused. We paid careful attention to frequent platelet transfusions that may produce anti-platelet and donor-specific antibodies. This complication could have led to platelet transfusion refractoriness and antibody-related rejection in renal

Table 2 Selection of Renal Replacement Therapy, Platelet Counts, Perioperative management and bleeding complications in Patients with MYH9-RD

Age, sex	Platelets ($\times 10^9$/L)	Dialysis	Perioperative care	Bleeding episodes, Comments	Ref
33, M	4	PD → HD → RTx	Plt transfusion with a target of 100×10^9 for 7 days during RTx	Anti-platelet antibody positive	[4]
8, M	5	HD → RTx	Plt transfusion with a target of 100×10^9 for 7 days during RTx	Bleeding of the oral cavity	[4]
22, M	5	PD → RTx	Transfusion of 30 units of platelet for RTx	NS	[16]
30, M	7	HD	NS	Recurrent bleeding incidents from venous access during HD. Plt transfusion every other week. TPO-RA used	[6]
45, F	8	HD	NS	Nose bleeds	[7]
66, F	8	dialysis	NS	Nose bleeds, bruise	[5]
23, M	< 10	RTx	Plt transfusion with a target of 100×10^9	NS	[21]
25, M	10	HD	NS	Nose bleeds, mucosal bleedings. No heparin used during HD	[8]
24, M	18–46	dialysis	NS	Two severe nose bleeds	[9]
11, M	25	RTx	Plt transfusion with a target of 100×10^9 for 7 days during RTx	Hematoma after renal biopsy	[4]
22, M	28–31	HD → RTx	Thromboelastometry used without transfusion	NS	[10]
11, M	36	RTx	Plt transfusion with a target of 100×10^9 for 7 days during RTx	NS	[4]
70, F	45	HD	NS	Use of heparin during HD	[11]
13, M	45	HD	NS	Plt transfusion reaction present	[12]
34, M	46	HD	Plt transfusion for AVF creation	Nose bleeds. No heparin used during HD	[13]
16, M	70	PD → HD → RTx	Plts 115×10^9 after transfusion for RTx	NS	[14]
10, M	NS	HD	NS	Nose bleeds	[17]
27, M	NS	PD	NS	NS	[18]
20, M	NS	HD → RTx	Plt transfusion to maintain a minimum of 50×10^9	Postoperative intra-abdominal hematoma, duodenal ulcer	[19]
7, F	NS	HD → PD	Plt transfusion before renal biopsy	NS	[12]
17, F	NS	RTx	Plt transfusion to maintain a minimum of 50×10^9	Postoperative intracapsular hemorrhage, postoperative intra-abdominal hematoma	[21]
35, M	NS	HD → PD → HD	NS	Nose bleeds, prolonged bleeding after the PD catheter insertion, multiple bleeding into the PD dialysate	[20]

HD hemodialysis, *PD* peritoneal dialysis, *Ref* references, *M* male, *F* female, *NS* not stated, *Plt* platelet, *RTx* renal transplantation, *AVF* arteriovenous fistula, *TPO-RA* Thrombopoietin receptor agonist, *MD* motor domain, *TD* Tail domain

transplantation [27, 28]. Fortunately, no anti-platelet antibodies or donor-specific antibodies were detected in this case.

Our patient was clinically diagnosed with Fechtner syndrome, with genetic testing revealing a heterozygous in-frame variant of 3195–3215 (p. A1065_A1072 del). To identify the association between MYH9 mutations and nephropathy, Pecci et al. evaluated gene-system-phenotype correlations in 255 cases from 121 families. They revealed that mutations in the head (motor) domain, essential for cell motility and maintenance of cell shape, were associated with a higher incidence of nephropathy compared with tail domain mutations [23]. Furthermore, the clinical phenotype varied according to mutation site. For instance, the Arg702 substitution in the head domain was associated with severe thrombocytopenia and nephropathy [23, 29]. Since the patient's condition progressed to ESRD, a mutation in the head domain was expected. However, the result revealed a heterozygous in-frame mutation in the coiled-coil or tail domain, not the head domain. Patients with the same mutations as in our patient are summarized in Table 3 [1, 15, 23, 30–33]. Of note, although severe renal manifestation was reported in a 26-year-old Chinese man in whom ESRD developed [15], mild renal manifestations were mainly reported. Thus, this mutation has been recognized to cause mild nephropathy. However, our patient's condition progressed into ESRD at a young age. We cannot exclude the possibility that a heterozygous in-frame mutation (p. A1065_A1072 del) at 3195–3215 on exon 25 causes

Table 3 Clinical presentation of cases with mutations that result in the removal or duplication of the one specific amino-acid sequence as in this case

Age, sex	Family	Location	Mutations	Platelets ($\times 10^9$/L)	ESRD	Urinary protein	Comments	Ref
47, M	1	Japan	p.E1066_A1072del	65	No	Yes	–	[31]
56, M	2	Japan	p.A1065_A1072dup	82	No	Yes	–	[30]
50, F	3	Italy	p.E1066_A1072dup	70–100	No	No	Slight easy bruising	[32]
25, F	3	Italy	p.E1066_A1072dup	90–100	No	No	–	[32]
23, M	3	Italy	p.E1066_A1072dup	30–80	No	No	–	[32]
26, M	4	China	p.A1065_A1072del	NS	Yes	No	–	[15]
7, F	4	China	p.A1065_A1072del	NS	No	Yes	–	[15]
4, M	4	China	p.A1065_A1072del	NS	No	Yes	–	[15]
1.5, NS	5	Italy	p.E1066_A1072del	68	No	No	–	[1]
38, NS	5	Italy	p.E1066_A1072del	NS	No	Yes	–	[23]
25, NS	6	Italy	p.E1066_A1072del	NS	No	No	–	[23]
6, M	7	Japan	p.A1065_A1072del	54	No	Yes	Hematoma after renal biopsy	[33]

ESRD end-stage renal disease, *M* male, *F* female, *NS* not stated, *Ref* references

severe nephropathy in combination with environmental factors or other genetic problems. Further research and an accumulation of cases are required to verify this possibility.

Our patient plans to use blastocyst freezing to have a baby in the future. Previous reports have shown a high risk of graft loss associated with pregnancy within 1–2 years after renal transplantation [34]. Following the KDIGO guidelines [35], the patient plans to resume this infertility treatment after waiting 1 year after transplantation, with the conditions that urinary protein remains negative and renal function remains stable. It has been reported that since humoral factor(s) could contribute to the recurrence of FSGS after renal transplantation, recurrence is 20–40% for initial transplantation and 80% for re-transplantation. Post-transplant recurrence for patients with inherited FSGS as in our case is 5–8%, significantly less than the overall rate [36]. However, we cannot exclude the possibility that our patient would experience the recurrence of FSGS, since a mutant podocyte cytoskeletal protein is detected in Fechtner syndrome and some podocyte mutant proteins could contribute to recurrence after transplantation [37]. We also will consider switching from MMF, and potentially everolimus, to other immunosuppressive drugs.

Although this patient was considered to be a de novo case, penetrance of MYH9-RD-related thrombocytopenia was complete, with a 50% chance of offspring inheriting it [29]. In a systematic review of pregnancies in patients with May–Hegglin anomaly (another form of MYH9-RD), 78 neonates survived and two intrauterine deaths occurred in 75 pregnancies. Of the 78 survivors, 34 were diagnosed with May–Hegglin anomaly, and three required prophylactic platelet transfusion [38]. A previous review reported that postpartum hemorrhage was observed in four pregnancies but did not require emergency hysterectomy for uncontrolled bleeding at postdelivery. Given that the review focused only on May–Hegglin anomaly without nephropathy, the risk of complications is expected to be higher in cases with chronic kidney disease. Although the penetrance of MYH9-RD is variable, with phenotypes varying within families, careful monitoring of both mother and newborn is critical [16].

In summary, we report a case of Fechtner syndrome in which the patient underwent successful HD and renal transplantation without severe bleeding by maintaining adequate platelet counts. Since there have been few reports focusing on the selection of renal replacement therapy and anticoagulants during dialysis for MYH9-RD, this report should advance our understanding of the management of renal replacement therapy in such patients. Since our patient hopes to have children, we need to carefully evaluate the association between in-frame mutations and renal prognoses. An accumulation of cases is warranted to decide on clinical management based on genetic information and predict prognosis in patients and their descendants.

Abbreviations

AVF	Arteriovenous fistula
eGFR	Estimated glomerular filtration rate
ESRD	End-stage renal disease
HD	Hemodialysis
MYH9-RD	Myosin heavy chain 9-related disease
NMMHC-IIA	Nonmuscle myosin of class II
PD	Peritoneal dialysis
UPCR	Urinary protein-to-creatinine ratio

Acknowledgements
We would like to thank the treating medical staff for their skillful care of this patient and Editage (www.editage.com) for English-language editing.

Author contributions
EH collected and analyzed the clinical data. EY, SY, KU, DK, TN, NY, TT, TK, KM, TY, KK and KH were involved in the clinical care of the patient. KH and KK conducted genetic testing. EH and SY were involved in drafting and revision of the original manuscript. KU, TY, and HI helped to edit the main manuscript. SY and KH supervised the manuscript preparation. All authors contributed to the preparation of the manuscript. All authors read and approved the final manuscript.

Funding
No funding was received to prepare this manuscript.

Availability of data and materials
The patient results used and/or analyzed in this report are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable (case report).

Consent for publication
Informed consent was obtained from the patient.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Division of Endocrinology, Metabolism and Nephrology, Department of Internal Medicine, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo, Japan. [2]Apheresis and Dialysis Center, Keio University School of Medicine, 35 Shinanomachi, Shinjuku, Tokyo, Japan. [3]Center for Medical Genetics, Keio University School of Medicine, 35 Shinanomachi, Shinjuku, Tokyo, Japan.

Received: 14 June 2023 Accepted: 27 September 2023
Published online: 04 October 2023

References

1. Seri M, Pecci A, Di Bari F, Cusano R, Savino M, Panza E, et al. MYH9-related disease: May–Hegglin anomaly, sebastian syndrome, Fechtner syndrome, and Epstein syndrome are not distinct entities but represent a variable expression of a single illness. Medicine (Baltimore). 2003;82(3):203–15. https://doi.org/10.1097/01.md.0000076006.64510.5c.
2. Ai Q, Zhao L, Yin J, Jiang L, Jin Q, Hu X, et al. A novel de novo MYH9 mutation in MYH9-related disease: a case report and review of literature. Medicine (Baltimore). 2020;99(4):e18887. https://doi.org/10.1097/md.0000000000018887.
3. Kopp JB, Winkler CA, Nelson GW. MYH9 genetic variants associated with glomerular disease: what is the role for genetic testing? Semin Nephrol. 2010;30(4):409–17. https://doi.org/10.1016/j.semnephrol.2010.06.007.
4. Hashimoto J, Hamasaki Y, Takahashi Y, Kubota M, Yanagisawa T, Itabashi Y, et al. Management of patients with severe Epstein syndrome: review of four patients who received living-donor renal transplantation. Nephrology (Carlton). 2019;24(4):450–5. https://doi.org/10.1111/nep.13253.
5. Huang YC, Shih YH, Lin CY, Chiu PF, Kuo SF, Lin JS, et al. A family with an MYH9-related disorder with different phenotypes masquerading as immune thrombocytopaenia: an underreported disorder in Taiwan. Int J Hematol. 2020;112(6):878–82. https://doi.org/10.1007/s12185-020-02947-1.
6. Gröpper S, Althaus K, Najm J, Haase S, Aul C, Greinacher A, et al. A patient with Fechtner syndrome successfully treated with romiplostim. Thromb Haemost. 2012;107(3):590–1. https://doi.org/10.1160/th11-07-0474.
7. Mori A, Takeda H, Kobayashi M, Misawa T, Watanabe R, Abe S, et al. Successful cochlear implantation in a patient with Epstein syndrome during long-term follow-up. Auris Nasus Larynx. 2022;49(2):308–12. https://doi.org/10.1016/j.anl.2020.09.008.
8. Costa RF, Bucharles SGE, Kagueiama DE, Kus CP, Andrade AA, Dirschnabel AJ, et al. The surgical management of a patient with chronic renal failure and macrothrombocytopenia related to the MYH9 gene mutation: a case report. Spec Care Dentist. 2022;42(6):651–6. https://doi.org/10.1111/scd.12727.
9. Makino S, Kunishima S, Ikumi A, Awaguni H, Shinozuka J, Tanaka S, et al. Sporadic Epstein syndrome with macrothrombocytopenia, sensorineural hearing loss and renal failure. Pediatr Int. 2015;57(5):977–81. https://doi.org/10.1111/ped.12736.
10. Higashi M, Kaku K, Okabe Y, Yamaura K. Anesthetic management of living-donor renal transplantation in a patient with epstein syndrome using rotational thromboelastometry: a case report. A A Pract. 2020;14(13):e01350. https://doi.org/10.1213/xaa.0000000000001350.
11. Ishida R, Kusaba T, Kirita Y, Matsuoka E, Nakayama M, Uchiyama H, et al. Case of an hemodialysis patient with MYH9 disorders. Nihon Jinzo Gakkai Shi. 2011;53(2):195–9.
12. Moxey-Mims MM, Young G, Silverman A, Selby DM, White JG, Kher KK. End-stage renal disease in two pediatric patients with Fechtner syndrome. Pediatr Nephrol. 1999;13(9):782–6. https://doi.org/10.1007/s004670050700.
13. AN. A case of hemodialysis introduction to a patient with Fechtner Syndrome. Shizuoka Red Cross Hosp. 2006;26(1):54–8.
14. Barrah S, Kheder R, Jebali H, Krid M, Smaoui W, Beji S, et al. Epstein syndrome. Saudi J Kidney Dis Transpl. 2020;31(4):865–7. https://doi.org/10.4103/1319-2442.292323.
15. Zhao SL, Zhao F, Zhang AH, Huang SM. Clinical features and MYH9 gene variant in two Chinese siblings with Fechtner syndrome. Zhonghua Er Ke Za Zhi. 2019;57(4):286–90. https://doi.org/10.3760/cma.j.issn.0578-1310.2019.04.011.
16. Takaaki Yamagata MN, Yoko S, Tatsuya S, Naoki S, Tetsuo T, Yoshifumi U, et al. A case of living donor renal transplantation for Fechtner syndrome. Japn J Transp. 2005;40(2):196.
17. Alhindawi E, Al-Jbour S. Epstein syndrome with rapid progression to end stage renal disease. Saudi J Kidney Dis Transpl. 2009;20(6):1076–8.
18. Ishida M, Mori Y, Ota N, Inaba T, Kunishima S. Association of a novel in-frame deletion mutation of the MYH9 gene with end-stage renal failure: case report and review of the literature. Clin Nephrol. 2013;80(3):218–22. https://doi.org/10.5414/cn107237.
19. Ogura M, Kikuchi E, Kaito H, Kamei K, Matsuoka K, Tanaka H, et al. ABO-incompatible renal transplantation in Epstein syndrome. Clin Transplant. 2010;24(Suppl 22):31–4. https://doi.org/10.1111/j.1399-0012.2010.01274.x.
20. Richardson D, Shires M, Davison AM. Renal diagnosis without renal biopsy. Nephritis and sensorineural deafness. Nephrol Dial Transplant. 2001;16(6):1291–4. https://doi.org/10.1093/ndt/16.6.1291.
21. Min SY, Ahn HJ, Park WS, Kim JW. Successful renal transplantation in MYH9-related disorder with severe macrothrombocytopenia: first report in Korea. Transplant Proc. 2014;46(2):654–6. https://doi.org/10.1016/j.transproceed.2013.11.144.
22. Park JH, Her C, Min HK, Kim DK, Park SH, Jang HJ. Nafamostat mesilate as a regional anticoagulant in patients with bleeding complications during extracorporeal membrane oxygenation. Int J Artif Organs. 2015;38(11):595–9. https://doi.org/10.5301/ijao.5000451.
23. Pecci A, Klersy C, Gresele P, Lee KJ, De Rocco D, Bozzi V, et al. MYH9-related disease: a novel prognostic model to predict the clinical evolution of the disease based on genotype–phenotype correlations. Hum Mutat. 2014;35(2):236–47. https://doi.org/10.1002/humu.22476.
24. Kaufman RM, Djulbegovic B, Gernsheimer T, Kleinman S, Tinmouth AT, Capocelli KE, et al. Platelet transfusion: a clinical practice guideline from the AABB. Ann Intern Med. 2015;162(3):205–13. https://doi.org/10.7326/m14-1589.
25. Liumbruno G, Bennardello F, Lattanzio A, Piccoli P, Rossetti G. Recommendations for the transfusion of plasma and platelets. Blood Transfus. 2009;7(2):132–50. https://doi.org/10.2450/2009.0005-09.
26. Saposnik B, Binard S, Fenneteau O, Nurden A, Nurden P, Hurtaud-Roux MF, et al. Mutation spectrum and genotype-phenotype correlations in a

large French cohort of MYH9-related disorders. Mol Genet Genomic Med. 2014;2(4):297–312. https://doi.org/10.1002/mgg3.68.
27. Group TTtRAtPS. Leukocyte reduction and ultraviolet B irradiation of platelets to prevent alloimmunization and refractoriness to platelet transfusions. N Engl J Med. 1997;337(26):1861–9. https://doi.org/10.1056/nejm199712253372601.
28. Ma N, Guo JP, Zhao XY, Xu LP, Zhang XH, Wang Y, et al. Prevalence and risk factors of antibodies to HLA according to different cut-off values of mean fluorescence intensity in haploidentical allograft candidates: a prospective study of 3805 subjects. Hla. 2022. https://doi.org/10.1111/tan.14704.
29. Savoia A, Pecci A. MYH9-related disease. In: Adam MP, Mirzaa GM, Pagon RA, Wallace SE, Bean LJH, Gripp KW et al., editors. GeneReviews(®). Seattle (WA): University of Washington, Seattle Copyright © 1993–2022, University of Washington, Seattle. GeneReviews is a registered trademark of the University of Washington, Seattle. All rights reserved.; 1993.
30. Teshirogi S, Muratsu J, Kasahara H, Terashima K, Miki S, Minami T, et al. Two cases of the MYH9 disorder fechtner syndrome diagnosed from observation of peripheral blood cells before end-stage renal failure. Case Rep Nephrol. 2019;2019:5149762. https://doi.org/10.1155/2019/5149762.
31. Miyazaki K, Kunishima S, Fujii W, Higashihara M. Identification of three in-frame deletion mutations in MYH9 disorders suggesting an important hot spot for small rearrangements in MYH9 exon 24. Eur J Haematol. 2009;83(3):230–4. https://doi.org/10.1111/j.1600-0609.2009.01274.x.
32. De Rocco D, Pujol-Moix N, Pecci A, Faletra F, Bozzi V, Balduini CL, et al. Identification of the first duplication in MYH9-related disease: a hot spot for unequal crossing-over within exon 24 of the MYH9 gene. Eur J Med Genet. 2009;52(4):191–4. https://doi.org/10.1016/j.ejmg.2009.01.006.
33. Matsumoto T, Yanagihara T, Yoshizaki K, Tsuchiya M, Terasaki M, Nagahama K, et al. Renal biopsy-induced hematoma and infection in a patient with asymptomatic May–Hegglin anomaly. J Nippon Med Sch. 2021;88(6):579–84. https://doi.org/10.1272/jnms.JNMS.2021_88-609.
34. Rose C, Gill J, Zalunardo N, Johnston O, Mehrotra A, Gill JS. Timing of pregnancy after kidney transplantation and risk of allograft failure. Am J Transplant. 2016;16(8):2360–7. https://doi.org/10.1111/ajt.13773.
35. Kasiske BL, Zeier MG, Chapman JR, Craig JC, Ekberg H, Garvey CA, et al. KDIGO clinical practice guideline for the care of kidney transplant recipients: a summary. Kidney Int. 2010;77(4):299–311. https://doi.org/10.1038/ki.2009.377.
36. Trautmann A, Bodria M, Ozaltin F, Gheisari A, Melk A, Azocar M, et al. Spectrum of steroid-resistant and congenital nephrotic syndrome in children: the PodoNet registry cohort. Clin J Am Soc Nephrol. 2015;10(4):592–600. https://doi.org/10.2215/CJN.06260614.
37. Benoit G, Machuca E, Antignac C. Hereditary nephrotic syndrome: a systematic approach for genetic testing and a review of associated podocyte gene mutations. Pediatr Nephrol. 2010;25:1621–32. https://doi.org/10.1007/s00467-010-1495-0.
38. Hussein BA, Gomez K, Kadir RA. May–Hegglin anomaly and pregnancy: a systematic review. Blood Coagul Fibrinol. 2013;24(5):554–61. https://doi.org/10.1097/MBC.0b013e32835fad03.

Publisher's Note