Anatomy of the Macula

The macula comprises less than four percent of total retinal area in human but is responsible for almost all of our useful, photopic vision. Within the macula, a two millimeters lesion centered on the fovea will affect an estimated 225,000 cones in the average individual, 25 per cent of the total ganglion cell output to the brain, and result in legal blindness ***(Provis et al., 2005).***

Macroscopic anatomy:

The anatomic macula is defined as that area of the posterior retina having at least two layers of nuclei in the ganglion cell layer. Clinically, the macula (Fig.1) is identified as the yellow zone temporal and slightly below the center of the optic nerve head. The yellow color of the macula is due to its content of two xanthophyl pigments, lutein and zeaxanthin, derived from carotenoids in the diet. These pigments are antioxidants and are thought to protect the fragile photoreceptor outer segments from photo-oxidation and to absorb phototoxic short wavelength light. By absorbing blue light, the macular pigments may also decrease chromatic aberration in the macula. This area extends 6 to 7 mm from the temporal edge of the optic nerve head and includes most of the area between the vascular arcades.

In the center of the yellow region, an annular light reflex defines the fovea. The tiny reflex in the center of the foveal reflex identifies the foveola ***(Bone et al., 2003).***

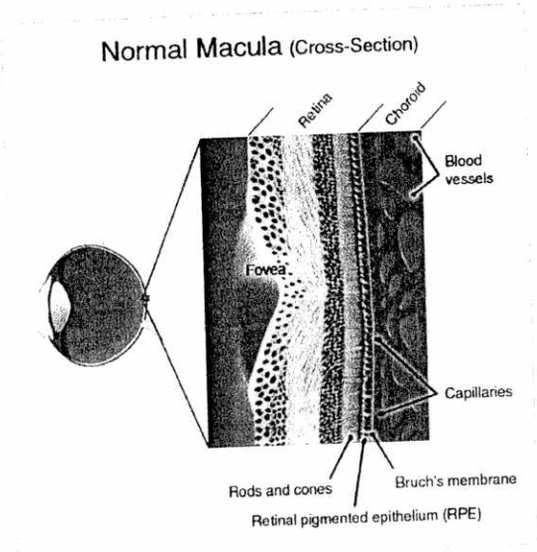

Figure 1 *cross section of the normal macula* ***(Penfold et al 2001)***

The fovea *(fovea centralis):* is a depression in the inner retinal surface at the center of the macula with a diameter of 1.5 mm (about 1 disc diameter). Ophthalmoscopically it gives rise to an oval light reflex because of the increased thickness of the retina and internal limiting membrane at its border.

The foveola *(foveal pit):* forms the central floor of the fovea and has a diameter of 0.35 mm. It is the thinnest part of the retina.

The foveal avascular zone *(FAZ):* is located within the fovea but extends beyond the foveola. The exact diameter is variable and its location can be determined with accuracy only by fluorescein angiography.

The umbo: is a tiny depression in the very center of the foveola which corresponds to the foveolar reflex, loss of which may be an early sign of damage ***(Kanski, 2007)***.

Microscopic anatomy:

The retina is composed of 10 layers, from the outside (nearest the blood vessel enriched choroid) to the inside (nearest the gelatinous vitreous body) they are:

1- Retinal pigmented epithelium (RPE): a single layer of cubical cells which are supporting cells for the neural portion of the retina. It is also dark with melanin which decreases light scatter within the eye. The cells are in close contact with Bruch's membrane.

Macular RPE cells are characterized by being narrower, taller and more highly uniform than cells of RPE elsewhere. Pigment granules are present throughout cytoplasm of macular RPE where they are present mainly in apical cytoplasm of extramacular RPE. So, more pigment granules per unit area are present in the macula than elsewhere. Also, pigment granules are different in extramacular RPE (melanin granules) than macular RPE (pure lipofuscin granules and mixture of lipofuscin and melanin granules).

2- *Photoreceptors:* Human retina contains two types of photoreceptor cells, rods and cones. Rods are about 120 millions and are responsible for the light sense, light movement and scotopic vision. While cones are about 6 millions with the maximum concentration at the center of the retina and are responsible for the color sense and photopic vision. The fovea contains only cones.

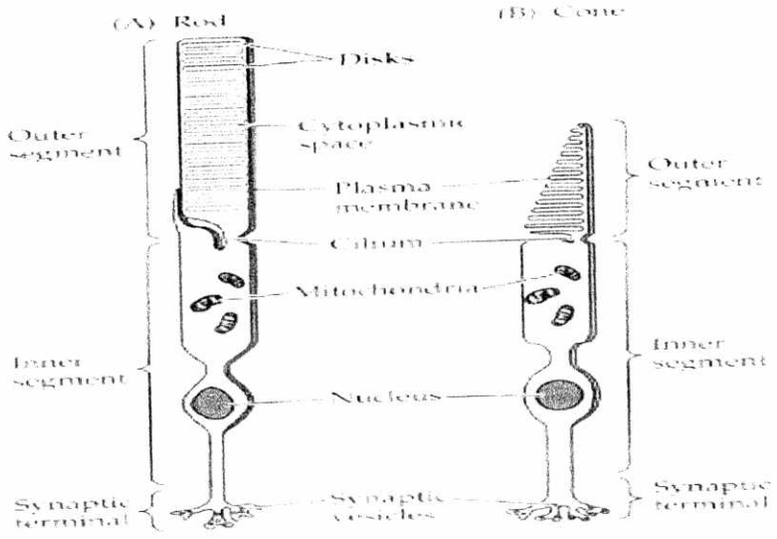

Figure 2 Photoreceptors *(Curcio et al.,1991)*

3- ***External (outer) limiting membrane:*** widely fenestrated membrane that contains holes through which cones and rods pass.

4- ***Outer nuclear layer (ONL):*** contains the cell bodies of cones and rods.

5- ***Outer plexiform layer (OPL):*** contains the cone and rod axons, horizontal cell dendrites, bipolar dendrites.

Henle fiber layer is the portion of OPL in the central retina in which photoreceptors axons (inner fibers) course obliquely roughly parallel to ILM. These are fibers of cones diverted from the center of the fovea. They assume steeper slope towards the periphery so they are practically vertical at the margin of the central area. This arrangement of inner fibers creates a large potential space allowing pathological accumulation of edema fluid and exudates. This is clinically seen as radially oriented cystoid spaces of macular star with lipid exudation ***(Gass,1997).***

6- Inner nuclear layer: contains the nuclei of horizontal cells, bipolar cells, amacrine cells, and Muller cells.

7- Inner plexiform layer: shows the synapse between the axons of bipolar cells, amacrine cells and dendrites of ganglion cells.

8- Ganglion cell layer: contains the nuclei of ganglion cells which are the second order neuron in the visual pathway.

The ganglion cell layer in the macula is characterized by being greater than one cell in thickness. Outside of the macula, the ganglion cell layer consists of a single row of continuous cells.

9- Axons (nerve fibers) layer: contains the nerve fibers from ganglion cells traversing the retina to leave the eye at the optic disk).

10- Internal limiting membrane: separates the retina from the vitreous.

(Kolb et al., 1992).

Macula is further defined by high concentration of cones among photoreceptors, thick ILM and obliquely oriented fibers of OPL (Henle fibers) ***(McDonel,1994).***

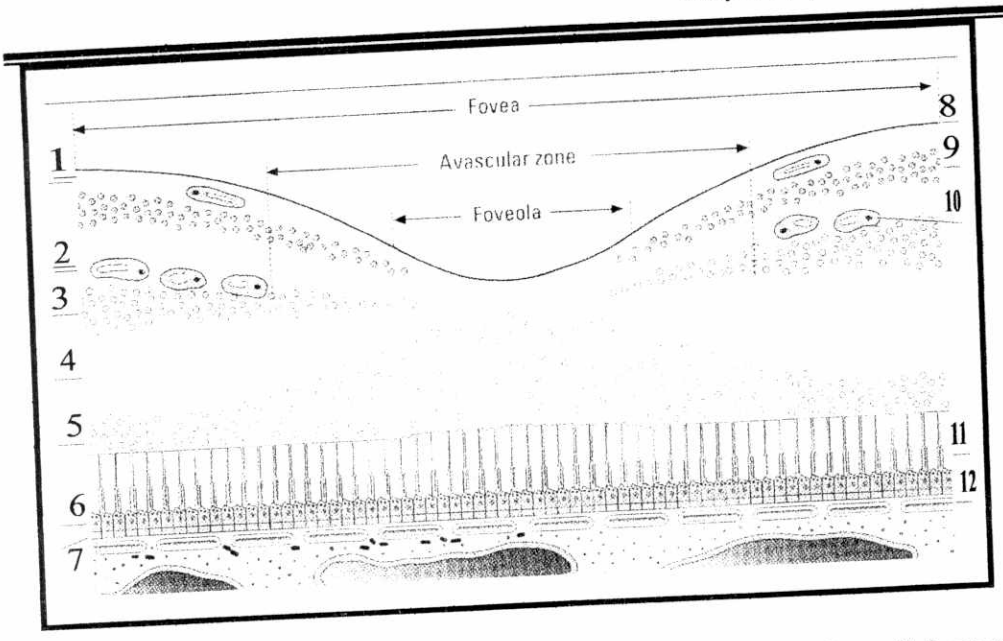

Fig 3 : Cross section of the fovea. 1) Nerve fiber layer; 2) Inner plexiform layer; 3) Inner nuclear layer; 4) Outer plexiform layer (Henle layer); 5) Outer nuclear layer; 6) RPE 7) Bruch's membrane; 8) Inner limiting membrane; 9) Ganglion cell layer; 10) Retinal capillaries; 11) Rods and cones; and 12) Choriocapillaris. ***(Kanski , 2007)***

Blood supply of the macula:

The macula is divided into 2 layers according to blood supply:

1- Outer layer:

RPE, photoreceptors (especially the foveal cones) and OPL are supplied by transudation from choriocapillaris network which is derived from posterior ciliary arteries (choroidal circulation).

The choriocapillaris is thicker over the posterior pole than the periphery and it is thicker over the macular area than any other part. The choroidal capillaries are larger in diameter than retinal capillaries. They are formed only of a basal membrane and a single layer of endothelial cells, which is perforated by pores ***(Yanoff et al., 2003).***

2- Inner layer :

Terminate externally at outer border of the internal nuclear layer, this layer are supplied from capillary network of central retinal artery (CRA), which is the first branch of the ophthalmic artery (retinal circulation) ***(Gass,1997).***

In approximately 20% of patients, it was found that a variable portion of the papillomacular area was supplied by one or more cilioretinal arteries derived from the ciliary circulation. Occasionally a large cilioretinal artery may supply virtually the entire macula ***(Justice and Lehmann 1976).***

The peripheral macular region is richly vasculaized by three arcades or layers of capillaries that are all situated within the inner half of the retina. A deep capillary net, lying at the outer boundary of the inner nuclear layer, and two superficial nets, one entirely in the nerve fiber layer and the boundary of the inner nuclear layer. This is in contrast with the remainder of the retina, which is supplied by two layers of capillaries except the far periphery, which is supplied, by only a single layer ***(Gass,1997).***

This dual supply has evolved to supply nutrients to the retina. The choroid and its capillary bed—the choriocapillaris—are indirectly supplying oxygen and nutrients to the photoreceptors. The retinal vasculature has evolved separately, to supply the inner retina in species where the retina has increased in thickness. The choriocapillaris is separated from the neural retina by the retinal pigment epithelium (RPE) and Bruch's Membrane ***(Provis et al., 2005).***

The blood- retinal barriers:

Outer blood-retinal barrier:

The RPE cells form the outer blood retinal barrier. RPE cells measure 16 μm in height and 10-60 μm in diameter. The apical zonulae

monoacids this means that metabolic substrates have to be transported through the inner blood retinal barrier by means of a carrier mediated transport system. Active transport takes place either through specific channels constituted of trans-membranous proteins or by pinocytosis through the cytoplasm of endothelial cells. Several ocular diseases and surgical trauma alter permeability of the blood ocular barrier. Disruption of the blood retinal barrier has been demonstrated using ocular fluorophotometry in diabetes and in systemic hypertension ***(Neuhaus et al.,1991).***