A tapetal-like fundus reflex in a healthy male: evidence against a role in the pathophysiology of retinal degeneration?

Patrik Schatz,1,2,3 Jesper Bregnhoj,1,3 Henrik Arvidsson,1 Dror Sharon,4 Liliana Mizrahi-Meissonnier,4 Birgit Sander,1 Karen Grønskov,1 Michael Larsen1,3

1Department of Ophthalmology, Glostrup Hospital, University of Copenhagen, Denmark; 2Department of Ophthalmology, Lund University Hospital, University of Lund, Sweden; 3National Eye Clinic for the Visually Impaired and Kennedy Center, Glostrup, Denmark; 4Department of Ophthalmology, Hadassah-Hebrew University Medical Center, Jerusalem, Israel

Purpose: To report on the retinal function and structure in a 37-year-old male who presented with a tapetal-like reflex (TLR) indistinguishable from that seen in female carriers of X-linked retinitis pigmentosa (XLRP).

Methods: Clinical examination included dark adaptometry, full-field electroretinography (ERG), multifocal ERG, optical coherence tomography, and fundus autofluorescence photography. Molecular genetic testing included screening for known mutations in autosomal dominant, autosomal recessive, and X linked retinitis pigmentosa (RP) genes with a commercially available chip, and sequencing analysis of retinitis pigmentosa GTPase regulator (RPGR)-open reading frame 15 (ORF15).

Results: Fundus examination revealed a bilateral TLR, which is typical of female carriers of XLRP. Imaging studies and electrophysiological testing was unremarkable, except for a significant increase in full-field ERG amplitudes after prolonged dark adaptation as compared to after standard dark adaptation. Mutation screening was negative.

Conclusions: TLR was found for the first time, to the best of our knowledge, in a male subject. There were no definitive signs of retinal degeneration, suggesting that this reflex in itself is not necessarily a precursor of the retinal degeneration that can be seen in female carriers of XLRP.

Although their pathophysiology is largely unknown, unusual fundus reflexes may have differential diagnostic implications in retinal degenerations. In Oguchi disease, one of the various congenital stationary night blindnesses, a golden tapetal reflex has been described, which disappears after 2–3 h of dark adaptation; this is referred to as the Mizuo phenomenon [1-3]. The concentration of potassium in the retina has been implicated in the pathogenesis of this phenomenon, since it has been observed in animal studies that a small potassium chloride leak from a defective microelectrode into the inner retina produces a similar yellow-golden sheen [4]. A similar phenomenon has been described in X-linked retinoschisis (XLRS), possibly as a result of a decreased potassium scavenging capacity of retinal Müller cells. The latter assumption could potentially also explain the reduced electroretinographic b-wave in this condition, as it is generated by K+ flow through the Müller cells, mainly as a result of light-evoked depolarization of “ON” bipolar neurons [5-7]. Light falling on the retina results in hyperpolarization of the photoreceptors and in increased extracellular potassium. In the dark-adapted state, the extracellular K+ concentration is much lower again, with normalization of the reflex. Further conditions associated with abnormal fundus reflectivity include early X-linked retinitis pigmentosa (XLRP) in young males [8] and Sheen retinal dystrophy [9].

The tapetal-like fundus reflex (TLR) of female carriers of XLRP is considered to be specific to them. It is described as brightly scintillating particulate reflection on ophthalmoscopic examination, with relative sparing of the fovea [10]. The origin of this reflex has been subject to image analysis and fundus reflectometry studies [10,11]. It has been suggested that an increase in reflectance of the outer segments of the photoreceptors underlies the TLR [11].

Carriers of XLRP may also display a range of abnormalities of retinal function [12,13]. However, the nature of the relation between the retinal degeneration and the TLR has not been fully determined.

In the following, we report the finding of such a reflex in a healthy 37-year-old male in whom no association with RP could be demonstrated. For comparison, we also include findings from two female carriers of XLRP.

METHODS

The study was approved by an institutional ethics committee and informed consent was obtained. The male patient was examined with full-field electroretinography (ffERG), Goldmann-Weeker dark adaptometry, multifocal electroretinography (mERG, VERIS 4; EDI, San Mateo, CA), optical coherence tomography (OCT-4; Zeiss Humphrey Instruments, Dublin, CA), and fundus

Correspondence to: Patrik Schatz, Department of Ophthalmology, Glostrup Hospital, University of Copenhagen, Copenhagen, Denmark; Phone: +45 38 63 38 63; FAX: +45 38 63 39 00; email: patrik.schatz@med.lu.se
autofluorescence photography (Spectralis HRA-OCT; Heidelberg Engineering, Heidelberg, Germany) was performed as described previously [14,15]. Dark adapted FfERG was performed according to International Society for Clinical Electrophysiology of Vision (ISCEV) standard, as well as after prolonged dark adaptation for 24 h, achieved by overnight patching of the right eye. After topical anesthesia of the eye, a Burian Allen bipolar contact lens (Hansen Labs, Coralville, IA) was applied on the cornea, and a ground electrode was applied on the forehead. Responses were obtained with a wide-band filter (−3 dB at 1 Hz and 500 Hz) stimulated with a single full-field flash (30 µsec) with blue light (Wratten filter 47, 47A, and 47B, Kodak, Rochester, NY) and with white light (3.93 cd/m^2). Cone responses were obtained with 30-Hz flickering white light (0.81 cd/m^2) averaged from 20 sweeps.

Figure 1. Fundus photography in a healthy male patient demonstrating the presence of bilateral tapetal-like reflex.

Figure 2. Fundus autofluorescence in the male patient with a tapetal-like reflex, demonstrating no obvious abnormality.
For comparison, we retrospectively reviewed fundus photography from carriers of XLRP in the photographic archives of our clinic, in search for TLR. In addition, a 33-year-old female carrier of XLRP with no TLR, with a known mutation c.854G>A in retinitis pigmentosa GTPase regulator (RPGR) was examined by mfERG and fundus autofluorescence photography as follows. We overlaid the focal ERGs from the mfERG on the fundus autofluorescence photograph, attempting at an exact correspondence between the focal ERGs and their retinal location of origin. For this, we used the projection of the mfERG stimulus hexagons on the infrared fundus image that is present during the mfERG investigation. The mfERG array was then transferred over to the fundus autofluorescence photograph, with an attempt to preserve the same correspondence relative to retinal location.

Molecular genetic testing in the male patient included screening for known autosomal recessive, autosomal dominant, and X-linked RP mutations by a commercially available microarray technique (Asper Ophthalmics, Tartu, Estonia). Previously published mutations in the following genes were screened:

1. The autosomal recessive retinitis pigmentosa (AR-RP) test, including the ceramide kinase-like (CERKL), cyclic nucleotide-gated channel alpha 1 (CNGA1), cyclic nucleotide gated channel beta 1 (CNGB1), C-mer proto-oncogene tyrosine kinase (MERTK), phosphodiesterase 6A (PDE6A), phosphodiesterase 6B (PDE6B), nuclear receptor subfamily 2 group E, member 3 (NR2E3), retinal dehydrogenase 12 (RDH12), retinal G protein coupled receptor (RGR), retinaldehyde binding protein 1 (RLBP1), S-antigen (SAG), tubby like protein 1 (TULP1), Crumbs homolog 1 (CRB), retinal pigment epithelium-specific protein 65 kDa (RPE65), Usher syndrome 2A (USH2A), clarin 1 (USH3A), and lecithin retinol acyltransferase (LRAT) genes;

2. The AD-RP test, including the carbonic anhydrase IV (CA4), Fascin homolog 2 (FSCN2), inosine monophosphate dehydrogenase 1 (IMPDH1), neural retina leucine zipper (NRL), pre-mRNA processing factor 3 homolog (PRPF3), pre-mRNA processing factor 31 homolog (PRPF31), pre-mRNA processing factor 8 homolog (PRPF8), retinal degeneration slow (RDS), rhodopsin (RHO), retinal outer segment membrane protein 1 (ROM1), retinitis pigmentosa 1 (RP1), retinitis pigmentosa 9 (RP9) and cone-rod homeobox (CRX) genes; and

3. The X-linked retinitis pigmentosa (XL-RP) test, including the retinitis pigmentosa 2 (RP2) and retinitis pigmentosa GTPase regulator (RPGR; only exons 1–14) genes.

As the RPGR open reading frame (ORF) 15 is not included in the latter test, we performed direct sequencing of PCR products to screen RPGR ORF15 [16].

In addition, PCR analysis of polymorphic microsatellite markers on the X and Y chromosomes (QSTR-XYv2 kit from Elucigen; Gen Probe, San Diego, CA) was performed to determine whether there was a normal male set of chromosomes.

RESULTS

A now 37-year-old patient presented at our department more than 10 years before after a trauma to the head region. In a routine examination, we discovered unusual yellowish
reflexes scattered in both fundi, extending from the perimacular region into the midperiphery (Figure 1). Peripheral retina was unremarkable, specifically there was no retinoschisis. The patient had two healthy brothers and a healthy daughter. All family members, including mother and father, had normal fundi and fundus photographs (except for presumably age-related scattered drusen around the vascular arcades and in the posterior pole in the mother), full vision, and no visual symptoms. There was no family history of any ophthalmic or other disease, except a reported cataract in a grandparent. The patient was asymptomatic and had a best corrected visual acuity of 1.0 (decimal acuity scale) in both eyes. FfERG was performed to rule out a retinal degeneration, and was found to be normal.

The patient was re-examined 10 years later, including clinical and electrophysiological evaluation and molecular genetic tests.

Fundus autofluorescence (Figure 2), dark adaptometry (Figure 3, lower left panel), optical coherence tomography (OCT; Figure 3, upper left panel), and mfERG (Figure 3, upper right panel) were normal. FfERG was within normal limits after the standard 30 min dark adaptation; however, rod and cone responses increased by >50% each after prolonged 24 h dark adaptation (Figure 4, Table 1).

Analysis for known mutations in RP genes revealed no mutations. In addition, a PCR analysis for polymorphic microsatellite markers on the X and Y chromosomes displayed the presence of one X chromosome and one Y chromosome.

In a retrospective review of fundus photography in the photographic archives of our clinic we identified a bilateral TLR in a 22-year old female carrier of XLRP, belonging to a family with the single base pair deletion c.3395delA (g.ORF15+1642delA) at the 3’ end of the ORF15 exon in RPGR resulting in a premature stop codon (Figure 5) [17]. Further investigation, for example electrophysiology, was not possible at this point.

A 33-year-old female carrier with c.854G>A, a known mutation in RPGR [18], but in whom no TLR was present, was investigated. The fundus and OCT (Figure 6) did not demonstrate any obvious abnormalities; however, autofluorescence photography and mfERG (Figure 7) demonstrated localized variation of autofluorescence intensity along with areas of focally reduced function by mfERG (Figure 7). MfERG ring averages and OCT foveal thickness from the latter patient and from the male patient with the TLR are presented in Table 2.

**DISCUSSION**

The described male patient presented with bilateral TLR, indistinguishable from that associated with female carriers of XLRP. We confirmed male sex by PCR analysis of the X and Y chromosomes. This also excludes Klinefelter syndrome (47, XXY), which could theoretically explain a phenotype associated with the female sex in a male patient [19]. The TLR of female carriers of XLRP is considered to be specific for this condition, and has not, to the best of our knowledge, been previously described in a male.

Abnormal fundus reflections in male patients may be seen in Oguchi disease, XLRS, sheen retinal dystrophy, and early XLRP [1-9]. However, these conditions are frequently associated with profound retinal degeneration, specific alterations in the fERG after standard dark adaptation for 30 min and/or structural alterations in the inner retina, none of which was present in our patient. Furthermore, these abnormal reflections differ in appearance from the TLR seen in female carriers of XLRP and in our patient.

Standardized electrophysiological examination including fERG after 30 min dark adaptation failed to reveal any significant abnormality in our patient. There was no change of fundus appearance over a follow-up period of more than 10 years. The stability of the TLR is also reported for female carriers of XLRS, thus challenging the assumption that the TLR is a stage of the retinal degeneration [10,11]. Our findings related to this reflex in a healthy male seem to support...
### Table 1. Full-field electroretinography results.

| Subject          | Rod amplitude (μV) DA 30 min | Rod amplitude (μV) DA 24 h | Rod-cone amplitude (μV) DA 30 min | Rod-cone amplitude (μV) DA 24 h | 30 Hz flicker amplitude (μV) DA 30 min | 30 Hz flicker amplitude (μV) DA 24 h | 30 Hz flicker implicit time (ms) DA 30 min | 30 Hz flicker implicit time (ms) DA 24 h |
|------------------|-----------------------------|---------------------------|------------------------------------|-----------------------------------|----------------------------------------|----------------------------------------|------------------------------------------|------------------------------------------|
| Male patient     | 147                         | 234                       | 292                                | 431                               | 55                                     | 86                                     | 26.9                                     | 27.7                                     |
| Normal Median    | 137                         | 305                       |                                    |                                   | 53                                     |                                        | 29.1                                     |                                          |
| Normal Range     | 64-221                      | 158-546                   |                                    |                                   | 20-117                                 |                                        | 25.2-33.2                                |                                          |

All amplitudes in the table refer to b-wave amplitudes. DA: Dark adaptation; μV: microvolt; ms: milliseconds; min: minutes; h: hours; Hz: Herz.
Table 2. Optical coherence tomography and multifocal electroretinography findings.

| Subject          | MfERG Ring 1–2 amplitude (nV/deg<sup>2</sup>) | MfERG Ring 1–2 latency (ms) | MfERG Ring 3–6 amplitude | MfERG Ring 3–6 latency (ms) | OCT foveal thickness (μm) |
|------------------|---------------------------------------------|-----------------------------|--------------------------|----------------------------|--------------------------|
| XLRP carrier     | 11.4                                        | 30                          | 7.4                      | 30.8                       | 199                      |
| Male patient     | 38.9                                        | 29.2                        | 27.2                     | 28.3                       | 215                      |
| **Normal**       | **Median**                                  | **29.3**                    | **26.3**                 | **12.7**                   | **182**                  |
| **Range**        | **22.8–35.2**                               | **25.8–29.5**               | **10.6–20.2**            | **25.0–28.3**              | **157–207**              |

OCT: Optical coherence tomography. MfERG: multifocal electroretinography. XLRP carrier: 33 year old female carrier of X linked retinitis pigmentosa. ms: milliseconds.
this notion. On the other hand, female carriers usually only present with degeneration later in life. They may have normal fERG and visual fields, especially in younger age groups [12]. We cannot exclude the possibility that this male patient will develop signs of retinal degeneration later on.

There was a significant and similar (>50%) increase in fERG rod and cone response amplitudes after prolonged dark adaptation compared to after standard dark adaptation. A similar or even larger magnitude of improvement of responses in the fERG may be observed in specific disorders due to mutations in visual cycle genes, leading to deficient recycling of 11-cis retinal to reconstitute rhodopsin, for example fundus albipunctatus [15]. However, the latter condition features severely reduced or even nonrecordable responses after standard dark adaptation, in contrast to our patient who presented with fERG responses within normal limits after standard 30 min dark adaptation. In fundus albipunctatus, white dots visible on fundus exam coincide with focal hyperreflective accumulations that span from Bruch's membrane across the retinal pigment epithelium and
photoreceptor outer and inner segments on OCT [15]. However, our patient presented with normal OCT. Thus, the structural substrate, if any, of the TLR in our subject remains elusive. One reviewer suggested the possibility of a specific distribution of amelanotic retinal pigment epithelium cells, underlying the TLR.

Genetic screening regarding XLRP genes included the two major XLRP genes: RP2, which accounts for 10%–20% of recessive XLRP, and RPGR, which accounts for 50%–80% of recessive XLRP [20]. However, at least four additional loci are mapped for which the genes are not yet identified [21]. In a recent study, it was suggested that the genetic defects in RPGR and RP2, which are considered to lead to dysfunction of the connecting cilium of the photoreceptor cells, could result in accumulation of retinoid compounds in the inner segments of the photoreceptors that could account for patches of increased autofluorescence observed in that study [13]. In the present study, we did not notice any abnormalities regarding fundus autofluorescence (Figure 2).

Although well documented in the literature, and considered specific for the condition, we are aware of only three studies that include photographic presentation of the TLR: Cideciyan and Jacobson [10], Wegscheider et al. [22], and recently Genead et al. [13].

For comparison, we present a fundus photograph (Figure 5) of the TLR in a female carrier of XLRP, and we investigated a 33-year-old female carrier of XLRP, without any TLR. (Figure 6 and Figure 7). The patchy reduction of mfERG is compatible with random X inactivation and the Lyon hypothesis [23], and has been demonstrated before in female carriers of XLRP [12]. Interestingly, remaining responses in the mfERG seem to correspond to remaining autofluorescence (Figure 7). It may be suggested that localized photoreceptor apoptosis lead to secondary atrophy of the retinal pigment epithelium, explaining the regional variation of autofluorescence. However, the relation between regional variation in fundus autofluorescence and retinal function may be more complex and requires further investigation.

To conclude, this is to our knowledge the first description of the TLR, which was previously considered specific to female carriers of XLRP, in a healthy male patient, in whom clinical investigations and molecular genetic analysis failed to reveal any definitive association with retinal degeneration. This indicates that, at least until 30–40 years of age or longer, TLR may be present in spite of the absence of further typical signs of retinal degeneration. However, the nature and origin of the phenomenon are still not clear and further studies are required.

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