Chapter 2

Background

This chapter presents some background, which is related to optic disk detection. The topics include characteristics of optic disk, retinopathy of prematurity(ROP), system and materials and medical importance of optic disk detection.

2.1 Optic disk characteristic

The optic disk, shown in Figure 2.1(a), is also called the blind spot. It is called this because there are no receptors in the part of the retina. The optic disk is the brightest part in the normal fundus image that can be seen as a pale, round or oval disk in shape. It is the entrance region of blood vessels and optic nerves to the retina and it often works as a landmark and reference for the other features in the retinal fundus image. Usually in a normal eye, physical diameter of the optic disk is about 1.5 mm to 1.7 mm on average. The location of the optic disk is essential in retinal image analysis to measure distance and identify other anatomical parts in retinal images. Pathology on or near the optic disk can have a more severe effect in vision.

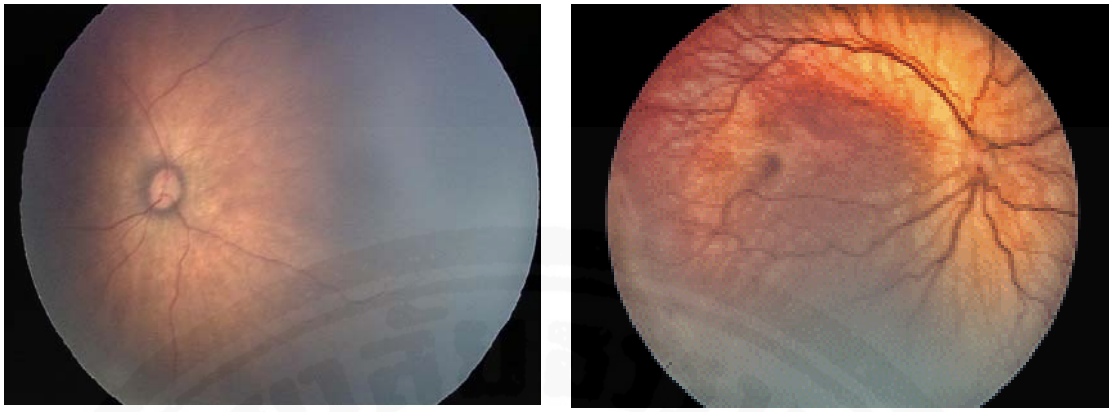
2.1.1 Understanding the optic disk

Colour: Red-yellow; the yellowish color (optic cup)
Form and size: Round to oval with diameter ranging from 1.5 mm to 1.7 mm
Margins: Sharply outline.
Vessels: They originate within the perimeter of the disk and both the arteries and veins appear distinct.

2.2 Retinopathy of Prematurity (ROP)

Retinopathy of Prematurity (ROP) is a developmental disease used to describe abnormal blood vessels and scar tissue growing inside and over the retina of the eye. The incidence of ROP rises with lower gestational age and birth weight. In patients with ROP, the premature baby's blood vessels in his eye are very sensitive to oxygen and light then the blood vessels stop growing and new abnormal blood vessels grow instead of normal retinal blood vessels. It usually affects babies and leads to blindness or poor vision (McNamara and Connolly, 1999; Palmer *et al*., 1991).

The location of ROP, shown in Figure 2.1(b), refers to the location relative to the optic nerve. The retinal vessels normally start their growth at the optic nerve and gradually move toward the edge of the retina. Vessels that are farther from the optic nerve or closer to the edge of the retina are more mature and less concerning. The ophthalmologist can be examined the ROP symptoms at four weeks of baby's age. The following information presents pathogenesis, cause and risk factor, staging disease and classification of ROP.



(a) **(b)**

Figure 2.1 (a) Optic Disk Image (b)Optic Disk with the condition ROP

2.2.1 Pathogenesis

1. At twelve to eighteen weeks of gestation, vascularization of the retina begins.
2. First the primitive future endothelial cells form cords that canalize into a network of evenly spaced capillaries, which further differentiate into primitive and then mature arterioles and venules.
3. Vessels grow outward from the optic disk toward the nasal and temporal periphery of the retina.
4. If an adverse event (see Causes and Risk Factors) occurs to these vessels, the natural progress is arrested.
5. After the initial injury, vessel growth can resume normally or the primitive vessels pile up within the retina, growing without forward progress and forming a ridge of tissue that can become extremely large. This tissue may then regress, and vessels once again progress toward the periphery, or the ROP can worsen through the growth of fibrovascular tissue into the vitreous cavity.
6. The formation of scar tissue and its progression over the retina and into the vitreous body may determine the prognosis and visual outcome.
7. In severe cases these abnormal vessels may grow into the vitreous cavity and cause tractionalretinal detachment and subsequent blindness.
8. The human retina may not be completely vascularized at term. This may account for the rare occurrence of ROP in full term neonates.

2.2.2 Causes and risk factors

The exact causes of ROP are not completely understood. The degree of prematurity and birth weight of a baby play a big part in the development of ROP. The small and sick baby has a high risk to be ROP. The premature baby's blood vessels in his eye are very sensitive to oxygen and light. It usually affects babies less than 1500 grams. There are a number of risk factors for the development of ROP (McNamara and Connolly, 1999).

1. **Birth weight and gestational age:** These are the two most important risk factors for ROP. The younger the gestational age and lesser the birth weight, the greater are the chances of developing ROP. More premature neonates are likely to develop a more severe from of disease.

2. **Oxygen therapy:** Though not the only aetiological agent, as it was once thought to be,

excessive use is an important contributory factor. It has been seen that premature neonates develop ROP even without being exposed to oxygen and, conversely, others do not develop ROP despite being on oxygen.

3. **Other factors:** A number of other risk factors in the development of ROP include sepsis, multiple blood transfusions, multiple births, hyaline membrane disease, using of aminophylline, antibiotics, apnoeic spells, low pH, and ultraviolet light therapy

2.2.3 Staging of disease

The definition in staging of disease is described below:
Stage 1: Demarcation line
This is a flat white line within the plane of the retina that clearly delineates the vascularized posterior retina from the vascular anterior portion. Abnormal branching or arcading of vessels is recognizable immediately posterior to the demarcation line (Figure 2.2(a)).

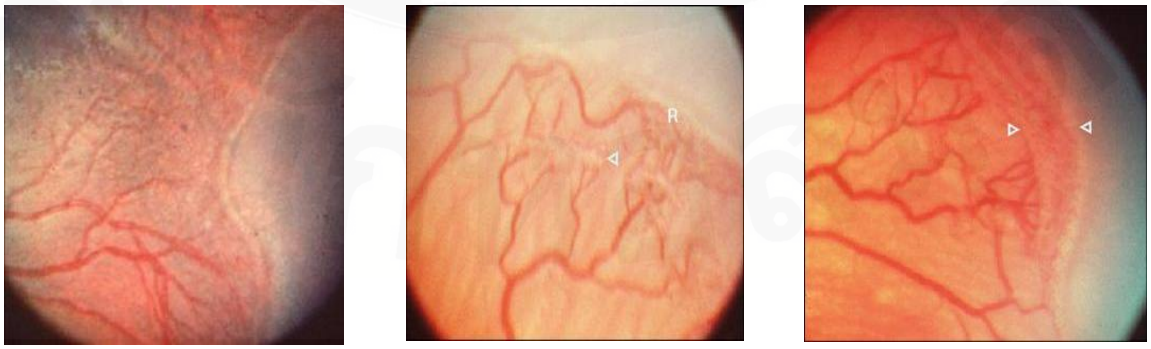
Stage 2: Ridge of the demarcation line
A ridge(R) of scar tissue and new blood vessels place in the demarcation line. The white line now has width and height and occupies some volume. Vascular shunting occurs in this stage (Figure 2.2(b)).

Stage 3: Ridge with extra-retinal fibrovascular proliferation
In this step, the vascular ridge was increased the size with growth of fibrovascular tissue on the ridge and extending out into the vitreous (Figure 2.2(c)).

Stage 4: Subtotal (Partial) Retinal Detachment
a. Stage 4A: Macula on - detachment does not include the macula, and the vision may be good.
b. Stage 4B: Macula off - macula is detached, and the visual potential is markedly decreased.

Stage 5: Complete retinal detachment

Stage 6: Plus Disease: Vessels are dilated and tortuous.
It may also include growth and dilation of abnormal blood vessels on the surface of the iris, rigidity of the iris and vitreous haze (exudates along the retinal vessels).



(a) **(b)** **(c)**

Figure 2.2 (a) Demarcation line (b) Ridge of the demarcation line (c) Ridge with extra-retinal fibrovascular proliferation

2.2.4 Classification of ROP:

The International Classification System of ROP allows the examiner to specify parameters of the disease, location, extent of developing vasculature involved and staging.

Location: is expressed as zone I, II, or III, each zone is centered on the optic disk because normal retinal vascular growth progresses peripherally from the disk toward the ora serrata (Figure 2.3).
1. Zone I: Posterior pole or inner zone; in all directions from the optic disk to a distance twice that between the disk and the macula.
2. Zone II: From the edge of zone I peripherally to a point tangential to the nasal ora serrata and an area near the temporal anatomic equator.
3. Zone III: The remaining crescent of the fundus temporally anterior to zone II. This zone is the last to be vascularized.

Table 2.1: Area of ROP Involvement Zones

Zone I	A circle is drawn on the posterior pole, with the optic disk as the centre and twice the disk-macula distance as the radius, constitutes zone I. Any ROP in this zone is usually very severe because of a large peripheral area of avascular retina
Zone II	A circle is drawn with the optic disk as the centre and disk to nasal ora serrata as the radius. The area between zone I and this boundary constitutes zone II
Zone III	The temporal arc of retina left beyond the radius of zone II is zone III (Figure 2.3)
Extent	The extent is denoted by the clock hours of retinal involvement in the particular zone
Rush Disease	This is rapidly progressive ROP in zone I, usually seen in extremely sick babies

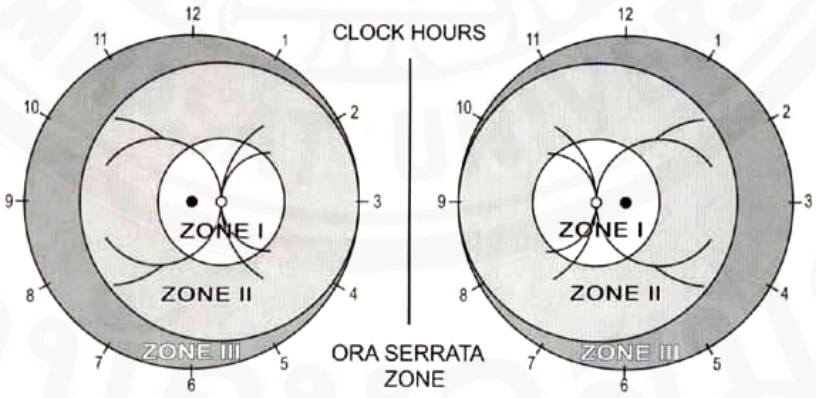


Figure 2.3 Guideline diagram used in the classification of retinopathy of prematurity

2.3 System and Materials

In this work, the system implemented in MATLAB 7.0.4(R14) on a 3 GHz Pentium 4 machine, the images obtained from Kingston University, UK and Thammasat hospital, Thailand. The example of retinal images in ROP Infant was shown in Figure 2.4. There

were a representative sample of a set of normal retinal image and abnormalities. The training set was randomly from the screening set of one hundred retinal images. The image size was set to 640 x 480 pixels, 72 inch/pixel. All the images were JPEG compressed. In order to acquire the pathological test set, all cases of optic disk detection marked as ground truth image by the ophthalmologists.

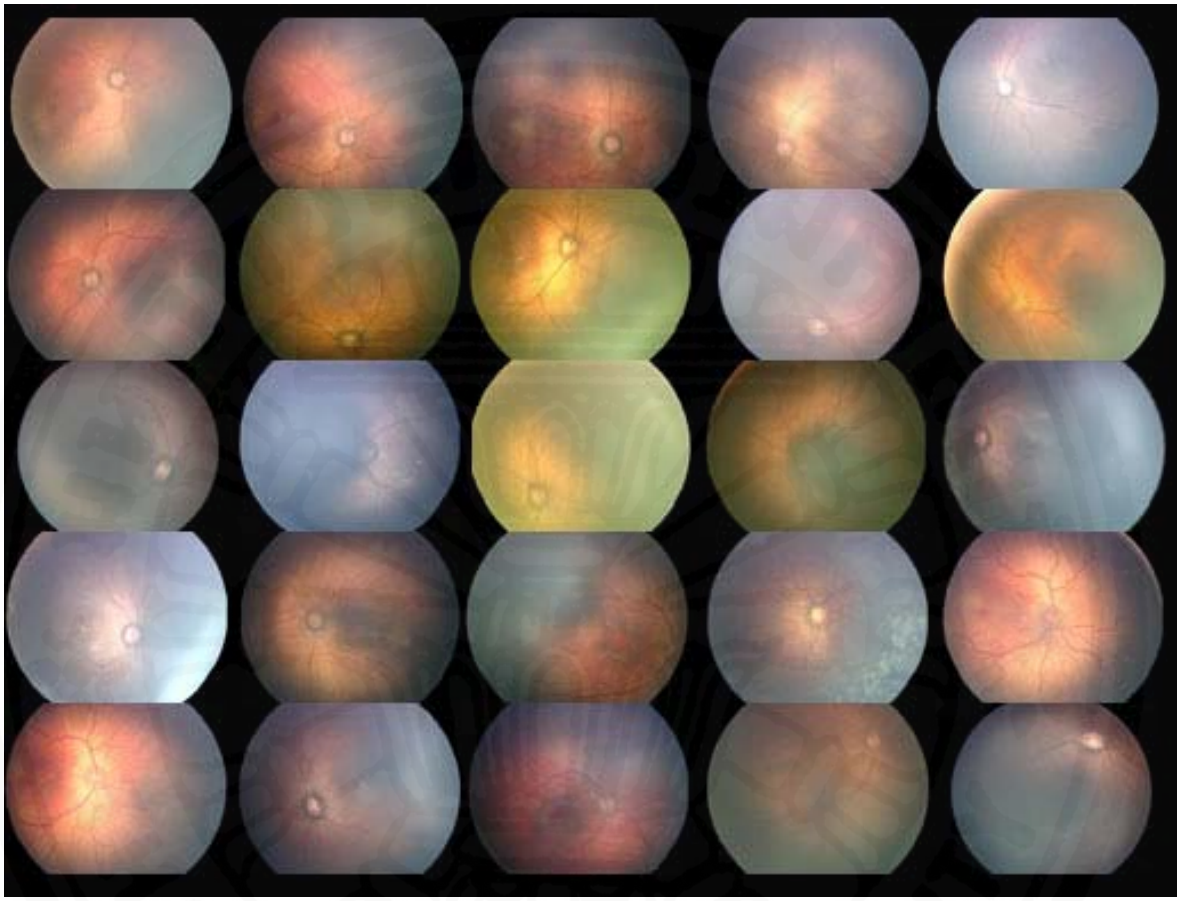


Figure 2.4 The example of optic disk data set

2.4 Medical Importance of Optic Disk Detection

Precise localization of optic disk boundary is an important sub problem of higher level problems in ophthalmic image processing. Specifically, in retinopathy of prematurity, proliferative diabetic retinopathy, fragile vessels develop in the retina and largely in the OD region, in response to circulation problems created during earlier stages of the disease. If the optic disk has been identified, the position of areas of clinical importance such as the fovea may be determined. Moreover, OD detection is fundamental for establishing a frame of reference within the retinal image and is, thus, important for any image analysis application. Current methods of detection and assessment in the stage of ROP are manual, expensive, potentially inconsistent, and require highly trained personnel to facilitate the process by searching large numbers of fundus images. Many of these images from screening programmes will be normal, but some will require grading of abnormalities by ophthalmologist. When abnormalities do not treatment immediately, the patient may loss the vision. In contrast to this, a good, automatic method based on modern digital image processing technique will be faster, will need less may be no human intervention, and will yield consistent results.