Genotype-phenotype correlation in a family with Arg135Leu rhodopsin retinitis pigmentosa

K T Oh, D M Oh, R G Weleber, E M Stone, A Parikh, J White, K A DeBoer-Shields, L Streb, C Vallar

Aim: To describe the clinical characteristics and disease course of a large family with retinitis pigmentosa (RP) from an Arg135Leu change in rhodopsin.

Methods: 29 patients in this family were evaluated. Goldmann visual fields were performed on 14 affected individuals, Ganzfeld electroretinography (ERG) on eight individuals (11–56 years), and blood samples collected on 10 individuals (11–58 years). Patient visual field data were compared with previously reported patients with different rhodopsin mutations using linear regression.

Results: An Arg135Leu mutation was identified in rhodopsin. Distinct stages of clinical evolution were identified for this family ranging from normal, white dots, classic bone spicules and, finally, ending with extensive retinal pigment epithelium (RPE) atrophy. 9/16 patients over the age of 20 years also demonstrated marked macular atrophy. All patients who underwent full field ERG testing demonstrated non-recordable ERGs. The overall regression model comparing solid angles of visual fields from patients with rhodopsin mutations (Pro23His, Pro347Ala, Arg135Leu) shows significant effects for age (p = 0.0005), mutation (p = 0.0014), and interaction between age and mutation (p = 0.018) with an R² of 0.407.

Conclusions: An Arg135Leu change in rhodopsin results in a severe form of RP that evolves through various fundus appearances that include white dots early in life and classic appearing RP later. This transmembrane change in rhodopsin proves to be more severe than in a family with an intradiscal change and a family with a cytoplasmic change.

RESULTS

Clinical findings

Ten patients at various disease stages ranging in age from 11–58 years had blood samples sent to the Carver Molecular Ophthalmology Laboratory for analysis. Screening using an amplification refractory mutation system (ARMS) disclosed neither the Pro23His nor Arg135Trp changes in rhodopsin. Samples that had aberrant migration patterns of polymerase chain reaction products, using single stranded conformational polymorphism analysis, were sequenced bidirectionally with fluorescent dideoxynucleotides on an ABI model 377 automated sequencer. An Arg135Leu change in rhodopsin was identified in all samples.

Molecular analysis and findings

Ten patients at various disease stages ranging in age from 11–58 years had blood samples sent to the Carver Molecular Ophthalmology Laboratory for analysis. Screening using an amplification refractory mutation system (ARMS) disclosed neither the Pro23His nor Arg135Trp changes in rhodopsin. Samples that had aberrant migration patterns of polymerase chain reaction products, using single stranded conformational polymorphism analysis, were sequenced bidirectionally with fluorescent dideoxynucleotides on an ABI model 377 automated sequencer. An Arg135Leu change in rhodopsin was identified in all samples.

SUBJECTS AND METHODS

This study had approval of the institutional review board of the University of North Carolina (UNC). A total of 24 affected patients, all members of a 13 generation family with ADRP (fig 1), were examined at UNC. Five additional affected and multiple unaffected patients were examined at a family reunion by the author. Patients clearly reported nyctalopia from early childhood and this symptom was used to determine disease status. Affected patients from four different generations and two separate branches of the family came to UNC. Patients underwent a standard eye examination, Goldmann perimeter, electroretinographic testing, and fundus photography. Patients with hand movement or worse vision did not undergo ancillary testing. Full field electroretinography and multifocal electroretinography (mfERG) were performed according to ISCEV standards. Eight patients underwent full field ERG testing with an LKC Veritas system (Gaithersburg, MD, USA). Three patients underwent mfERG using a Veris system (ElectroDiagnostics, Inc, San Mateo, CA, USA). Goldmann visual fields (GVF) were converted to solid angle (in steradians) using described methods. A linear regression model was performed from patients with Arg135Leu, Pro23His and Pro347Ala mutations in rhodopsin (JMP SAS, Cary, NC, USA).

Abbreviations: ADRP, autosomal dominant retinitis pigmentosa; ARMS, amplification refractory mutation system; GVF, Goldmann visual fields; mfERG, multifocal electroretinography; RP, retinitis pigmentosa; RPA, retinitis punctata albescens; RPE, retinal pigment epithelium
widespread white dots and minimal RPE changes with only the youngest patient (age 7 years) not demonstrating any definite signs (fig 3B and 3C). In the second to third decades, the white dots fade and are replaced by RPE atrophy and bone spicules (fig 3D) and, finally, the fundus shows marked RPE atrophy and choroidal sclerosis (fig 3E and F).

Electroretinographic findings
We evaluated eight patients with full field electroretinography (ages 11–50 years) and three patients with mfERG. All patients undergoing full field electroretinography showed non-recordable responses. For mfERG testing, only the 16 year old demonstrated recordable retinal function, though no other patients younger than 40 years were tested. Repeat mfERG for this patient 13 months later found considerable further loss of recordable amplitude.

Perimetric findings
Fifteen patients underwent Goldmann perimetry. There was no measurable field with the I4e isoptre by the fourth decade of life. The V4e test target became undetectable by the sixth decade of life (fig 4). When the solid angle of I4e isoptre was compared to the clinical characteristics of the Pro23His and the Pro347Ala change in rhodopsin, there was a significant difference in the loss of visual field for patients with an Arg135Leu change in rhodopsin compared with the other mutations. The difference between visual field data for patients with the rhodopsin Arg135Leu RP and those with either other change remained significant at the 0.0005 level after Bonferroni correction (fig 5). The overall regression model comparing patients with rhodopsin mutations (Pro23His, Pro347Ala, Arg135Leu) shows significant effects for age (p = 0.0005), mutation (p = 0.0014), and interaction between age and mutation (p = 0.018) with an R² of 0.407. Comparison of Arg135Leu change and Pro23His change demonstrated a significant difference in these populations (p = 0.0002) but no significance in the effect of age or the interaction of age and mutation. Comparison of Arg135Leu change and Pro347Ala change shows significant effect of age (p = 0.0001), mutation (p = 0.0001), and the interaction of age with mutation (p = 0.0003).

DISCUSSION
Rhodopsin related disease may present with a wide spectrum of severity and clinical features, including regional and diffuse RP, sectoral RP,26 and congenital stationary night blindness.27 Sandberg previously identified the importance of the locus of mutations in rhodopsin to a specific patient’s disease course, showing that intradiscal variations such as Pro23His carried the mildest course of disease and cytoplasmic variations such as at codon 347 carried the most severe prognosis.3 The severity of mutations in the intracytoplasmic region of rhodopsin is well documented though only a few clinical studies exist for changes in the transmembrane region.32 Pannarale described one family with an Arg135Trp mutation in rhodopsin with a very severe course. That family demonstrated non-recordable electroretinographic responses by the third decade of life but low, recordable wave forms for younger patients.17 Thus, changes associated with codon 135 may result in a more severe course.30 The appearance of white dots in association with rhodopsin and, specifically, Arg135Trp rhodopsin related RP, was described by Souied as an early finding in that form of RP.31 The term retinitis punctata albescens (RPA) was originally used to denote a specific form of RP.32 Although some have questioned in the...
past whether RPA was a specific disorder or simply a phenotype or stage of classic RP, recently, RPA has been recognised as a specific autosomal recessive retinal degeneration that results from mutations in the gene RLBP1. Admittedly, though, the white dots in RPA, although similar, are clinically different from those observed in our family.

In summary, we present a family with RP caused by an Arg135Leu mutation in rhodopsin. This family demonstrated a particularly severe course that was worse than families with cytoplasmic or intradiscal mutations in rhodopsin. From a cross sectional study of patients, we inferred the progression of disease for this family. In the first decade of life, affected patients will be symptomatic without clinical signs on fundus examination. By the second decade, patients develop extensive fine white dots at the level of the retinal pigment epithelium in the absence of extensive RPE atrophy or bone spicules. The white dots fade by the third decade of life leaving bone spicules with widespread RPE atrophy. This appearance steadily worsens with increasing age and is associated with progressive decrease in visual field area. Patients uniformly developed cataracts by the second decade of life and appeared to respond favourably to cataract extraction. However, macular atrophy, as observed in our patients, is not uncommon in patients with changes at codon 135 of rhodopsin. Central acuity appeared to be closely related to the degree of macular atrophy.

Figure 3  Fundus appearance. (A) Fundus image of affected man, aged 41 years. Note the parafoveal atrophy of the retinal pigment epithelium (RPE). There is RPE atrophy and bone spicules beyond the arcades. Arterioles are attenuated. (B) Fundus image of affected boy, aged 9 years. Note the relative lack of fundus findings. This patient has some pallor to the optic nerve and attenuation of his arterioles. Periphery demonstrated no evidence of RPE atrophy, bone spicules, or white dots. (C) Fundus image of affected girl, aged 11. Note the extensive white dots and RPE mottling in the mid-periphery. Bone spicules are notably absent. (D) Fundus image of affected girl, aged 16. Note the presence of white dots and RPE atrophy. Bone spicules are beginning to develop in the mid-periphery. (E) Fundus image of affected woman, aged 45 years. Note the extensive RPE thinning and atrophy both in the mid-periphery and the macula. The optic nerve is pale and there is arteriolar attenuation. (F) Fundus image of affected man, aged 57 years. Note the extensive RPE clumps in the mid-periphery and visible sclerotic choroidal vessels.
with rhodopsin, we are the first to clearly document that this clinical appearance is largely dependent on the age of the subject. We also further demonstrated the importance of age and genotype for the modelling of disease course as previously described. The R² value predicts that up to 40.7% of disease variation may be predicted on the basis of patient age and specific genotype. While other factors will influence disease course, this value calls attention to the importance of these two variables. The severity of this particular form of retinitis pigmentosa and the careful understanding of its natural history will be important considerations in the inclusion of patients with this condition in future clinical trials.

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