Evaluation of the macular changes after successful retinal detachment surgery using optical coherence tomography

Thesis
Submitted in partial fulfillment of M.D. degree in ophthalmology

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2013

Acknowledgements

First and foremost thanks to ***Allah*** *who granted me the power to accomplish this work.*

I would like to express my deep appreciation to ***Prof. Dr. Taha Labib,*** *Professor of Ophthalmology, Faculty of Medicine, Cairo University, for his kind supervision wise guidance, patience, continuous encouragement and great help throughout this work.*

I wish to express my sincere gratitude to ***Prof Dr. Amr Azab*** *professor of ophthalmology, Research Institute of Ophthalmology, for his great help, continuous supervision and effort with me throughout this study. He supplied me with valuable informations which were important pillars in my thesis.*

My sincere appreciation to ***Prof.Dr.med. Ulrich Bartz-Schmidt;*** *Professor of ophthalmology, Universityeye Eye Hospital Tuebingen, for for his generous assistant, constant support and guidance throughout the study.*

I wish to thank all my patients, without whom this work would have never been completed.

Finally whatever I say will never be enough to thank my wife and family, I greatly appreciate their moral help, they were always supplying me with the feeling of hope, love and encouragement.

This thesis is dedicated to a great and special father and mother. It is also dedicated to a cooperative kind wife and to my beloved family.

Sameh M. M. Abou-El Khir

TABLE OF CONTENTS

List of Abbreviations

BCVA	:	Best Corrected Visual Acuity
BIOM	:	Binocular indirect ophthalmomicroscope
C2F6	:	Perfluoroethane
C3F8	:	Perfluoropropane
C4F8	:	Perfluorobutane
ELM	:	External Limiting Membrane
FD	:	Fourier domain
FFA	:	Fundus fluorescein angiography
GCL	:	Ganglion cell layer
GRT	:	Giant Retinal Tear
ICAM	:	Intracellular adhesion molecule
ILM	:	Internal limiting membrane
INL	:	Inner nuclear layer
IOL	:	Intra-ocular lens
IOP	:	Intra-ocular Pressure
IS	:	Inner Segment
MMP		Matrix Metalloproteinase
µm	:	Micrometer
NSR	:	Neurosensory Retina
OCT	:	Optical Coherence Tomography
OS	:	Outer Segment
PED	:	Pigment epithelial detachment
PFCL	:	Perfluorocarbon liquid
ppV	:	Pars Plana Vitrectomy
RD	:	Retinal detachment
ROE	:	Retinal Outer Segment
RPE	:	Retinal Pigment Epithelium
RRD	:	Rhegmatogenous Retinal Detachments
SB	:	Scleral Buckling
SRF	:	Sub-Retinal Fluid
SFT	:	Subretinal Fluid Thickness
SRS	:	Subretinal Space
UHR	:	Ultrahigh-Resolution
VA	:	Visual Acuity
3-D	:	3-Dimensional

List of Figures

List of Tables

Introduction

Retinal detachment often is a preventable cause of vision loss. It is defined as separation of the neurosensory retina (NSR) from the underlying pigment epithelium in association with accumulation of subretinal fluid. [1]

A retinal detachment occurs when the forces of adhesion between the neurosensory retina (NSR) and the retinal pigment epithelium RPE are overwhelmed. This can occur by different mechanisms. Regardless of the mechanism, all types of retinal detachment have one characteristic in common, the accumulation of subretinal fluid. [2]

Despite the high level of anatomic success, visual results remain compromised mainly because of permanent functional damage once the macula becomes detached. [3]

The Reattachment rate after retinal detachment surgery is quite high.. Although the retina is completely reattached, functional recovery cannot be accomplished completely. Although some studies have shown a relation between duration of macular detachment and visual acuity, others have not. [4]

Visual recovery after treatment of retinal detachment varies from case to case despite apparent ophthalmoscopic retinal reattachment. Although many prognostic factors have been suggested in regard to postoperative visual acuity, the relation between the tomography of the reattached retina and the visual acuity have not been well studied. [5]

Patients with macula-off rhegmatogenous retinal detachments (RRDs) can have poor visual recovery, specific color vision defects, or metamorphopsia

postoperatively despite successful retinal reattachment. In these cases, subtle changes in the foveal structure, which may be causing visual disturbances, can be difficult to identify during standard clinical examinations such as slit-lamp biomicroscopy or binocular indirect ophthalmoscopy. [6]

Wolfensberger and Gonver reported a possible association between incomplete visual recovery and the presence of residual subretinal fluid (SRF) postoperatively. [7]

Optical coherence tomography is a noninvasive, patient- and operator-friendly technique that has the advantage of imaging and quantitatively analyzing retinal thickness, nerve fiber layer, and optic nerve structures with good reproducibility. [8]

The advent of optical coherence tomography (OCT) offers the theoretical possibility of high-resolution measurements of both retinal thickness and the dimensions of the retinal component layers, especially the thickness of subfoveal fluid in detached fovea. Images are generated as a result of the interaction between a partially coherent beam of optical radiation and tissue components. The most important optical phenomena in OCT signal generation are the scatter, reflection, and absorption of incident light. In current biomedical applications, near infrared radiation is used almost exclusively as a source of illumination. [9]

Optical coherence tomography (OCT) (Stratus OCT, Carl Zeiss Meditec, Inc., Dublin, CA) is a commercially available computer-assisted precision optical instrument that generates cross-sectional images (tomograms) of ocular structures with close to 10-μm axial resolution. [10]

Spectral/Fourier domain detection represents a recent advance in OCT technology that enables imaging speeds of >25,000 axial scans per second, or ~50 times faster than time-domain detection. [11]

Ultrahigh-resolution (UHR) OCT, which provides an axial resolution of approximately 3 to 5 μm compared with that of approximately 10 μm with conventional Stratus OCT, facilitates improved visualization of the intra-retinal microstructures and identification of pathologic changes. [12]

Spectral/Fourier domain OCT images more accurately represent true retinal topography than do time-domain OCT images. Because of the increased speed of image acquisition, motion artifacts are minimized, resulting in higher quality images and finer discrimination of intraretinal layers. [13]

Improved resolution enhances visualization of the intraretinal structures, particularly at the level of the external limiting membrane (ELM) and photoreceptor inner segment/outer segment (IS/OS) junction, which may indicate the integrity of the photoreceptor layer. [14]

Spectral or Fourier domain OCT is so named because the interference spectrum of echo time delays of light is measured by a spectrometer and high-speed charge-coupled device (CCD) camera. Because the interference spectrum is composed of oscillations whose frequencies are proportional to the echo time delay, axial scan measurements can be obtained by calculating the Fourier transform. (A Fourier transform is a mathematical operation that extracts the frequency content of a signal). [8]

FD-OCT provides a rapid sweep of serial OCT B-scan images that detect subtle microstructural changes in the area of interest (Retinal pigment

epithelium-photoreceptor complex) and reconstruction of a 3-dimensional (3-D) view of the microstructures. [15]

The gases most commonly used in ophthalmic surgery are air, sulfur hexafluoride (SF6), perfluoropropane (C3F8), perfluoroethane (C2F6) and perfluorobutane (C4F8). The gases mentioned differ in terms of how long they will remain in the eye and in their expansion capacity (table 1). [16]

TABLE 1

Physical attributes of commonly used intraocular gases

Gas	Expansion behavior at a concentration of 100% (factor)	Concentration that is usually applied (%)	Number of days that intraocular gas remains in the eye
Air	0		5 to 7
SF_6	2	20	10 to 14
C_2F_6	3.5	16	30 to 35
C_3F_8	4	12	55 to 65

Aim of the work

This work will assess the postoperative sub-clinical features of the foveal microstructures using OCT in patients presented with retinal detachment with detached macula (macula-off). Visual acuity (VA) and macular changes as the height of subfoveal fluid (subretinal fluid thickness, SFT) are measured before and after retinal surgery. The correlation between postoperative VA and SFT over time will be explored, as one would expect increasing VA with decreasing SFT.

Anatomy and Physiology of the Retina and Subretinal Fluids

The fundus oculi is the part of the eye that is visible on ophthalmoscopy, including the retina and its vessels and the optic nerve head (or optic disc). The macula, 5- 6 mm in diameter, lies between the temporal vascular arcades. At the macula's center lies the fovea, rich in cones and responsible for color vision and the highest visual acuity. In the far periphery, the ora serrata is the junction between the retina and the pars plana. [17]

The retina consists of millions of cells packed together in a tightly knit network spread over the surface of the back of the eye. These cells can be divided into a three basic cell types, photoreceptor cells, neuronal cells, and glial cells.[18]

With the exception of the fovea, ora serrata, and optic disc, the neural retina is organized in layers, dictated by the direction of the müllerian glia, its organizational backbone. Essentially, there is the photoreceptor layer plus the bipolar and ganglion cell layer, which represent the outer first neuron and inner second neuron of the visual pathway. The müllerian glia elaborate the internal limiting membrane as its basement membrane and extend to the external limiting membrane, where it communicates with the apices of the RPE (Figure 1.1).[19]

The inner nuclear layer is home to the nuclei of the müllerian glia, the bipolar cells, and the horizontal and amacrine cells. The amacrine cells lie on the inside of the inner nuclear layer, and the horizontal cells lie on the outside. The

inner nuclear layer has plexiform layers on either side, which connect it to the outer photoreceptor layer and the (inner) ganglion cell layer. From this simple anatomical consideration, it follows that rods and cones synapse with bipolar and horizontal cells in the outer plexiform layer. As a result of the increased length of Henle's fibers, the junctional system (the middle limiting "membrane") is found in the inner third of the outer plexiform layer, which is the only truly plexiform portion of this layer. The bipolar cells and amacrine cells of the inner nuclear layer synapse with the dendrites of the ganglion cells in the inner plexiform layer. In embryogenesis, müllerian glia, along with their internal limiting membrane and orientation, antedate photoreceptor differentiation; this is analogous to the rest of the central nervous system, in which structural development precedes individual cell differentiation.[19]

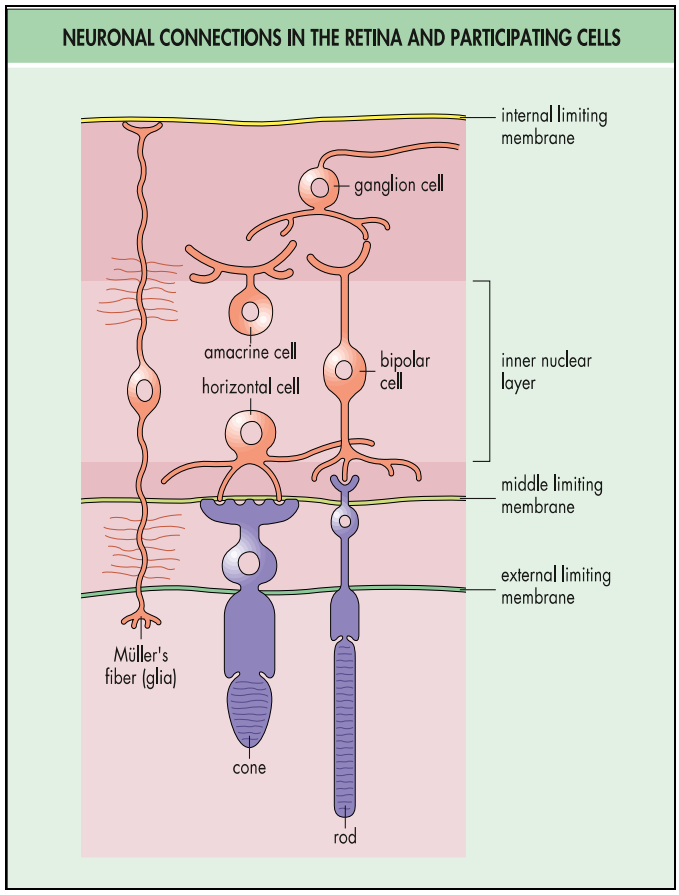

Fig. 1.1: Neuronal connections in the retina and participating cells.[19]

The Macula

The umbo, foveola, fovea, parafovea, and perifovea together constitute the macula, or central area.[20] The central area can be differentiated from the extra-areal periphery by the ganglion cell layer. In the macula, the ganglion cell layer is several cells thick; however, in the extra-areal periphery, it is only one cell thick. The macular border coincides with the course of the major temporal arcades and has an approximate diameter of 5.5 mm, which comprises the diameter of the fovea (1.5 mm), twice the width of the parafovea (2 × 0.5 = 1 mm), and twice the width of the perifovea (2 × 1.5 = 3 mm).[21]

Fovea

The fovea represents an excavation in the retinal center and consists of a margin, a declivity, and a bottom (Figure 1.2, 1.3). The bottom corresponds to the foveola, the center of which is called the umbo. The umbo represents the precise center of the macula, the area of retina that results in the highest visual acuity. Usually, it is referred to as the center of the fovea or macula. Although both terms are commonly used clinically, neither is a precise anatomical designation.[19]

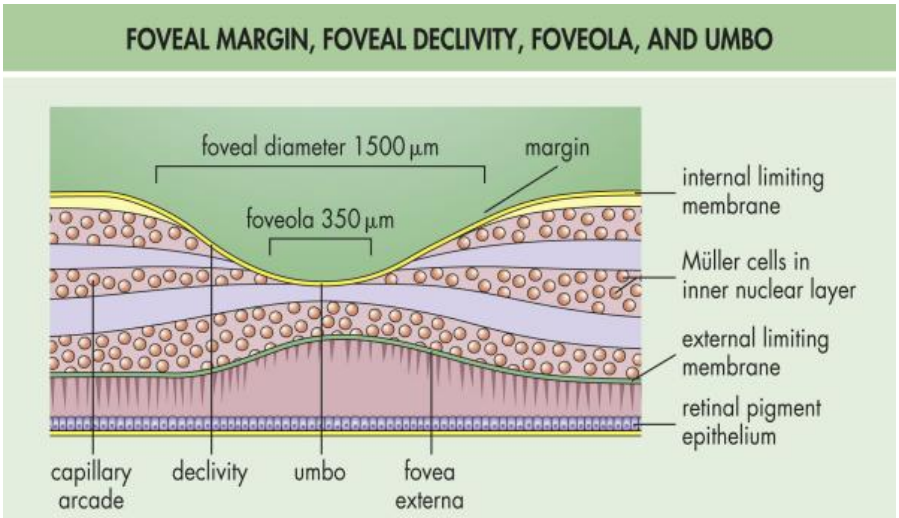

Fig. 1.2 *Foveal margin, foveal declivity, foveola, and umbo*[19]