Determination of optical properties of the rat eye using in vivo high-resolution MR imaging

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Introduction

The optical properties of the eye are of great interest for the development of new diagnostic tools in ophthalmology. To develop high-resolution *in vivo* imaging systems a number of exact measurements are required. Previously these measurements were performed *ex vivo* using optical [1] and histomorphological [2] techniques. However these measurements are prone to preparation artifacts that compromise the validity of the measurements. The most precise way to determine these indices *in vivo* is to perform animal highresolution morphological MR imaging and subsequent post-processing. For this we used 3D MR imaging in combination with specific sequences that allow spatially highly resolved images of the optical apparatus and subsequent postprocessing to calculate a theoretical model of the rat eye.

Materials and Methods

MRI measurements were performed on 5 female Wistar rats (10 weeks old) on a 9.4 T animal scanner (Bruker BioSpec 94/20) using a linear volume coil with an inner diameter of 58mm. The MR protocol consisted of a localizer sequence, a T2-weighted RARE (TR/TE: 4200ms/36ms, FOV 30x30mm matrix 256x256, in plane resolution of 117 x 117µm) to get a anatomic overview and to plan the subsequent highresolution 3D_Turbo Rare (TR/TE: 1500ms/40ms, FOV 30x30x7,5mm matrix 256x256x64, isometric resolution of 117 x 117x117µm) and T2-RARE (TR/TE: 2500ms/36ms, FOV 30x30mm matrix 384x384, in plane resolution of 78 x 78µm) scans. From these scans the image data was extracted as individual .tiff files. Each individual section was rotated until the equator of the eye was approximately vertical (all sections were rotated by the same angle). The region of interest was selected and cropped. A `Canny' edge detection algorithm was used to detect the boundaries between the different optical elements of the eye. False edges were removed manually. The resultant 3-D stack was a binary set with zero value everywhere except at the boundaries where the value was one. This produced two concentric shells, the external one corresponding with the retina and cornea, and the interior one with the crystalline lens (Figure 1). The boundary of the crystalline lens was identified manually allowing separation of the two shells in separate image stacks. In the central image of each one of the resultant stacks we used the line joining the maximum and minimum points of each shell to define the plane (perpendicular to this particular image) splitting the front from the back part of each shell (we call this the middle plane). In the case of the external shell the front region is the cornea, and the back region the retina. For the crystalline lens this defined the front and back surfaces of the lens. The 3-D co-ordinates of each point in the shells were then calculated to create a 2-D map where the value at each x,y co-ordinate point gave the distance from the middle plane to the shell in question. The radius of curvature and aesphericity could then be estimated from this 2-D map. We could also parametrise the surfaces by fitting a polynomial expansion to the 2-D map (Figure 2). Given the geometry close to a sphere, a Zernike polynomial expansion was a useful choice. A least square fit was used.

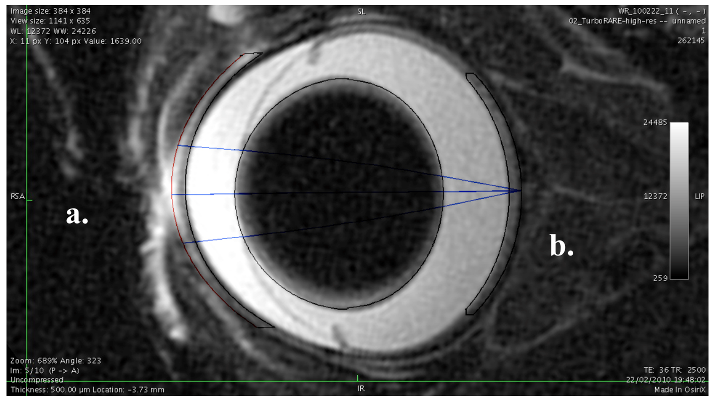

Figure 1. Highresolution T2-Rare image: Vertical plane of the rat eye containing concentric shells: a) cornea, b) retina

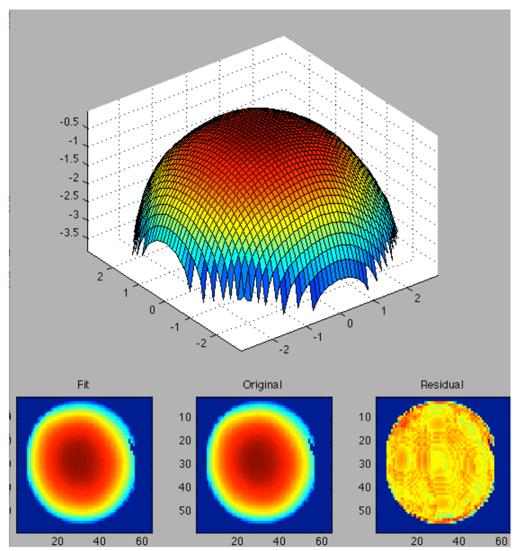

Figure 2: fitted polynomal expansion with original and residual distances from the middle plane.

Results and Discussion

We were able to use *in vivo* MR image data to calculate a theoretical, parametric model for the rat eye. This will help to facilitate the development of new diagnostic tools in ophtalmologic basic reearch.

References: 1. Chaudhuri A et al. Aspheric curvatures, refractive indices and chromatic aberration for the rat eye. 1. Vision Res. 1983;23(12):1351-63**.**
2. Remtulla S, Hallett PE. A schematic eye for the mouse, and comparisons with the rat. Vision Res. 1985;25(1):21-31.