Atypical Presentation of a MERRF-Like Phenotype with Late-Onset Visual Decline and Stimulus-Sensitive Myoclonus: A Case Report

Chayanis Yolsiriwat, MD[1], Pharanpong Taemeeyapradit, MD, MSc[2,3], Kongpop Sutantikorn, MD[1,3], Peerasit Treesuthacheep, MD, MSc[1,3], Somjet Tosamran, MD, MSc[1,3], Thanakit Pongpitakmetha, MD, MSc[1,4,5,6], Prakit Anukoolwittaya, MD[1,5], Jakkrit Amornvit, MD[1,4], Suda Jirasakuldej, MD[1,3], Pasin Hemachudha, MBBS, MSc[1,7], Oranuch Chuapakdee, MD, MSc[1], Warongporn Phuenpathom, MD, PhD[1,8]

[1] Division of Neurology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand; [2] Division of Neurology, Department of Medicine, Songkhla Hospital, Songkhla, Thailand; [3] Chulalongkorn Comprehensive Epilepsy Center of Excellence, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand; [4] Chula Neuroscience Center, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand; [5] Comprehensive Headache and Orofacial Pain (CHOP) Service and Research Group, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand; [6] Department of Pharmacology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand; [7] Thai Red Cross Emerging Infectious Diseases and Health Science Centre, King Chulalongkorn Memorial Hospital, Bangkok, Thailand; [8] Chulalongkorn Center of Excellence for Parkinson's Disease and Related Disorders, Chulalongkorn University Hospital, Bangkok, Thailand

Abstract

Background: Myoclonic epilepsy with ragged red fibers (MERRF) is a rare mitochondrial encephalomyopathy with highly variable clinical expression. Although the classical phenotype includes myoclonus, generalized seizures, cerebellar ataxia, and ragged red fibers on muscle biopsy, many patients present with incomplete or misleading features.

Case Report: This case report describes a late-onset presentation in a 43-year-old woman with a 5-year history of progressive bilateral visual decline initially attributed to cataracts. Persistent visual impairment after lens extraction prompted further evaluation. During ophthalmological examination, she developed reproducible generalized myoclonic jerks triggered by visual stimulation. Fundoscopy revealed retinitis pigmentosa, and further history identified progressive sensorineural hearing loss. Neurological examination showed stimulus-provoked myoclonus and mild proximal weakness with preserved cognition. Electroencephalography demonstrated generalized 3 Hz spike-wave discharges with a photoparoxysmal response, and brain magnetic resonance imaging showed symmetrical basal ganglia hyperintensities. Muscle biopsy revealed scattered cytochrome c oxidase-negative/succinate dehydrogenase-positive fibers, supporting mitochondrial dysfunction. Whole mitochondrial genome sequencing of peripheral blood did not detect pathogenic variants, highlighting the limitations of genetic testing. In the absence of molecular confirmation, these findings are consistent with a mitochondrial encephalomyopathy within the MERRF spectrum.

Conclusion: The patient was treated with levetiracetam and a mitochondrial supplement regimen, with clinical stability at 18-month follow-up and no further seizures. This case illustrates how late-onset, atypical presentations—particularly visual symptoms, intermittent myoclonus, and absent family history—may obscure underlying mitochondrial disease. It highlights the importance of integrating multimodal investigations and reinforces the continued relevance of muscle biopsy in the genomic era.

Keywords: Myoclonic epilepsy with ragged red fibers; Mitochondrial encephalomyopathies; Retinitis pigmentosa

Received 30 December 2025 | Revised 4 May 2026 | Accepted 16 May 2026

J Med Assoc Thai 2026;109(9):764-71

https://doi.org/10.35755/jmedassocthai.2026.9.03977

Myoclonic epilepsy with ragged red fibers (MERRF) is a rare mitochondrial encephalomyopathy, most commonly caused by pathogenic variants in the mitochondrial $tRNA^{Lys}$ (*MT-TK*) gene[1]. The

Correspondence to:

Phuenpathom W.

Chulalongkorn Center of Excellence for Parkinson's Disease & Related Disorders, Department of Medicine, Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok 10330, Thailand.

Phone: +66-2-2564000 ext. 70702-3

Email: wph@chulapd.org

ORCID: 0000-0003-3057-9183

How to cite this article:

Yolsiriwat C, Taemeeyapradit P, Sutantikorn K, Treesuthacheep P, Tosamran S, Pongpitakmetha T, Anukoolwittaya P, Amornvit J, Jirasakuldej S, Hemachudha P, Chuapakdee O, Phuenpathom W. Atypical Presentation of a MERRF-Like Phenotype with Late-Onset Visual Decline and Stimulus-Sensitive Myoclonus: A Case Report. J Med Assoc Thai 2026;109:764-71.

What is already known about this topic?

MERRF is a rare mitochondrial encephalomyopathy classically characterized by myoclonus, generalized seizures, cerebellar ataxia, and ragged-red fibers on muscle biopsy. Although these hallmark features define the syndrome, many patients do not present with the full triad at onset, and the median age of symptom onset is approximately 26 years. Extra-neurological manifestations—including retinitis pigmentosa, optic atrophy, and sensorineural hearing loss—may precede neurological symptoms and contribute to diagnostic delay. While genetic confirmation is important, only a subset of patients carry the common m.8344A>G MT-TK mutation; mtDNA and nuclear gene sequencing are often required. However, access to comprehensive genetic testing may be limited by cost or availability, making muscle biopsy a valuable diagnostic tool when molecular confirmation is not feasible.

What does this study add?

This case illustrates an atypical late-onset presentation of MERRF in a 43-year-old woman whose initial progressive visual decline and cataract-related misdiagnosis obscured recognition of mitochondrial disease. The combination of retinitis pigmentosa, intermittent stimulus-sensitive myoclonus, mild proximal weakness, and preserved cognition deviated from the classical phenotype and delayed diagnostic consideration of MERRF. Despite financial limitations preventing complete mtDNA and nuclear gene testing, muscle biopsy provided essential pathological evidence of mitochondrial dysfunction and enabled diagnosis in the absence of genetic confirmation. This report highlights the importance of multimodal diagnostic integration and emphasizes maintaining a high index of suspicion for mitochondrial disease in adults with unexplained visual decline and episodic myoclonus, even when the onset is subtle or significantly delayed.

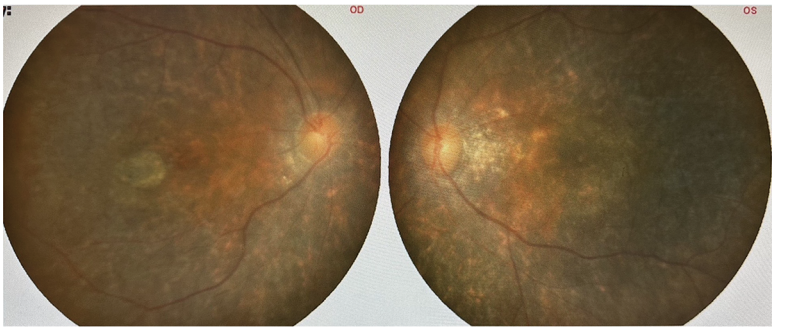

Figure 1. Fundus photographs showing retinitis pigmentosa. Bilateral pigmentary changes and attenuated retinal vessels are visible. The optic discs are normal.

classical phenotype includes myoclonic epilepsy, cerebellar ataxia, and ragged red fibers on muscle biopsy[2]. However, the clinical presentation is highly variable, and many patients do not exhibit the complete syndrome at onset. MERRF most commonly presents in childhood or early adulthood, although symptom onset may occur across a wide age range[3,4]. Diagnostic challenges arise from the overlap with other progressive myoclonus epilepsies, such as Unverricht-Lundborg disease or neuronal ceroid lipofuscinosis, and with idiopathic myoclonic epilepsy[2]. In addition, extra neurological manifestations—including bilateral optic atrophy, retinitis pigmentosa, and hearing loss—may precede neurological features and further obscure the diagnosis[5]. This case illustrates how mitochondrial encephalomyopathy within the MERRF spectrum may initially masquerade as an ophthalmological or late-onset idiopathic epilepsy syndrome, with intermittent myoclonus, absent family history, and lack of early weakness delaying diagnosis. Careful integration of clinical, electrophysiological, radiological, and pathological findings is essential to establish the correct diagnosis.

Case Report

A 43-year-old woman presented with a 5-year history of progressive bilateral visual decline. She was initially diagnosed with cataracts and underwent bilateral lens extraction; however, her visual acuity progressively worsened two years later. This raised the first diagnostic challenge, as the persistence of visual impairment suggested an atypical course beyond a primary lens disorder. She was therefore referred to our hospital for further evaluation.

During ophthalmological examination, she developed sudden, generalized myoclonic jerks lasting about 5 seconds, reproducibly triggered by visual testing (https://drive.google.com/file/d/1GxzDJRIEfaVijyYYNPkWIm_eUbBxZbQc/view). There was no prior history of myoclonic jerks before this presentation, suggesting a relatively recent onset. She was subsequently admitted for further evaluation. Fundoscopic examination at our hospital demonstrated retinitis pigmentosa without optic atrophy (Figure 1). A more detailed history revealed progressive hearing loss beginning at approximately 40 years of age, which was confirmed on audiometry as bilateral mild sensorineural impairment. Neurological examination showed stereotyped generalized myoclonic jerks provoked by visual stimulation and mild proximal weakness (grade IV) affecting neck flexion and shoulder abduction, while cognition was preserved (Montreal Cognitive Assessment [MoCA]-Thai version, 26/30).

Ancillary investigations provided further diagnostic clues but also highlighted the complexity of the case. Routine electroencephalography (EEG) demonstrated reproducible 3 Hz generalized spike-wave discharges with a photoparoxysmal response, supporting photosensitive myoclonic epilepsy (Figure 2). Brain magnetic resonance imaging (MRI) showed symmetrical T1 and T2 hyperintensities in the basal ganglia, a supportive but non-specific feature of mitochondrial encephalopathies (Figure 3). Muscle biopsy of the left deltoid revealed scattered fibers with cytochrome c oxidase (COX)-negative and succinate dehydrogenase (SDH)-positive staining, indicative of mitochondrial dysfunction, which, in combination with the clinical findings, is compatible with mitochondrial encephalomyopathy within the MERRF spectrum (Figure 4). However, whole mitochondrial genome sequencing did not identify common pathogenic variants, underscoring the genetic heterogeneity of mitochondrial encephalomyopathy within the MERRF spectrum and the limitations of current testing strategies. Mitochondrial nuclear gene testing was not

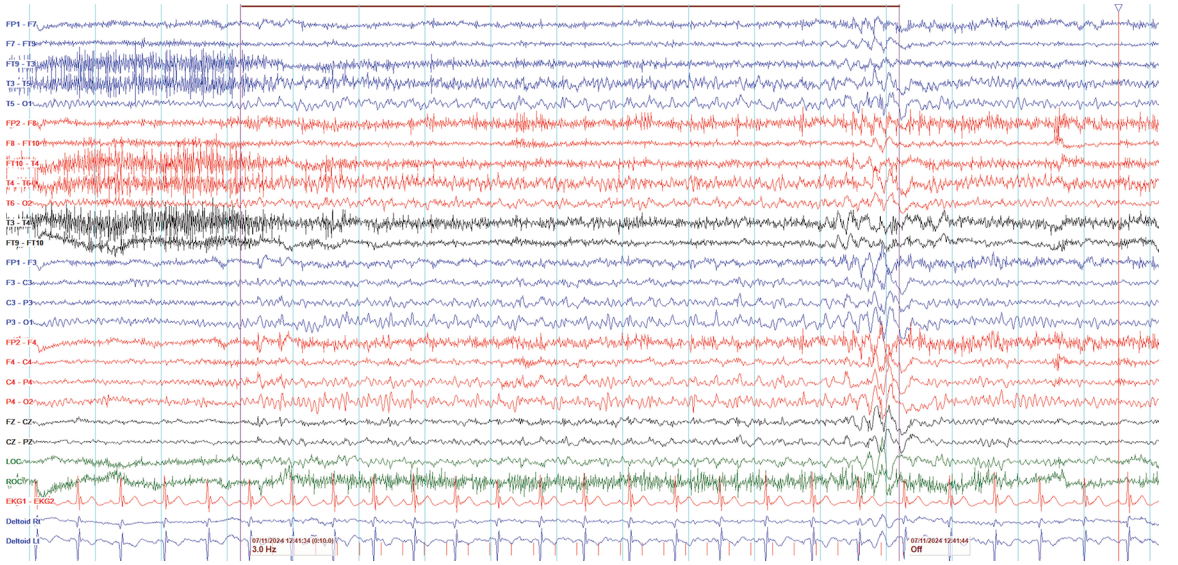

Figure 2. Electroencephalography during photic stimulation. Generalized 3 Hz spike-wave discharges with photoparoxysmal response are demonstrated.

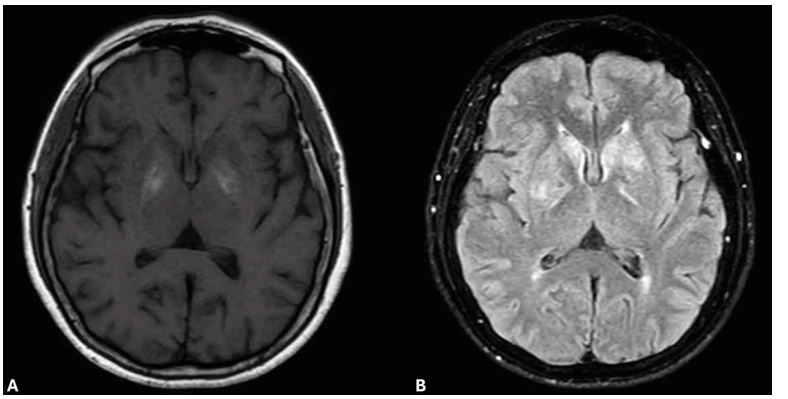

Figure 3. Brain magnetic resonance imaging. (A) Axial T1-weighted image demonstrating bilateral hyperintensity of the globus pallidi. (B) Axial T2- fluid-attenuated inversion recovery sequences showing symmetrical hyperintensity in the bilateral caudate nuclei, putamina, and some parts of the globus pallidi without contrast enhancement. These findings are supportive of mitochondrial encephalopathy.

pursued due to financial constraints.

Despite these challenges, the convergence of multisystem involvement, electrophysiological and radiological findings, and pathological confirmation established a diagnosis of mitochondrial encephalomyopathy within the MERRF spectrum. She was commenced on 500 mg/day levetiracetam together with a mitochondrial supplement regimen including coenzyme Q10 200 mg/day, L-arginine 6 g/day, B-complex vitamins, vitamin C 500 mg/day, and vitamin E 1,200 mg/day. Supportive measures included physiotherapy, hearing aids, and counselling regarding the avoidance of drugs or substances causing mitochondrial toxicity and genetic counselling. At 18-month follow-up, her clinical condition remained stable, with no recurrence of seizures and no significant progression of visual impairment or proximal muscle weakness.

Discussion

This case highlights the diagnostic challenges of mitochondrial encephalomyopathy within the MERRF spectrum when clinical presentation diverges from the classical phenotype, which includes myoclonus, generalized seizures, cerebellar ataxia, and ragged-red fibers on muscle biopsy[1,4]. Our patient initially presented with visual decline and intermittent stimulus-provoked myoclonus, without overt neurological

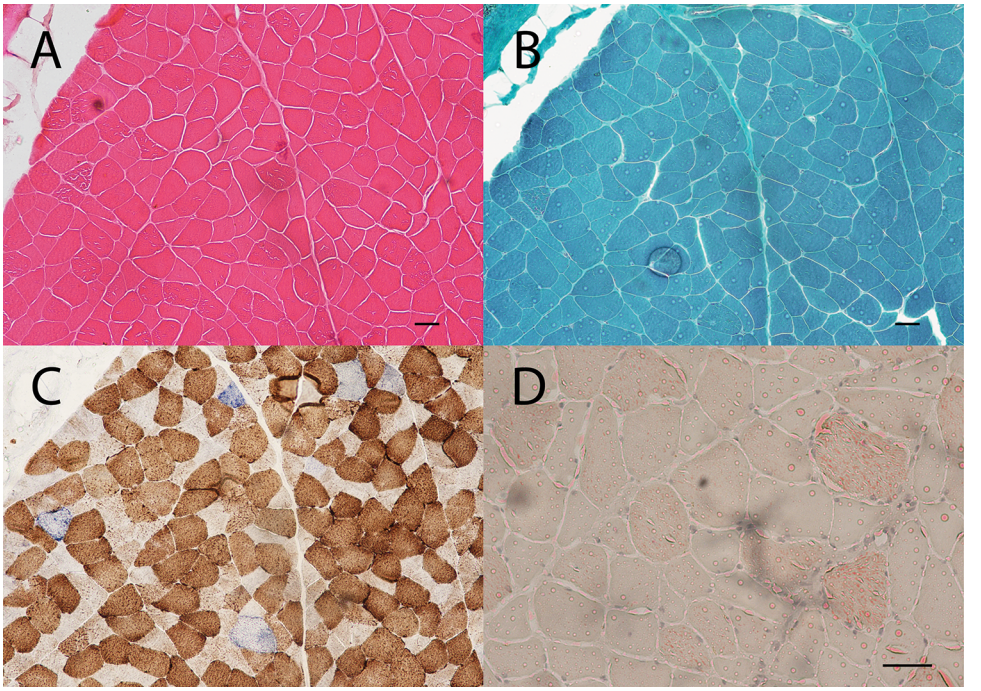

Figure 4. Muscle biopsy of the left deltoid. (A) Hematoxylin and eosin staining shows variation in fiber size with irregular internal architecture in some muscle fibers, scale bar=50 µm. (B) Modified Gomori Trichrome staining demonstrates irregularly shaped fibers, without evident subsarcolemmal mitochondrial accumulation, scale bar=50 µm. (C) Cytochrome c oxidase/succinate dehydrogenase (COX/SDH) dual staining demonstrates scattered fibers with both COX-negative/SDH-positive and COX-negative/SDH-negative patterns, scale bar=50 µm. (D) Oil Red O staining shows muscle fibers with slightly increased intracytoplasmic lipid droplets, scale bar=50 µm.

deficits—features that easily fit within more common ophthalmological or idiopathic epileptic syndromes. The presence of coexisting cataracts added further diagnostic ambiguity, masking the underlying retinal pathology. Such incomplete or misleading presentations illustrate how mitochondrial disease may atypically manifest as isolated organ dysfunction before evolving into a typically recognizable multisystem disorder[5]. In this context, the presence of progressive multisystem involvement—including visual impairment, hearing loss, stimulus-sensitive myoclonus, and subtle proximal weakness—should be considered important clinical "red flags" that may suggest an underlying mitochondrial disorder and prompt earlier diagnostic evaluation.

In our patient, the diagnostic process was obscured by three main factors. First, the earliest complaint was late-onset progressive visual decline at age 38, which is older than the commonly reported age of onset for mitochondrial encephalomyopathy within the MERRF spectrum, although adult-onset presentations have been described[6]. This pattern may therefore reflect delayed recognition rather than a truly atypical age at onset. The symptoms were initially attributed to cataracts—a common condition in the general population that can easily mask rarer underlying etiologies. Although cataract is not among the most typical ophthalmological manifestations, it has been reported in mitochondrial disorders and may further complicate diagnostic interpretation, particularly when coexisting retinal pathology is not initially apparent[7]. The lack of visual improvement following bilateral lens extraction suggested an alternative mechanism, but it was only later that retinitis pigmentosa was recognized. Retinitis pigmentosa has been described in several mitochondrial syndromes, including MERRF, Mitochondrial Encephalomyopathy, Lactic Acidosis, and Stroke-like episodes (MELAS), and Kearns-Sayre syndrome, but is often overlooked when ocular pathology appears to explain the visual loss[6,8]. The discrepancy between the two ophthalmological assessments likely reflected a combination of factors, including limited retinal visibility through opaque lenses, early or atypical manifestations of mitochondrial retinopathy, and a cognitive bias toward attributing symptoms to a common ocular condition.

Second, the myoclonus was not continuous or disabling. Instead, it appeared only during visual

stimulation and could be reproducibly elicited with 30 Hz flicker during ophthalmological assessment. Intermittent, stimulus-provoked myoclonus is easily misinterpreted as other abnormal movements, such as tics or tremor, or classified within idiopathic photosensitive epilepsies[9]. In our case, however, the duration of the abnormal movements was sufficient to identify them as generalized, brief jerky movements. There was no prior history of progressive myoclonus, weakness, or ataxia. In the absence of EEG, this led to an initial consideration of isolated idiopathic myoclonic epilepsies or late-onset progressive myoclonus epilepsies without myopathy, such as Unverricht-Lundborg disease or neuronal ceroid lipofuscinosis. Both of these conditions typically present at an earlier age and with more florid seizure semiology, yet in the absence of additional neurological abnormalities, they remain reasonable differential diagnoses[2,10]. The episodic nature and relatively late onset of the myoclonus further delayed recognition that these features reflected an underlying mitochondrial disorder. On comprehensive neurological examination, mild weakness of shoulder abduction and neck flexion was identified, which proved to be an important clinical clue to the diagnosis of mitochondrial encephalomyopathy within the MERRF spectrum in this case.

Third, there was no apparent family history of seizures or neuromuscular disease. The absence of family history is frequently misleading in mitochondrial disorders. Maternal carriers may harbour low-level or tissue-specific heteroplasmy and remain minimally symptomatic, leading to apparently negative pedigrees[11]. Simplex cases may also occur due to de novo mitochondrial deoxyribonucleic acid (mtDNA) mutations or nuclear gene variants with variable penetrance[12]. Furthermore, standard sequencing panels often target common mtDNA variants, and rarer mutations may be missed, creating the impression of a sporadic, non-genetic condition[13]. This further challenged the diagnosis of mitochondrial aetiology in our patient.

Despite the challenges of clinical diagnosis, we undertook further investigations to support mitochondrial encephalomyopathy within the MERRF spectrum. Neurophysiological testing provided a first decisive clue. EEG during photic stimulation revealed generalized spike-wave discharges at 3 Hz associated with myoclonic jerks — a pattern frequently observed in mitochondrial epilepsies[14]. In MERRF, photoparoxysmal responses (PPRs) are well documented[15]. By contrast, other photosensitive myoclonic epilepsies may show photic-induced discharges at different frequencies or with varying patterns of amplification. For example, neuronal ceroid lipofuscinosis (particularly *CLN2*) is typically associated with low-frequency sensitivity, with PPRs elicited at 1-3 Hz, while Unverricht-Lundborg disease demonstrates broader frequency sensitivity but with earlier onset and more florid seizure semiology[16,17]. Such variability limits the specificity of EEG findings alone and highlights the importance of integrating them with clinical and pathological features[14]. Brain MRI provided additional supportive evidence in our patient, demonstrating symmetrical T2 hyperintensities in the basal ganglia. This finding is consistent with a mitochondrial disorder, as the basal ganglia are particularly vulnerable structures due to their high metabolic demand and susceptibility to impaired oxidative phosphorylation[18].

The definitive diagnostic step was the muscle biopsy, performed after mild proximal weakness was noted. Histopathological analysis of the left deltoid revealed variation in fiber size with scattered COX-negative/SDH-positive fibers and a few COX-negative/SDH-negative fibers[19]. Modified Gomori trichrome staining showed irregular fibers without evident subsarcolemmal mitochondrial accumulation, and Oil Red O staining demonstrated mildly increased intracytoplasmic lipid droplets. Although classic ragged-red fibers were absent, the presence of COX-negative/SDH-positive fibers indicated mitochondrial respiratory chain dysfunction, which, together with the clinical findings, was compatible with mitochondrial encephalomyopathy within the MERRF spectrum[6,20]. These findings support mitochondrial dysfunction but are not specific for MERRF, underscoring the importance of integrating clinical, electrophysiological, radiological, and pathological data. In the era of next-generation sequencing, muscle biopsy remains an indispensable tool in selected cases, providing direct morphological and biochemical evidence of mitochondrial dysfunction. In this patient, it offered crucial pathological confirmation that complemented genetic and clinical data, supporting the diagnosis of mitochondrial encephalomyopathy within the MERRF spectrum[19].

Molecular testing of peripheral blood did not reveal pathogenic variants in the mitochondrial genome. This highlights an additional complexity in mitochondrial encephalomyopathy within the MERRF spectrum. Although the commonest mutation is the A8344G variant in the *MT-TK* gene, not all patients harbour this change, and nuclear genes can also be implicated[12]. The absence of genetic confirmation does not exclude

the diagnosis when there is a strong clinicopathological correlation[21]. Indeed, in resource-limited settings or where nuclear gene testing is not feasible, the diagnosis may rely on the clinical phenotype plus supportive biopsy evidence[22]. In our patient, although genetic confirmation was lacking, the combined features of myoclonic epilepsy, retinitis pigmentosa, basal ganglia signal change, and the results of muscle biopsy were sufficient to establish MERRF[22,23].

Phenotypic variation is a defining feature of mitochondrial DNA disorders, and our case exemplifies this heterogeneity[12]. The "classic" presentation of MERRF consists of myoclonus, progressive ataxia, generalized seizures, and ragged red fibers on muscle biopsy, usually associated with the m.8344A>G mutation in *MT-TK*[3,6]. However, clinical expression is highly variable, and many patients fail to display the full syndrome at onset[21].

Previous reports of late-onset mitochondrial encephalomyopathy within the MERRF spectrum have described patients presenting predominantly with progressive myoclonus, epilepsy, or myopathy[3]. In contrast, our patient presented primarily with visual decline, with neurological features becoming apparent only later. This highlights that the distinguishing feature in this case lies in the sequence and predominance of symptoms, rather than age at onset alone.

In our patient, visual decline due to retinitis pigmentosa and cataracts preceded neurological manifestations, and myoclonus was intermittent and stimulus-provoked rather than continuous or disabling. The weakness was subtle, confined to proximal muscles, and cognitive function remained relatively preserved, features that diverge from the typical picture of progressive myoclonus and ataxia[24]. Variable tissue distribution of mutant mtDNA, heteroplasmy thresholds, and nuclear or environmental modifiers contribute further to the unpredictability of clinical expression[12]. Recognizing this variability is essential, as reliance on the "classical" phenotype may delay diagnosis, whereas careful attention to subtle systemic features can reveal the mitochondrial basis of atypical presentations[21].

From a management perspective, accurate diagnosis is important not only for prognostication but also for treatment selection. Certain anti-seizure medications—most notably valproate—are relatively contraindicated in primary mitochondrial disease, particularly when *POLG* variants are possible, due to the risk of severe hepatotoxicity and exacerbation of mitochondrial dysfunction[25,26]. Our patient was commenced on levetiracetam, which has a generally favourable tolerability profile and is commonly used in mitochondrial epilepsies[26]. In addition, she received a "mitochondrial cocktail" consisting of coenzyme Q10, L-carnitine, L-arginine, B-complex vitamins, vitamin C, vitamin E, and alpha-lipoic acid. Although these supplements are widely prescribed in clinical practice, current evidence for their efficacy remains limited and heterogeneous, largely based on observational studies and expert consensus rather than randomized controlled trials[26-28]. Supportive measures—such as physiotherapy to address proximal weakness, hearing aids for sensorineural loss, and lifestyle counselling to avoid potential mitochondrial toxins—are integral components of care and are endorsed in consensus management recommendations, even though the interventional evidence continues to evolve[25].

Conclusion

In conclusion, this case exemplifies the early diagnostic pitfalls of mitochondrial encephalomyopathy within the MERRF spectrum. Unusual patterns of presentation may mimic more common disorders, emphasizing the need for careful clinical reassessment and multimodal diagnostic integration. This case highlights several clinical "red flags" that may suggest an underlying mitochondrial disorder, including progressive multisystem involvement with visual impairment, hearing loss, stimulus-sensitive myoclonus, and subtle proximal muscle weakness. Recognition of these features may facilitate earlier diagnosis and reduce the risk of misclassification. Clinicians should therefore maintain a high index of suspicion for mitochondrial disease in patients with unexplained progressive visual or auditory decline, especially when myoclonus emerges or subtle weakness is detected[13,21]. Recognition of these clinical "red flags" may facilitate earlier diagnosis and help reduce diagnostic delay in similar cases. Multidisciplinary collaboration remains essential, and early recognition allows tailored therapy, avoidance of harmful medications, and appropriate supportive measures[24].

Acknowledgement

The authors are grateful to doctors and nurses for their support and care of the patient.

Authors Contributions

CY, PTA, and WP were responsible for the study concept and design, and prepared the initial draft of the manuscript. PTA, KS, ST, and JA performed the EEG acquisition and figure preparation. CY

and PTA contributed equally to this work and share first authorship. WP served as corresponding author and guarantor, assuming overall responsibility for the integrity of the study from conception through publication. CY, PTA, KS, PTR, ST, TP, PA, JA, SJ, PH, and OC participated in data interpretation, critically revised the manuscript for significant intellectual content, and approved the final version for submission.

Clinical Trial Registration

Not applicable, as this manuscript is a case report and no clinical trial registration was required.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Patient-identifying information has been removed to protect confidentiality.

Ethics Approval and Consent to Participate

This case report was conducted in accordance with institutional ethical standards and received approval from the Institutional Review Board, Faculty of Medicine, Chulalongkorn University (COE No. 084/2025, IRB No. 0812/68). Written informed consent was obtained from the patient for publication of the report and associated images. Consent for participation in the study was also secured prior to inclusion.

Funding Disclosure

The authors have not declared a specific grant for this research from any funding agency in the public, commercial, or not-for-profit sectors.

Use of Artificial Intelligence

Artificial intelligence (AI)-assisted language tools (Grammarly) were used to improve English language clarity, grammar, and manuscript organization. The authors reviewed and edited all AI-assisted content and take full responsibility for the final version of the manuscript.

References

1. Finsterer J, Zarrouk-Mahjoub S. Management of epilepsy in MERRF syndrome. Seizure 2017;50:166-70.
2. Cameron JM, Ellis CA, Berkovic SF. ILAE genetics literacy series: progressive myoclonus epilepsies. Epileptic Disord 2023;25:670-80.
3. Silverio YC, Zhao H, Treidler S. A case of myoclonic epilepsy with ragged-red fibers (MERRF) syndrome in a five-generational family (P11-11.005). Neurology 2024;102 (7 suppl 1):5490. doi: 10.1212/WNL.0000000000205852.
4. Velez-Bartolomei F, Lee C, Enns G. MERRF. In: Adam MP, Feldman J, Mirzaa GM, Pagon RA, Wallace SE, Amemiya A, editors. GeneReviews® [Internet]. Seattle (WA): University of Washington; 1993-2026 [updated 2021 Jan 7; cited 2026 May 20]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK1520/.
5. Chen BS, Harvey JP, Gilhooley MJ, Jurkute N, Yu-Wai-Man P. Mitochondria and the eye-manifestations of mitochondrial diseases and their management. Eye (Lond) 2023;37:2416-25.
6. Cohen BH. MERRF: myoclonus epilepsy and ragged-red fibers. In: Saneto RP, Parikh S, Cohen BH, editors. Mitochondrial Case Studies. Boston: Academic Press; 2016. p. 31-6.
7. Wang JW, Yuan XB, Chen HF. Late-onset mitochondrial encephalomyopathy with lactic acidosis and stroke-like episodes syndrome with mitochondrial DNA 3243A>G mutation masquerading as autoimmune encephalitis: A case report. World J Clin Cases 2023;11:3275-81.
8. Mullie MA, Harding AE, Petty RK, Ikeda H, Morgan-Hughes JA, Sanders MD. The retinal manifestations of mitochondrial myopathy. A study of 22 cases. Arch Ophthalmol 1985;103:1825-30.
9. Latorre A, van der Veen S, Pena A, Truong D, Erro R, Frucht S, et al. IAPRD new consensus classification of myoclonus. Parkinsonism Relat Disord 2025;132:107216. doi: 10.1016/j.parkreldis.2024.107216.
10. Zimmern V, Minassian B. Progressive myoclonus epilepsy: A scoping review of diagnostic, phenotypic and therapeutic advances. Genes (Basel) 2024;15:171. doi: 10.3390/genes15020171.
11. Ryzhkova AI, Sazonova MA, Sinyov VV, Galitsyna EV, Chicheva MM, Melnichenko AA, et al. Mitochondrial diseases caused by mtDNA mutations: A mini-review. Ther Clin Risk Manag 2018;14:1933-42.
12. Bernardino Gomes TM, Ng YS, Pickett SJ, Turnbull DM, Vincent AE. Mitochondrial DNA disorders: From pathogenic variants to preventing transmission. Hum Mol Genet 2021;30:R245-53.
13. Keogh MJ, Chinnery PF. How to spot mitochondrial disease in adults. Clin Med (Lond) 2013;13:87-92.
14. Bindoff LA, Engelsen BA. Mitochondrial diseases and epilepsy. Epilepsia 2012;53 Suppl 4:92-7.
15. Canafoglia L, Franceschetti S, Antozzi C, Carrara F, Farina L, Granata T, et al. Epileptic phenotypes associated with mitochondrial disorders. Neurology 2001;56:1340-6.
16. Trivisano M, Ferretti A, Calabrese C, Pietrafusa N, Piscitello L, Carfì' Pavia G, et al. Neurophysiological findings in neuronal ceroid lipofuscinoses. Front Neurol 2022;13:845877. doi: 10.3389/fneur.2022.845877.
17. Lasek-Bal A, Lukasik M, Żak A, Sulek A, Bosak M. Unverricht-lundborg disease: Clinical course and

seizure management based on the experience of polish centers. Seizure 2019;69:87-91.
18. Saneto RP, Friedman SD, Shaw DW. Neuroimaging of mitochondrial disease. Mitochondrion 2008;8:396-413.
19. Wiedemann FR, Bartels C, Kirches E, Mawrin C, Wallesch CW. Unusual presentations of patients with the mitochondrial MERRF mutation A8344G. Clin Neurol Neurosurg 2008;110:859-63.
20. Orsucci D, Caldarazzo Ienco E, Rossi A, Siciliano G, Mancuso M. Mitochondrial syndromes revisited. J Clin Med 2021;10:1249. doi: 10.3390/jcm10061249.
21. Forny P, Footitt E, Davison JE, Lam A, Woodward CE, Batzios S, et al. Diagnosing mitochondrial disorders remains challenging in the omics era. Neurol Genet 2021;7:e597. doi: 10.1212/NXG.0000000000000597.
22. Cohen BH. Neuromuscular and systemic presentations in adults: Diagnoses beyond MERRF and MELAS. Neurotherapeutics 2013;10:227-42.
23. Bhai S, Hirano M. Diagnosis of primary mitochondrial diseases. Muscle Nerve 2025;71:949-54.
24. Altmann J, Büchner B, Nadaj-Pakleza A, Schäfer J, Jackson S, Lehmann D, et al. Expanded phenotypic spectrum of the m.8344A>G "MERRF" mutation: Data from the German mitoNET registry. J Neurol 2016;263:961-72.
25. Parikh S, Goldstein A, Karaa A, Koenig MK, Anselm I, Brunel-Guitton C, et al. Patient care standards for primary mitochondrial disease: A consensus statement from the mitochondrial medicine society. Genet Med 2017;19:1380-97.
26. Barcelos I, Shadiack E, Ganetzky RD, Falk MJ. Mitochondrial medicine therapies: Rationale, evidence, and dosing guidelines. Curr Opin Pediatr 2020;32:707-18.
27. Parikh S, Saneto R, Falk MJ, Anselm I, Cohen BH, Haas R, et al. A modern approach to the treatment of mitochondrial disease. Curr Treat Options Neurol 2009;11:414-30.
28. Tarnopolsky MA. The mitochondrial cocktail: Rationale for combined nutraceutical therapy in mitochondrial cytopathies. Adv Drug Deliv Rev 2008;60:1561-7.