Section I

Clinical Methods in Ophthalmology: General Considerations

CHAPTER

1
History Taking and Scheme of Examination and Investigation of an Ophthalmic Case

Chapter Outline

HISTORY AND EXAMINATION

HISTORY

The importance of painstaking meticulous history cannot be overemphasized. The patient's history is the first and many times the most important aspect of an ophthalmological examination. It assists in restracting the various stages of the disease. The information gathered from history guides about the specific examination and diagnostic tests to be performed. The information gained also helps in planning the management. Last but not the least, history-taking provides an opportunity to develop appropriate docter–patient relationship.

During history-taking, one should be precise and pertinent. Questions should be asked in an organized manner and a fixed routine followed, so that the complete required information is obtained. The complete history-taking should be structured as:

- Demographic data
- Chief presenting complaints
- History of present illness
- History of past illness
- Family history.

Demographic data

Demographic data should include patient's name, age, sex, occupation and religion.

Name and address. Name and address are primarily required for patient's identification. It also proves useful for demographic research.

Age and sex. In addition to the utility in patient's identification, knowledge of age and sex of the patient is also useful for noting down and ruling

out the particular diseases pertaining to different age groups and a particular sex.

Occupation. An information about patient's occupation is helpful since ophthalmic manifestations due to occupational hazards are well known, e.g.:

- *Ocular injuries and trauma due to foreign bodies* have typical pattern in factory workers, lathe workers, farmers and sport persons.
- *Computer vision syndrome* is emerging as a significant ocular health problem in computer professionals.
- *Heat cataract* is known in glass factory workers.
- *Photophthalmitis* is known in welders not taking adequate protective measures.

In addition, information about the patient's occupation is useful in providing ocular health education and patient's visual rehabilitation.

Religion. Recording the religion of the patient may be helpful in ascertaining the diseases which are more common in a particular community. It also helps in knowing the aptitude and practices prevalent in different communities for various common eye problems.

Chief presenting complaints

The patient should be encouraged to narrate his complaints in detail and the examiner should be a patient listner. The relevent and important enquiries should be made by the examiner depending upon the patient's compliants. An enquiry should be made about mode of onset, duration, severity and accompaniment of each symptoms.

Some relevant features of the common ocular symptoms and their causes are described:

- Defective vision
- Watering and/or discharge from the eyes
- Redness
- Asthenopic symptoms
- Photophobia
- Burning/itching/foreign body sensation
- Pain (eyeache and/or headache)
- Deviation of the eye
- Diplopia
- Black spots in front of eyes
- Coloured halos
- Distorted vision.

History of present illness

The patients should be encouraged to narrate their complaints in detail and the examiner should be a patient listener. While taking history, the examiner should try to make a note of the following points about each complaint:

- Mode of onset with duration
- Severity
- Progression
- Accompaniment of each symptom.

Treatment history

A detail information about the treatment taken for the present symptoms including its effect on the symptoms is very important.

Leading questions to explore etiology

Leading questions to ascertain the probable cause of the disease should be part to the patient. For example, if a patient gets up at night with history of marked discomfort, pain and watering from the eyes; an enquiry should be made to know where the patient looked at welding are with marked eye in the evening. Similarly, if a patient present with subconjunctival haemorrhage without any history of trauma; an enquiry should be made about atleast of sneezing, coughing or any other cause of straining.

Medical history

A detailed history should be taken to explore the other associated medical diseases which may affect the management plan or final outcome of the treatments. For example, if a patient into operated for cataract the associated diabetes mellitus, hypertension, chronic bronchitis, any source of systemic infection should be explored and treated before the cataract operation is contempulated.

It is also important to know whether the patient is on any medication for some systemic disease or is known to be allergic to some drug.

History of past illness

A probe into history of past illness should be made to know:

- *History of similar ocular complaint in the past*. It is specially important in recurrent conditions

such as *herpes simplex keratitis, uveitis* and *recurrent corneal erosions.*

- *History of similar complaints in other eye* is important in bilateral conditions such as *uveitis, senile cataract* and *retinal detachment.*
- *History of trauma to eye in the past* may explain occurrence of lesions such as delayed rosette cataract and retinal detachment.
- It is important to know about *history of any ocular surgery in the past.*
- *History of any systemic disease in the past* such as tuberculosis, syphilis, leprosy may sometimes explain the occurrence of present ocular disease.
- *History of drug intake and allergies* is also important.

Family history

Efforts should be made to establish familial predisposition of inheritable ocular disorders like congenital cataract, ptosis, squint, corneal dystrophies, glaucoma and refractive error.

Common ocular symptoms and their causes

1. ***Defective vision.*** It is the commonest ocular symptom. Enquiry should reveal its onset (sudden or gradual), duration, whether it is painless or painful, whether it is more during the day, night or constant, and so on. Important causes of defective vision can be grouped as under:

Sudden painless loss of vision

- Central retinal artery occlusion
- Massive vitreous haemorrhage
- Retinal detachment involving macular area
- lschaemic central retinal vein occlusion.

Sudden painless onset of defective vision

- Central serous retinopathy
- Optic neuritis
- Methyl alcohol amblyopia
- Nonischaemic central retinal vein occlusion.

Sudden painful loss of vision

- Acute congestive glaucomas (primary or secondary)
- Acute iridocyclitis
- Chemical injuries to the eyeball
- Mechanical injuries to the eyeball.

Gradual painless defective vision

- Progressive pterygium involving papillary area
- Corneal degenerations
- Corneal dystrophies
- Developmental cataract
- Senile cataract
- Optic atrophy
- Chorioretinal degenerations
- Age-related macular degeneration
- Diabetic retinopathy
- Refractive errors.

Gradual painful defective vision

- Chronic iridocyclitis
- Corneal ulceration
- Chronic simple glaucoma.

Transient loss of vision (amaurosis fugax)

- Carotid artery disease
- Papilloedema
- Giant cell arteritis
- Migraine
- Raynaud's disease
- Severe hypertension
- Prodromal symptom of CRAO.

Night blindness (nyctalopia)

- Vitamin A deficiency
- Retinitis pigmentosa and other tapetoretinal degenerations
- Congenital night blindness
- Pathological myopia
- Peripheral cortical cataract.

Day blindness (hamaropia)

- Central nuclear or polar cataracts
- Central corneal opacity
- Central vitreous opacity
- Congenital deficiency of cones (rarely).

Diminution of vision for near only

- Presbyopia
- Cycloplegia
- Internal or total ophthalmoplegia
- Insufficiency of accommodation.

2. ***Other visual symptoms.*** Visual symptoms other than the defective vision are as follows:

- *Black spots or floaters in front of the eyes may* appear singly or in clusters. They move with the

movement of the eyes and become more apparent when viewed against a clear surface, e.g. the sky. Common causes of black floaters are:

- Vitreous haemorrhage
- Vitreous degeneration, e.g.
  - Senile vitreous degeneration
  - Vitreous degeneration in pathological myopia
- Exudates in vitreous
- Lenticular opacity.

Flashes of light in front of the eyes (photopsia). Occur due to traction on retina in following conditions:

- Posterior vitreous detachment
- Prodromal symptom of retinal detachment
- Vitreous traction bands
- Sudden appearance of flashes with floaters is a sign of a retinal tear
- Retinitis
- Migraine.

Distortion of vision

- Central chorioretinitis
- Central serous chorioretinopathy
- ARMD
- CNVM
- Keratoconus
- Corneal irregularity.

Glare

- Early cataract
- Corneal oedema
- Status postrefractive surgery.

Photophobia

- Corneal abrasion
- Acute conjunctivitis
- Keratitis
- Anterior uveitis
- Dilated pupil.

Coloured halos. Patient may perceive coloured halos around the light. It is a feature of:

- Acute congestive glaucoma
- Corneal oedema, e.g. bullous keratopathy
- Early stages of cataract
- Mucopurulent conjunctivitis.

Diplopia, i.e. perceiving double images of an object is a very annoying symptom. It should be ascertained whether it occurs even when the normal eye is closed (uniocular diplopia) or only when both eyes are open (binocular diplopia). Common causes of diplopia are:

Uniocular diplopia

- Subluxated lens
- Double pupil
- Incipient cataract
- Keratoconus
- Eccentric IOL.

Binocular diplopia

- Paralytic squint
- Myasthenia gravis
- Diabetes mellitus
- Thyroid disorders
- Blow-out fracture of floor of the orbit
- Anisometropic glasses (e.g. uniocular aphakic glasses)
- After squint correction in the presence of abnormal retinal correspondence (paradoxical diplopia).

3. *Watering from the eyes*. Watering from the eyes is another common ocular symptom. Its causes can be grouped as follows:

Excessive lacrimation, i.e. excessive formation of tears occurs in multiple conditions. *Epiphora*, i.e. watering from the eyes due to blockage in the flow of normally formed tears somewhere in the lacrimal drainage system.

4. *Discharge from the eyes*. When a patient complains of a discharge from the eyes, it should be ascertained whether it is mucoid, mucopurulent, purulent, serosanguinous or ropy. Discharge from the eyes is a feature of conjunctivitis, corneal ulcer, stye, burst orbital abscess, and dacryocystitis.

5. *Itching, burning and foreign body sensation in the eyes*. These are very common ocular symptoms. Their causes are:

- Conjunctivitis (e.g. allergic, chronic simple, and GPC)
- Blepharitis
- Dry eye
- Trachoma and other conjunctival inflammations
- Trichiasis and entropion.

6. ***Redness of the eyes.*** It is a common presenting symptom in many conditions, such as conjunctivitis, keratitis, iridocyclitis, acute glaucomas, conjunctival or corneal foreign body, trichiasis, episcleritis, scleritis, sub-conjunctival haemorrhage, endophthalmitis.

7. ***Ocular pain.*** Pain in and around the eyes should be probed for its onset, severity, and associated symptoms. It is a feature of ocular inflammations and acute glaucoma. Ocular pain may also occur as referred pain from the inflammation of surrounding structures, such as sinusitis, dental caries and abscess.

8. ***Asthenopic symptoms.*** Asthenopia refers to mild eyeache, headache and tiredness of the eyes which are aggravated by near work. Asthenopia is a feature of extraocular muscle imbalance and uncorrected mild refractive errors especially astigmatism.

9. ***Other ocular symptoms*** include:

- Deviation of the eyeball (squint)
- Protrusion of the eyeball (proptosis)
- Drooping of the upper lid (ptosis)
- Retraction of the upper lid
- Sagging down of the lower lids (ectropion)
- Swelling on the lids (e.g. chalazion and tumours).

GENERAL PHYSICAL AND SYSTEMIC EXAMINATION

General physical and systemic examination should be carried out in each case. Sometimes it may help in establishing the etiological diagnosis, e.g. ankylosing spondylitis may be associated with uveitis. Further, it is essential to treat associated diseases like bronchial asthma, hypertension, diabetes and urinary tract problems before taking up the patient for cataract surgery.

OCULAR EXAMINATION

- Testing of visual acuity
- External ocular examination
- Fundus examination
- Visual field examination
- Test for colour vision.

I. TESTING OF VISUAL ACUITY

Visual acuity should be tested in all cases, as it may be affected in numerous ocular disorders.

In real sense, acuity of vision is a retinal function (to be more precise of the macular area) concerned with the appreciation of form sense.

Distant and near visual acuity should be tested separately.

Distant visual acuity

Snellen's test types. The distant central visual acuity is usually tested by Snellen's test types. The fact that two distant points can be visible as separate only when they subtend an angle of 1 minute at the nodal point of the eye, forms the basis of Snellen's test-types. It consists of a series of black capital letters on a white board, arranged in lines, each progressively diminishing in size. The lines comprising the letters have such a breadth that they will subtend an angle of 1 min at the nodal point. Each letter of the chart is so designed that it fits in a square, the sides of which are five times the breadth of the constituent lines. Thus, at the given distance, each letter subtends an angle of 5 min at the nodal point of the eye (Fig. 1.1). The letters of the top line of Snellen's chart (Fig. 1.2) should be read clearly at a distance of 60 m. Similarly, the letters in the subsequent lines should be read from a distance of 36, 24, 18, 12, 9, 6 and 5 m, respectively.

Procedure of testing. For testing distant visual-acuity, the patient is seated at a distance of 6 m from the Snellen's chart, so that the rays of light are practically parallel and the patient exerts minimal accommodation. The chart should be properly illuminated (not less than 20 ft candles). The patient is asked to read the chart with each eye separately and the visual acuity is recorded as a fraction, the numerator being the distance

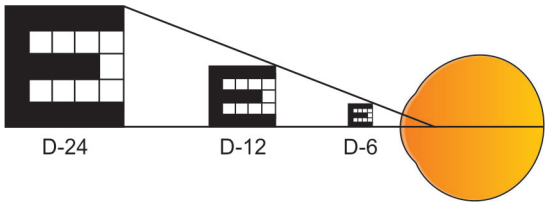


Fig. 1.1: *Principle of Snellen's test types.*

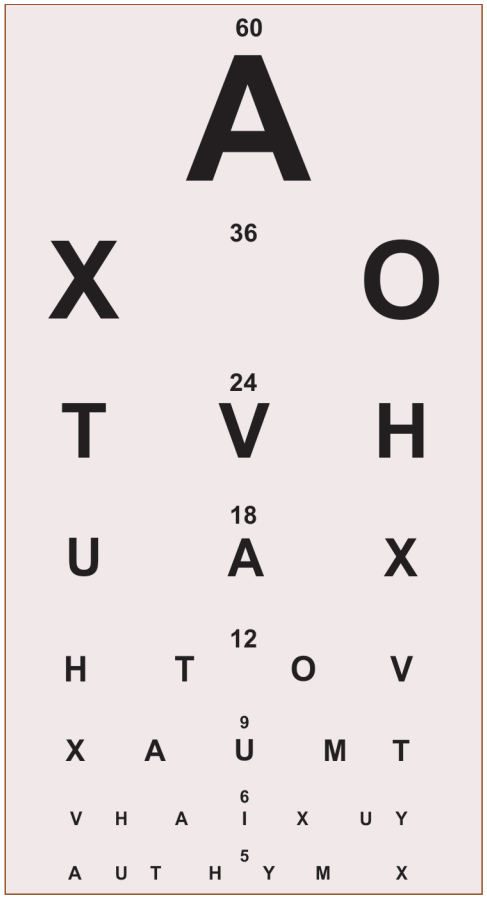


Fig. 1.2: *Snellen's test types.*

of the patient from the letters, and the denominator being the smallest letters accurately read.

When the patient is able to read up to 6 m line, the visual acuity is recorded as 6/6, which is normal.

Similarly, depending upon the smallest line which the patient can read from the distance of 6 m, his vision is recorded as 6/9, 6/12, 6/18, 6/24, 6/36 and 6/60, respectively. If he cannot see the top line from 6 m, he is asked to slowly walk towards the chart till he can read the top line. Depending upon the distance at which he can read the top line, his vision is recorded as 5/60, 4/60, 3/60, 2/60 and 1/60, respectively.

If the patient is unable to read the top line even from 1 m, he is asked to count fingers (CF) of the examiner. His vision is recorded as CF-3', CF-2', CF-1' or CF close to face, depending upon the distance at which the patient is able to count fingers. When the patient fails to count fingers, the examiner moves his hand close to the patient's face. If he can appreciate the hand movements (HM), visual acuity is recorded as HM +ve. When the patient cannot distinguish the hand movements, the examiner notes whether the patient can perceive light (PL) or not. If yes, vision is recorded as PL +ve and if not it is recorded as PL –ve.

Other tests which are based on the same principle as Snellen's test types are as follows:

a. Simple picture chart: Used for children >2 years
b. Landolt's C-chart: Used for illiterate patients
c. E-chart: Used for illiterate patients

Visual acuity equivalents in some common notations are depicted in Table 1.1.

Visual acuity for near

Near vision is tested by asking the patient to read the near vision chart (Fig. 1.3), kept at a distance of 35 cm in good illumination, with each eye separately. In near vision chart, a series of different sizes of printer type are arranged in increasing order and marked accordingly. Commonly used near vision charts are as follows:

1. *Jaeger's chart.* In this chart, prints are marked from 1 to 7 and accordingly patient's acuity is labelled as J1 to J7 depending upon the print he can read.

Table 1.1 *Visual acuity equivalents in some common notations*

Decimal-resolution system	*Snellen 6-m table*	*Snellen 20-foot table*	*Angle table*
1.0	6/6	20/20	1.0
0.8	5/6	20/25	1.3
0.7	6/9	20/30	1.4
0.6	5/9	15/25	1.6
0.5	6/12	20/40	2.0
0.4	5/12	20/50	2.5
0.3	6/18	20/70	3.3
0.1	6/60	20/200	10.0

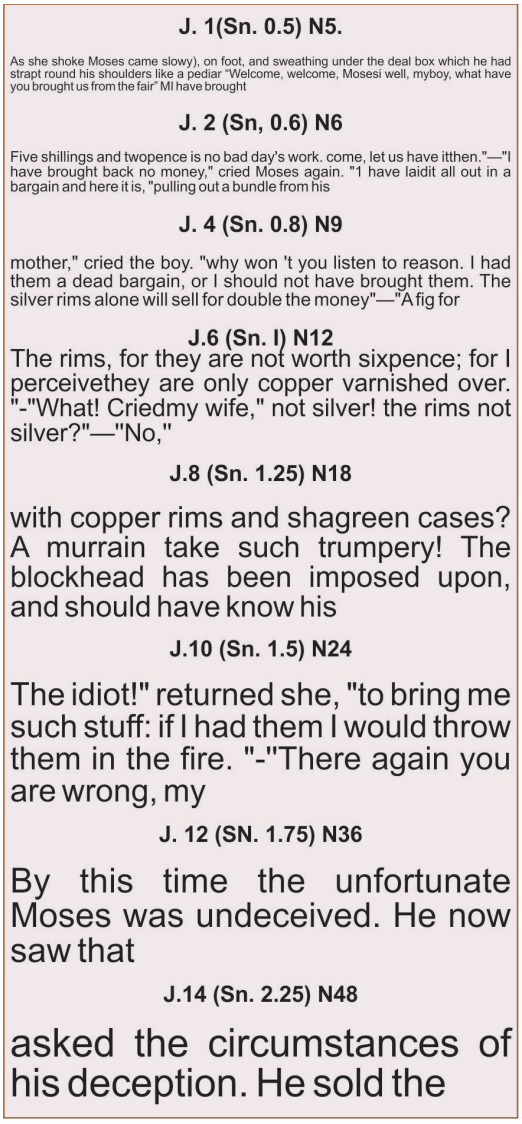


Fig. 1.3: *Near vision chart.*

2. *Roman test types.* According to this chart, the near vision is recorded as N5, N8, N10, N12 and N18 (Printer's point system) (Fig. 1.3).
3. *Snellen's near vision test types.*

Note: For details see chapter 2.

II. EXTERNAL OCULAR EXAMINATION

External ocular examination should be carried out as follows:

A. ***Inspection in diffuse light*** should be performed first of all for a preliminary examination of the eyeballs and related structures, viz. lids, eyebrows, face and head.

B. ***Focal (oblique) illumination examination*** should be carried out for a detailed examination under magnification. It can be accomplished using a magnifying loupe (uniocular or binocular) and a focussing torch light or preferably a slit-lamp.

C. ***Special examination*** is required for measuring intraocular pressure (tonometry) and for examining angle of the anterior chamber (gonioscopy).

Scheme of External Ocular Examination

Scheme of external ocular examination is described here. Scheme of examination includes the structures to be examined and the signs to be looked for. Further, the important causes of the common signs are also listed to fulfill the prerequisite that *'the eyes see what the mind knows'*. Both eyes should be examined in each case.

The external ocular examination should proceed in the following order:

1. Examination for the head posture. Position of the head and chin should be noted first of all. Head posture may be abnormal in a patient with paralytic squint (head is turned in the direction of the action of paralysed muscle to avoid diplopia) and incomplete ptosis (chin is elevated to uncover the pupillary area in a bid to see clearly).

2. Examination of forehead and facial symmetry:

- *Forehead may show increased wrinkling* (due to overaction of frontalis muscle) in patient with ptosis.
- *Complete loss of wrinkling* in one-half of the forehead is observed in patients with lower motor neuron facial palsy.
- *Facial asymmetry* may be noted in patient with Bell's palsy and facial hemiatrophy.

3. Examination of eyebrows

- *Level* of the two eyebrows may be changed in a patient with ptosis (due to overaction of frontalis).
- *Cilia* of lateral one-third of the eyebrows may be absent (madarosis) in patients with leprosy or myxoedema.

4. Examination of the eyelids. All the four eyelids should be examined for their position, movements, condition of skin and lid margins.

i. *Position.* Normally the lower lid just touches the limbus while the upper lid covers about 1/6th (2 mm) of cornea.

- *In ptosis*, upper lid covers more than 1/6th of cornea.
- Upper limbus is visible due to lid retraction as in thyrotoxicosis and sympathetic overactivity.

ii. *Movements of lids.* Normally the upper lid follows the eyeball in downward movement but it lags behind in cases of thyroid ophthalmopathy.

▪▪ *Blinking* is involuntary movement of eyelids. Normal rate is 12–16 blinks per minute. It is increased in local irritation. Blinks are decreased in trigeminal anaesthesia and absent in those with 7th nerve palsy.

▪▪ *Lagophthalmos* is a condition in which the patient is not able to close his eyelids. Causes of lagophthalmos are:

- Facial nerve palsy
- Extreme degree of proptosis
- Symblepharon.

iii. *Lid margin.* Note presence of any of the following:

▪▪ *Entropion* (inward turning of lid margin).
▪▪ *Ectropion* (outward turning of lid margin).
▪▪ *Eyelash abnormalities* such as:

- *Trichiasis*, i.e. misdirected cilia rubbing the eyeball. Common causes are trachoma, blepharitis, stye and lid trauma.
- *Distichiasis*, i.e. an abnormal extra row of cilia taking place of meibomian glands.
- *Madarosis*, i.e. absence of cilia may be seen in patients with chronic blepharitis, leprosy and myxoedema.
- *Poliosis*, i.e. greying of cilia is seen in old age and also in patients with Vogt-Koyanagi-Harada disease.

▪▪ *Scales* at lid margins are seen in blepharitis.
▪▪ *Swelling* at lid margin may be stye, papilloma or marginal chalazion.

iv. *Abnormalities of skin.* Common lesions are herpetic blisters, molluscum contagiosum lesions, warts, epidermoid cysts, ulcers, traumatic scar, etc.

v. *Palpebral aperture.* The exposed space between the two lid margins is called *palpebral fissure* which measures 28–30 mm horizontally and 8–10 mm vertically (in the centre). Following abnormalities may be observed:

▪▪ *Ankyloblepharon* is usually seen following adhesions of the two lids at angles, e.g. after ulcerative blepharitis and burns. It results in horizontally narrow palpebral fissure.
▪▪ *Blepharophimosis* (all around narrow palpebral fissure) is usually a congenital anomaly.
▪▪ *Vertically narrow palpebral fissure* is seen in:

- Inflammatory conditions of conjunctiva, cornea and uvea due to blepharospasm
- Ptosis (drooping) of upper eyelid
- Enophthalmos (sunken eyeball)
- Anophthalmos (absent eyeball)
- Microphthalmos (congenital small eyeball)
- Phthisis bulbi
- Atrophic bulbi.

▪▪ *Vertically wide palpebral fissure* may be noted inpatients with:

- Proptosis
- Large-sized eyeball (e.g. buphthalmos)
- Retraction of upper lid
- Facial nerve palsy.

5. Examination of lacrimal apparatus. A thorough examination of lacrimal apparatus is indicated in patients with epiphora, corneal ulcer and in all patients before intraocular surgery. The examination should include:

- *Inspection of lacrimal sac area* for redness, swelling or fistula.
- *Inspection of the lacrimal puncta*, for any defect such as eversion, stenosis, absence or discharge.
- *Regurgitation test.* It is performed by pressing over the lacrimal sac area just medial to the medial canthus and observing regurgitation of any discharge from the puncta. Normally it is negative. A *positive regurgitation test* indicates dacryocystitis. A *false negative regurgitation test* may be observed in internal fistula, wrong method of performing regurgitation test, patient might have emptied the sac just before coming to the examiner's chamber, encysted mucocele.

- *Lacrimal syringing.* It is done to locate the probable site of blockage in patients with epiphora (*see* page 483).
- *Other tests* such as *Jone's dye test I and II,* dacryocystography, etc. can be performed when indicated (*see* page 484).

6. Examination of eyeball as a whole observe the following points:

i. *Position of eyeballs.* Normally, the two eyeballs are symmetrically placed in the orbits in such a way that a line joining the central points of superior and inferior orbital margins just touches the cornea.

Abnormalities of the position of eyeball can be:

a. *Proptosis/exophthalmos,* i.e. bulging of eyeballs; note whether proptosis is:

- Axial or eccentric
- Reducible or nonreducible
- Pulsatile or nonpulsatile.

b. *Enophthalmos* (sunken eyeball)

ii. *Visual axes of eyeballs.* Normally the visual axes of the two eyes are simultaneously directed at the same object which is maintained in all the directions of gaze. Deviation in the visual axis of one eye is called *squint* (complete evaluation of a case of squint is as pecialised examination).

iii. *Size of eyeball.* Obvious abnormalities in the size of eyeball can be detected clinically. However, precise measurement of size can only be made by ultrasonography (A-scan). The size of eyeball is increased in conditions like buphthalmos and unilateral high myopia. *The causes of small-sized eyeball are:* congenital microphthalmos, phthisis bulbi, and atrophic bulbi.

iv. *Movements of eyeball* should be tested uniocularly (ductions) as well as binocularly (versions) in all the six cardinal directions of gaze.

7. Examination of conjunctiva

i. *Bulbar conjunctiva* can be examined by simply retracting the upper lid with index finger and lower lid with thumb of the left hand.

ii. *Lower palpebral conjunctiva and lower fornix* can be examined by just pulling down the lower lid and instructing the patient to look up (Fig. 1.4).

iii. *Upper palpebral conjunctiva* can be examined only after everting the upper eyelid. Eversion of upper lid can be carried out by one-hand or two-hand technique.

- *One-hand* technique. In it patient looks down and the examiner grasps the lid margin along with lashes with left index finger and thumb. Then swiftly everts the upper lid by making index finger a fulcrum. This, however, requires some practice.
- *Two-hand technique.* It is comparatively easier. Procedure is same as above, except that here the lid is rotated around a fixed probe which is held above the level of tarsal plate with right hand (Fig. 1.5). In slight modification of

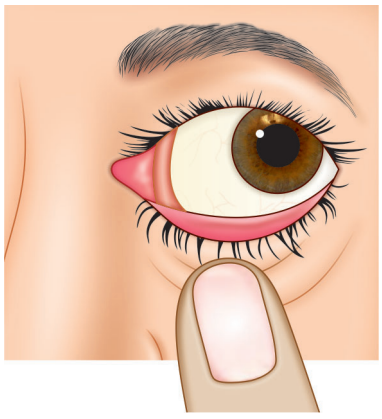


Fig. 1.4: *Examination of the lower fornix and lower palpebral conjunctiva.*

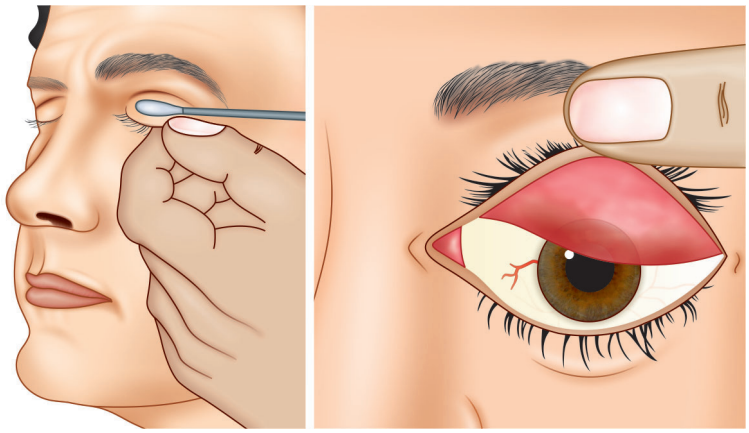


Fig. 1.5: *Two-hand technique of upper lid eversion.*

two-hand technique, index finger of right hand can be used instead of probe.

iv. ***Examination of superior fornix*** requires double eversion of upper lid using Desmarre's lid retractor.

Conjunctival signs: *Normal conjunctiva* is a thin semitransparent structure. A fine network of vessels is distinctly seen in it. Following signs may be observed:

▪▪ *Discolouration* of conjunctiva may be brownish in melanosis and argyrosis (silver nitrate deposits), greyish due to *surma* deposits, pale in anaemia, bluish in cyanosis and bright red due to subconjunctival haemorrhage.

▪▪ *Congestion of vessels.* Congestion may be superficial (in conjunctivitis) or ciliary/circumcorneal/deep (in iridocyclitis, and keratitis) or mixed (in acute congestive glaucoma). Differences between conjunctival and ciliary congestion are depicted in Table 1.2.

▪▪ *Conjunctival chemosis* (oedema) may be observed in allergic and infective inflammatory conditions.

▪▪ *Follicles.* These are seen as greyish white raised areas (mimicking boiled sago-grains) on fornices and palpebral conjunctiva. Follicles represent areas of aggregation of lymphocytes. Follicles may be seen in following conditions:

- Trachoma
- Acute follicular conjunctivitis
- Chronic follicular conjunctivitis
- Benign (school) folliculosis.

▪▪ *Papillae* are seen as reddish raised areas with flattops and velvety appearance. These represent areas of vascular and epithelial hyperplasia. Papillae are seen in the following conditions:

- Trachoma
- Spring catarrh
- Allergic conjunctivitis
- Giant papillary conjunctivitis.

▪▪ *Concretions* are seen as yellowish-white hard-looking raised areas, varying in size from pin-point to pin-head. They represent inspissated mucous and dead epithelial cells in glands of Henle. Common causes of concretions are trachoma, conjunctival degeneration and idiopathic.

▪▪ *Foreign bodies* are commonly lodged in fornices and sulcus subtarsalis on palpebral conjunctiva.

▪▪ *Scarring on the conjunctiva* may be in the form of a single line in the area of sulcus subtarsalis *(Arlt's line),* irregular, or star-shaped. Common causes of scarring are:

- Trachoma
- Healed membranous or pseudomembranous conjunctivitis
- Healed traumatic wounds
- Surgical scars.

▪▪ *Pinguecula* is a degenerative condition of conjunctiva observed in many adult patients. It is seen on the bulbar conjunctiva, near the limbus, in the form of a yellowish triangular nodule resembling a fat drop.

▪▪ *Pterygium* is a degenerative conjunctival fold which encroaches on the cornea in the palpebral area. It must be differentiated from

Table 1.2 *Differences between conjunctival and ciliary congestion*

S. no.	*Feature*	*Conjunctival congestion*	*Ciliary congestion*
1.	Site	More marked in the fornices	More marked around the limbus
2.	Colour	Bright red	Purple or dull red
3.	Arrangement of vessels	Superficial and branching	Deep and radiating from limbus
4.	On moving conjunctiva	Congested vessels also move	Congested vessels do not move
5.	On mechanically squeezing out the blood vessels	Vessels fill slowly from fornix towards limbus	Vessels fill rapidly from limbus towards fornices
6.	Blanching, i.e. putting one drop of 1 in 10000 adrenaline	Vessels immediately blanch	Do not blanch
7.	Common causes	Acute conjunctivitis	Acute iridocyclitis, keratitis (corneal ulcer)

pseudopterygium (an inflammatory fold of conjunctiva encroaching the cornea).

▪▪ *Conjunctival cysts* which may be observed are:

- Retention cyst
- Implantation cyst
- Lymphatic cyst
- Cysticercosis.

▪▪ *Conjunctival tumours.* A few common tumours are dermoids, papillomas and squamous cell carcinoma.

8. Examination of sclera. Normally anterior part of sclera covered by bulbar conjunctiva can be examined under diffuse illumination. Following abnormalities may be seen:

i. *Discolouration.* Normally sclera is white in colour. It becomes yellow in jaundice. Bluish discolouration may be seen as an isolated anomaly or in association with osteitis deformans, Marfan's syndrome, pseudoxanthoma elasticum. Pigmentation of sclera is also seen in naevus of Ota and melanosis bulbi.

ii. *Inflammation.* A superficial localised pink or purple circumscribed flat nodule is seen in *episcleritis.* While a deep, dusky patch associated with marked inflammation and ciliary congestion is suggestive of *scleritis.*

iii. *Staphyloma* is a thinned out bulging area of sclera which is lined by the uveal tissue. Depending upon its location, scleral staphylomas may be intercalary, ciliary, equatorial and posterior.

iv. *Traumatic perforations* in blunt trauma are usually seen in the region of limbus or at the equator.

9. Examination of cornea. Loupe and lens examination or preferably slit-lamp biomicroscopy is a must to delineate corneal lesions. While examining the cornea, a note of following points should be made:

i. *Size.* The anterior surface of normal cornea is elliptical with an average horizontal diameter of 11.7 mm and vertical diameter of 11 mm. Abnormalities of corneal size can be:

- *Microcornea,* when the anterior horizontal diameter is less than 10 mm. It may occur isolated or as a part of microphthalmos.
- Corneal size also decreases in patients with phthisis bulbi.
- *Megalocornea* is labelled when the horizontal diameter is more than 13 mm. Common causes are congenital megalocornea and buphthalmos.

ii. *Shape (curvature).* Normal cornea is like a watchglass with a uniform posterior curve in its central area. In addition to biomicroscopy, keratometry and corneal topography is required to confirm changes in corneal curvature. Abnormalities of corneal shape (curvature) are:

- *Keratoglobus.* It is an ectatic condition in which cornea becomes thin and bulges out like a globe.
- *Keratoconus.* It is an ectatic condition in which cornea becomes cone shaped.
- *Cornea plana,* i.e. flat curvature of cornea which may occur in patients with severe hypotony and phthisis bulbi and rarely as a congenital anomaly.

iii. Surface. Smoothness of corneal surface is disturbed due to abrasions, ulceration, ectatic scars and facets. Changes in smoothness of surface can be detected by slit-lamp biomicroscopy, window reflex test and Placido's disc examination.

Placido's keratoscopic disc. It is a disc painted with alternating black and white circles (Fig. 1.6). It may be used to assess the smoothness and curvature of corneal surface. Normally, on looking through the hole in the centre of disc a uniform sharp image of the circles is seen on the cornea (Fig. 1.7). Irregularities in the corneal surface cause distortion of the circles (Fig. 1.8).

iv. Sheen. Normal cornea is a bright shining structure. Sheen of corneal surface is lost in 'dry eye' conditions. A loss of the normal polish of the corneal surface causes loss in the sharpness of the outline of the image of circles on *Placido's disc test.*

v. *Transparency* of cornea is lost in corneal oedema, opacity, ulceration, dystrophies, degenerations, vascularization and due to deposits in the cornea.

Examination for corneal ulcer. Once corneal ulcer is suspected, a thorough biomicroscopic

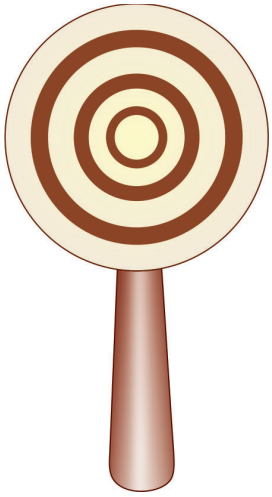


Fig. 1.6: *Placido's disc.*

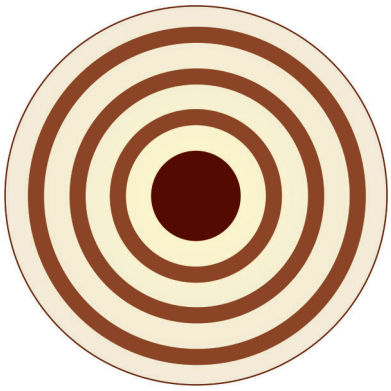


Fig. 1.7: *Placido's disc reflex from normal cornea.*

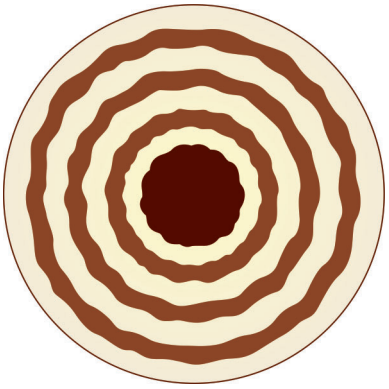


Fig. 1.8: *Placido's disc reflex from irregular corneal surface.*

examination before and after fluorescein staining should be performed to note the site, size, shape, depth, floor and edges of the corneal ulcer.

Examination for corneal opacity is best done with the help of a slit-lamp. Note the number, site, size, shape, density (nebular, macular or leucomatous) and surface of the opacity.

vi. ***Corneal vascularization***. The cornea is an avascular structure but its vascularization may occur in many diseases. When vessels are present, an exact note of their position, whether superficial or deep and their distribution whether localised, general, or peripheral should be made.

Differences between superficial and deep vascularization of cornea are shown in Table 1.3.

vii. ***Corneal sensations***. Cornea is a very sensitive structure, being richly supplied by the nerves. The sensitivity of cornea is diminished in many affections of the cornea, viz. herpetic keratitis, neuroparalytic keratitis, leprosy, diabetes mellitus, trigeminal block for postherpetic neuralgia and absolute glaucoma.

▪▪ *Testing corneal sensations.* Patient is asked to look ahead; the examiner touches the corneal surface with a fine twisted cotton wick (which is brought from the side to avoid menace reflex) and observes the blinking response. Normally, there is a brisk reflex closure of lids. Always compare the effect with that on the opposite side. The exact qualitative measurement of corneal sensations is made with the help of an aesthesiometer.

Table 1.3 *Differences between superficial and deep corneal vascularization*

Superficial corneal vascularization	*Deep corneal vascularization*
1. Corneal vessels can be traced over the limbus into the conjunctiva.	Corneal vessels abruptly end at the limbus.
2. Vessels are bright red and well-defined.	Vessels are ill-defined and cause only a diffuse reddish blush.
3. Superficial vessels branch in an arborescent manner.	Deep vessels run parallel to each other in a radial fashion.
4. Superficial vessels raise the epithelium and make the corneal surface irregular	Deep vessels do not disturb the corneal surface.

viii. ***Back of cornea*** should be examined for keratic precipitates (KPs) which are cellular deposits and a sign of anterior uveitis.

KPs can be of different types such as fine, pigmented or mutton fat.

ix. ***Corneal endothelium***. It is examined with specular microscope which allows a clear morphological study of endothelial cells including photographic documentation. The cell density of endothelium is around 3000 cells/mm^2 in young adults, which decreases with advancing age.

Biomicroscopic examination after staining of cornea with vital stains is as below:

i. ***Fluorescein staining*** of cornea is carried out either using one drop of 2 percent freshly prepared aqueous solution of the dye or a disposable autoclaved filter paper strip impregnated with the dye. The area denuded of epithelium due to abrasions or corneal ulcer when stained with fluorescein appear brilliant green. When examined using cobalt blue light, the stained area appears opaque green.

ii. ***Bengal rose*** (1%) stains the diseased and devitalized cells red, e.g. as in superficial punctate keratitis and filamentary keratitis. Bengal rose dye is very irritating. Therefore, a drop of 2% xylocaine should be instilled before using this dye.

iii. ***Alcian blue*** dye stains the excess mucus selectively, e.g. as in keratoconjunctivitis sicca.

10. Examination of anterior chamber. It is best done with the help of a slit-lamp.

i. ***Depth of anterior chamber***. Normal depth of anterior chamber is about 2.5 mm in the centre (slightly shallow in childhood and in old age). On slit-lamp biomicroscopy, an estimate of depth is made from the position of iris. Anterior chamber may be normal, shallow, deep or irregular in-depth.

Causes of shallow anterior chamber

- Primary narrow angle glaucoma
- Hypermetropia
- Postoperative shallow anterior chamber (after intraocular surgery due to wound leak or ciliochoroidal detachment)
- Malignant glaucoma
- Anterior perforations (perforating injuries or perforation of corneal ulcer)
- Anterior subluxation of lens
- Intumescent (swollen) lens.

Causes of deep anterior chamber

- Aphakia/pseudophakia
- Total posterior synechiae
- Myopia
- Keratoglobus
- Buphthalmos
- Keratoconus
- Anterior dislocation of lens into the anterior chamber
- Posterior perforation of the globe.

Causes of irregular anterior chamber

- Adherent leucoma
- Iris bombe formation due to annular synechiae
- Tilting of lens in subluxation.

ii. ***Contents of anterior chamber:*** Anterior chamber contains transparent watery fluid—the aqueous humour. Any of the following abnormal contents may be detected on examination:

- *Aqueouts flare* in anterior chamber occurs due to collection of inflammatory cells and protein particles in patients with iridocyclitis. Aqueous flare is demonstrated in fine beam of slit-lamp light as fine moving (Brownian movements) suspended particles. It is based on the Tyndall phenomenon (*see* page 155).
- *Hypopyon,* i.e. *Pus* in the anterior chamber may be seen in cases of infectious corneal ulcer, iridocyclitis, toxic anterior segment syndrome (TASS), endophthalmitis and panophthalmitis.
- *Pseudohypopyon* due to collection of tumour cells in anterior chamber and seen in patients with retinoblastoma.
- *Foreign bodies*—wooden, iron, glass particles, stone particles, cilia, etc. may enter the anterior chamber after perforating trauma.
- *Crystalline lens* may be observed in anterior chamber after anterior dislocation of lens.
- *Lens particles* in anterior chamber after trauma, planned extracapsular cataract extraction (ECCE) is a frequent observation.

- *Blood* in the anterior chamber is called *hyphaema* and may be seen after ocular trauma, surgery, herpes zoster and gonococcal iridocyclitis, blood dyscrasias, clotting disorder and intraocular tumours (e.g. retinoblastoma, angioma).
- *Parasitic cyst*, e.g. cysticercus cellulosae has been demonstrated in anterior chamber.
- *Artificial lens*. Anterior chamber intraocular lens may be observed in patients with pseudophakia.

iii. *Examination of angle of anterior chamber* is performed with the help of a gonioscope and slit-lamp. Gonioscopy is a specialized examination required in patients with glaucoma (*see* Chapter 13).

11. Examination of the iris. It should be performed with reference to following points:

i. *Colour of the iris.* It varies in different races; it is light blue or green in caucasians and dark brown in orientals. Heterochromia iridum (different colour of two iris) and heterochromia iridis (different colour of sectors of the same iris) may be present in some individuals. Heterochromia may be either due to involved iris being lighter or darker than the normal.

- *Causes of iris lighter than normal* are: congenital heterochromia, congenital Horner's syndrome, Fuch's heterochromic iridocyclitis, atrophic patches in chronic uveitis, juvenile xanthogranuloma, metastatic carcinoma and Wardenburg syndrome.
- *Causes of darker iris* include, iris naevi, ocular melanocytosis or oculodermal melanocytosis, haemosiderosis, siderosis bulbi, retained iris foreign body, malignant melanoma of iris and lymphoma.
- *Darkly pigmented spots (naevi)* are common freckles on the iris.

ii. *Pattern of normal iris* is peculiar due to presence of collarette, crypts and radial striations on its anterior surface. This pattern is disturbed due to 'muddy iris' in acute iridocyclitis and due to atrophy of iris in healed iridocyclitis.

iii. *Persistent pupillary membrane* *(PPM)* is seen sometimes as abnormal congenital tags of iris tissue adherent to the collarette area.

iv. *Synechiae,* i.e. adhesions of iris to other intraocular structures may be seen. Synechiae may be anterior (in adherent leucoma) or posterior (in iridocyclitis). Posterior synechiae may be total, annular (ring), or segmental.

v. *Iridodonesis* (tremulousness of the iris). It is observed when its posterior support is lost as in aphakia and subluxation of lens.

vi. *Nodules on the iris surface.* These are observed in granulomatous uveitis (Koeppe's and Busacca's nodules), melanoma, tuberculoma and gumma of the iris.

vii. *Rubeosis iridis* (new vessel formation on the iris). It may occur in patients with diabetic retinopathy, central retinal vein occlusion (CRVO), branch retinal vein occlusion (BRVO), ocular ischaemic syndrome, chronic uveitis, chronic retinal detachment, intraocular tumours, e.g. retinobalstoma.

viii. *A gap or hole in the iris.* It may be congenital coloboma or due to iridectomy (surgical coloboma). Separation of iris from ciliary body is called *iridodialysis.*

ix. *Aniridia or irideremia* (complete absence of iris). It is a rare congenital condition.

x. *Iris cyst.* It may be seen near the pupillary margin in patients using strong miotic drops.

12. Examination of pupil. Note the following points:

i. *Number.* Normally there is only one pupil. Rarely, there may be more than one pupil. This congenital anomaly is called *polycoria.*

ii. *Location.* Normally pupil is placed almost in the centre (slightly nasal) of the iris. Rarely, it may be congenitally eccentric (corectopia).

iii. *Size.* Normal pupil size varies from 3 to 4 mm depending upon the illumination. But it may be abnormally small *(miosis)* or large *(mydriasis).*

Causes of miosis

- Effect of local miotic drugs (parasympathomimetic drugs)
- Effect of systemic morphine
- Iridocyclitis (narrow, irregular, nonreacting pupil)
- Horner's syndrome
- Head injury (pontine haemorrhage)
- Senile rigid miotic pupil

- Due to effect of strong light
- During sleep pupil is pinpoint.

Causes of mydriasis

- Effect of topical sympathomimetic drugs (e.g. adrenaline and phenylephrine)
- Effect of topical parasympatholytic drugs (e.g. atropine, homatropine, tropicamide and cyclopentolate)
- Acute congestive glaucoma (vertically oval large immobile pupil)
- Absolute glaucoma
- Optic atrophy
- Retinal detachment
- Internal ophthalmoplegia
- 3rd nerve paralysis
- Belladonna poisoning.

▪▪ *Evaluation of anisocoria* (*see* Chapter 6).

iv. *Shape.* Normal pupil is circular in shape.

- *Irregular narrow, pupil* is seen in iridocyclitis
- *Festooned pupil* is the name given to irregular pupil obtained after patchy dilatation (effect of mydriatics in the presence of segmental posterior synechiae)
- *Vertically oval pupil* (pear-shaped pupil or updrawn pupil) may occur postoperatively due to incarceration of iris or vitreous in the wound at 12 o'clock position.

v. *Colour.* Of course, pupil is a hole in the iris, but the pupillary area does exhibit colour depending upon the condition of the structures located behind it. Pupil looks:

- *Greyish black* normally
- *Jet black* in aphakia
- *Greyish white* in immature senile cortical cataract
- *Pearly white* in mature cortical cataract
- *Milky white* in hypermature cataract
- *Brown* in cataracta brunescens
- *Brownish black* in cataracta nigra.
- *Leucocoria* (white reflex in pupil) in children is seen in congenital cataract, retinoblastoma, retrolental fibroplasia (retinopathy of prematurity), persistent primary hyperplastic vitreous and toxocara endophthalmitis. The yellowish white, semidilated, non-reacting pupil seen in retinoblastoma and pseudogliomas is also called *amaurotic cat's eye reflex.*
- *Greenish hue* is observed in pupillary area in some patients with glaucoma.
- *Dirty white exudates* may occlude the pupil *(occlusio pupillae)* in patients with iridocyclitis.

vi. *Pupillary reactions.* Note as follows:

▪▪ *Direct light reflex.* To elicit this reflex the patient is seated in a dimly-lighted room. With the help of a palm one eye is closed and a narrow beam of light is shown to other pupil and its response is noted. The procedure is repeated for the second eye. A normal pupil reacts briskly and its constriction to light is well-maintained.

▪▪ *Consensual light reflex.* To determine consensual reaction to light, patient is seated in a dimly-lighted room and the two eyes are separated from each other by an opaque curtain kept at the level of nose (either hand of examiner or a piece of cardboard). Then one eye is exposed to a beam of light and pupillary response is observed in the other eye. The same procedure is repeated for the second eye. Normally, the contralateral pupil should also constrict when light is thrown on to one pupil.

▪▪ *Swinging flash light test.* It is performed when relative afferent pathway defect is suspected in one eye (unilateral optic nerve lesion with good vision). To perform this test, a bright flash light is shone on to one pupil and constriction is noted. Then the flash light is quickly moved to the contralateral pupil and response is noted. This swinging to and fro of flash light is repeated several times while observing the pupillary response. Normally, both pupils constrict equally and the pupil to which light is transferred remains tightly constricted. In the presence of relative afferent pathway defect in one eye, the affected pupil will dilate when the flash light is moved from the normal eye to the abnormal eye. This response is called *'Marcus Gunn pupil'* or a relative afferent pupillary defect (RAPD). It is the earliest indication of optic nerve disease even in the presence of normal visual acuity.

- *Near reflex.* In it pupil constricts while looking at a near object. This reflex is largely determined by the reaction to convergence but accommodation also plays a part.

  To determine the near reflex, patient is asked to focus on a far object and then instructed suddenly to focus at an object (pencil or tip of index finger) held about 15 cm from patient's eye. While the patient's eye converges and focuses the near object, observe the constriction of pupil.
- *Abnormal pupillary reactions include: (i)* amaurotic pupil, (ii) efferent pathway defect, (iii) Wernicke's hemianopic pupil, (iv) Marcus Gunn pupil, (v) Argyll Robertson pupil, and (vi) the tonic pupil.

13. Examination of the lens. A thorough examination of the lens can be accomplished with the help of oblique illumination, slit-lamp biomicroscopy and distant direct ophthalmoscopy with fully-dilated pupils. Following points should be noted:

i. *Position.* A normal lens is positioned in the patellar fossa (space between the vitreous and back of iris) by the zonules. Abnormalities of position may be:

- *Dislocation of lens,* i.e. lens is not present in its normal position (i.e. patellar fossa) and all its supporting zonules are broken. In *anterior dislocation* the intact lens (clear or cataractous) is present in the anterior chamber. While in *posterior dislocation* the lens is present in vitreous cavity where it might be floating *(lensa nutans)* or fixed to the retina *(lensa fixata).*
- *Subluxation of lens,* i.e. lens is partially displaced from its position. Here zonules are intact in some quadrant and lens is shifted on that side. With dilated pupil, edge of the subluxated lens is seen as shining golden crescent on focal illumination and as a dark line (due to total internal reflection) on distant direct ophthalmoscopy. In the presence of substantial degree of subluxation, half pupil may be phakic and half aphakic (and patient may experience unilateral diplopia). Common causes of subluxation of lens are trauma. Marfan's syndrome, homocystinuria, Weill-Marchesani syndrome.
- *Aphakia* (absence of lens) is diagnosed by jet black pupil, deep anterior chamber, empty patellar fossa on slit-lamp biomicroscopy, hypermetropic eye on ophthalmoscopy, retinoscopy and absence of 3rd and 4th Purkinje images.
- *Pseudophakia.* When posterior chamber IOL is present it is diagnosed by a black pupil, deep anterior chamber, shining reflexes from the anterior surface of IOL and presence of all the four Purkinje's images. Examination after dilatation of pupil confirms pseudophakia.

ii. *Shape of lens.* Normal lens is a biconvex structure, which is nicely demonstrated in an optical section of the lens on slit-lamp examination (Fig. 1.9). The optical section of the lens shows from within outward embryonic, foetal, infantile and adult nuclei, cortex and capsule. An anterior Y-shaped and posterior inverted Y-shaped sutures may also be seen.

Abnormalities of the lens shape include:

- Spherophakia, i.e. spherical lens.
- Lenticonus anterior, i.e. an anterior cone-shaped bulge in the lens as seen in Alport syndrome.
- Lenticonus posterior, i.e. a cone-shaped bulge in the posterior aspect of lens.
- Coloboma of lens, i.e. a notch in the lens.

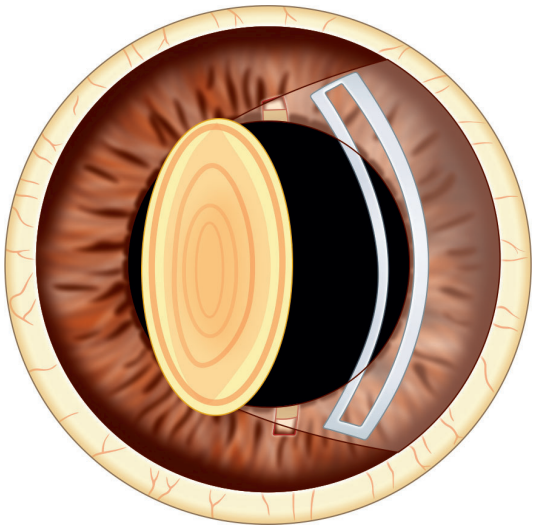


Fig. 1.9: *Optical section of the cornea and adult lens as seen on slit-lamp examination.*

iii. *Colour.* On focal illumination, the normal lens in young age appears almost clear or gives a faint blue hue.

- *In old age,* even the clear lens gives greyish white, hue due to marked scattering of light as a result of increased refractive index of the lens with advancing age. It is usually mistaken for cataract.
- *In cortical cataract,* lens may be greyish white, pearly white or milky white in colour in immature, mature and hypermature cataracts, respectively.
- *In nuclear cataract,* lens may look amber, brown or black in colour.
- *A rusty (orange) discolouration* is seen in cataractous lens with siderosis bulbi (due to retained intraocular iron foreign body).

iv. *Transparency.* Normal lens is a transparent structure. Any opacity in the lens is called *cataract,* which looks greyish or yellowish white on focal illumination. On *distant direct ophthalmoscopy,* the lenticular opacities appear black against a red fundal reflex. On slit lamp biomicroscopy, the morphology of cataract can be studied in detail:

- *Complicated cataract* in the early stages exhibits polychromatic lustre and gives breadcrumbs appearance
- *True diabetic cataract* presents *'snow flake'* opacities
- *Sunflower cataract* is typically seen in disorder of copper metabolism (Wilson's disease)
- *Rosette-shaped cataract,* early as well as late, is typical of concussion injury of lens.

v. *Deposits on the anterior surface of lens* may be:

- *Vossius ring.* It is a small ring-shaped pigment dispersal seen on the anterior surface of lens after blunt trauma. It corresponds in shape and size to the miosed pupil, i.e. smaller than the pupil.
- *Pigmented clumps* may be deposited on the anterior surface of lens in patients with iridocyclitis.
- *Dirty white exudates* may be present on the anterior surface of lens in patients with uveitis and endophthalmitis.
- *Rusty deposits,* i.e. deposition of ferrous ions just below the anterior capsule is seen in siderosis bulbi.
- *Greenish deposits,* i.e. deposition of copper ions is seen in chalcosis.

vi. *Purkinje images test.* This test does not have much significance and thus is not frequently employed in clinical practice. However, it is described as a tribute to the original worker who used this test to diagnose mature cataract and aphakia. Normally, when a strong beam of light is shown to the eye, four images (Purkinje images) are formed from the four different reflecting surfaces, viz. anterior and posterior surfaces of cornea and anterior and posterior surfaces of lens (Fig. 1.10). In patients with mature cataract, fourth image (formed by posterior surface of the lens) is absent, i.e. three Purkinje images are formed. In aphakia, third and fourth Purkinje images (formed by anterior and posterior surface of lens) are absent, i.e. only two images are formed.

14. The intraocular pressure (IOP). The measurement of IOP (ocular tension) should be

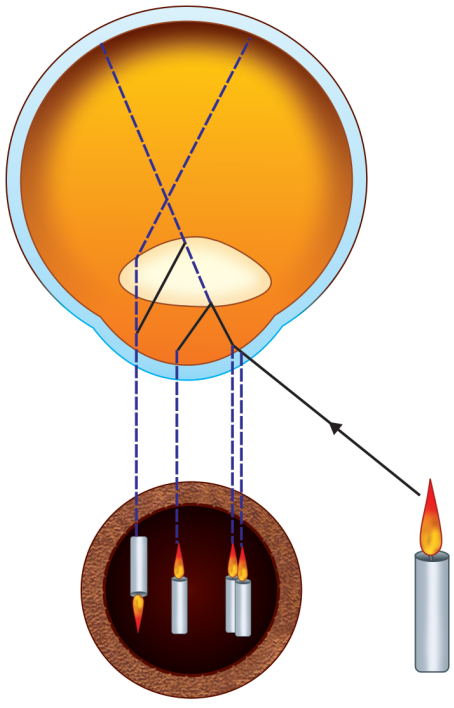


Fig. 1.10: *Purkinje images.*

made in all suspected cases of glaucoma and in routine after the age of 40 years. A rough estimate of IOP can be made by *digital tonometry*. For this procedure patient is asked to look down and the eyeball is palpated by index fingers of both the hands, through the upper lid, beyond the tarsal plate. One finger is kept stationary which feels the fluctuation produced by indentation of globe by the other finger (Fig. 1.11). It is a subjective method and needs experience. When IOP is raised, fluctuation produced is feeble or absent and the eyeball feels firm to hard. When IOP is very low eye feels soft like a partially filled water bag.

The exact measurement of IOP is done by an instrument called tonometer. Indentation (Schiotz tonometer) and applanation (e.g. Goldmann's tonometer) tonometers are frequently used.

- Normal IOP *range* is 10–21 mmHg with an average tension of 16 ± 5.0 mmHg.
- *Hypotony* is labelled when IOP is less than 10 mmHg. Causes of hypotony include ruptured globe, phthisis bulbi, retinal/choroidal detachment, iridocyclitis, ocular ischaemia, postoperative wound leak and traumatic ciliary body shutdown.

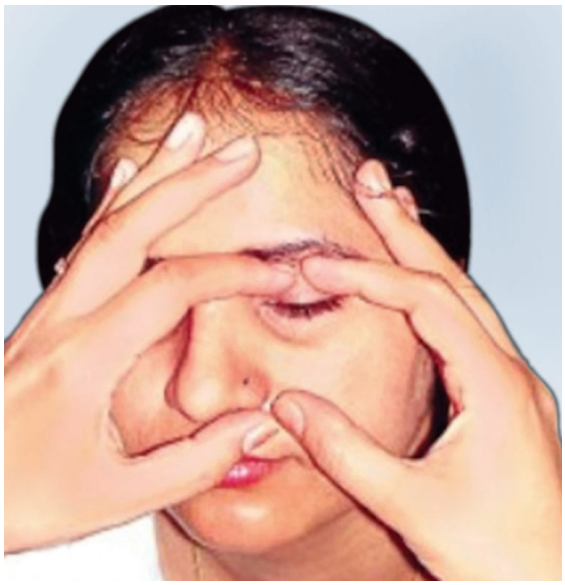


Fig. 1.11: *Technique of digital tonometry.*

- Glaucoma should be suspected when IOP is more than 21 mmHg and such patients should be thoroughly investigated.

III. FUNDUS EXAMINATION

This is essential to diagnose the diseases of the vitreous, optic nerve head, retina and choroid. For thorough examination of the fundus pupils should be dilated with 5% phenylephrine and/or 1% tropicamide eye drops. The fundus examination can be accomplished by ophthalmoscopy and slit-lamp biomicroscopic examination.

Observations during fundus examination

During fundus examination following observations should be made:

1. *Media.* Normally the ocular media is transparent. Opacities in the media are best diagnosed by distant direct ophthalmoscopy, where the opacities look black against the red glow.

Causes of opacities in media are corneal opacity, lenticular opacity, vitreous opacities (may be exudates, haemorrhage, degeneration, foreign bodies and vitreous membranes).

2. *Optic disc*

- *Size (diameter)* of the optic disc is 1.5 mm which looks roughly 15 times magnified during direct ophthalmoscopy. Disc is slightly smaller in hypermetropes and larger in myopes.
- *Shape* of the normal disc is circular. In very high astigmatism, disc looks oblong.
- *Margins* of the disc are well-defined in normal cases. Blurring of the margins may be seen in papilloedema, papillitis, postneuritic optic atrophy and in the presence of opaque nerve fibres.
- *Colour.* Normal disc is pinkish with central pallor area. (i) Hyperaemia of disc is seen in papilloedema and papillitis, (ii) Paler disc is a sign of partial optic atrophy, (iii) Chalky-white disc is seen in primary optic atrophy, (iv) Yellow-waxy disc is typical of consecutive optic atrophy.
- *Cup-disc ratio.* Normal cup disc ratio is 0.3. (i) Large cup may be physiological or

glaucomatous, (ii) cup becomes full in papilloedema and papillitis.

- *Splinter haemorrhages* on the disc may be seen in primary open angle glaucoma, normal tension glaucoma and papilloedema.
- *Neovascularization* of the disc may occur in diabetic retinopathy, CRVO and sickle cell retinopathy.
- *Opticociliary shunt* is a sign of orbital meningioma.
- *Peripapillary* crescent is seen in myopia.
- *Kesten-Baum index* refers to ratio of large blood vessels versus small blood vessels on the disc. Normal ratio is 4:16. This ratio is decreased in patients with optic atrophy.

3. *Macula.* The macula is situated at the posterior pole with its centre (foveola) being about 2 disc diameters lateral to temporal margin of disc. Normal macula is slightly darker than the surrounding retina. Its centre imparts a bright reflex (foveal reflex). Following abnormalities may be seen on the macula:

- *Macular hole.* It looks red in colour with punched-out margins.
- *Macular haemorrhage* is red and round.
- *Cherry red spot* is seen in central retinal artery occlusion, Tay-Sach's disease, Niemann-Pick's disease, Gaucher's disease and Berlin's oedema.
- *Macular oedema* may occur due to trauma, intraocular operations, uveitis and diabetic maculopathy.
- *Pigmentary disturbances* may be seen after trauma, solar burn, age-related macular degeneration (ARMD), central chorioretinitis and chloroquine toxicity.
- *Bull's eye macular lesions* are seen in ARMD, Stargardt disease, chloroquine retinopathy and cone dystrophy.
- *Hard exudates.* These may be seen in hypertensive retinopathy, exudative diabetic maculopathy, Coat's disease, CNVM.
- *Macular scarring.* It may occur following trauma and disciform macular degeneration.

4. *Retinal blood vessels.* Normal arterioles are bright-red in colour and veins are purplish with a caliber ratio of 2:3. Following abnormalities may be detected:

- *Narrowing of arterioles* is seen in hypertensive retinopathy, arteriosclerosis, and central retinal artery occlusion.
- *Tortuosity of veins* occurs in diabetes mellitus, central retinal vein occlusion and blood dyscrasias.
- *Sheathing* of vessels may be seen in periphlebitis retinae (Eale's disease, sarcoidosis, syphilis, tuberculosis, Behcet's disease, AIDS) and hypertensive retinopathy.
- *Vascular pulsations. Venous pulsations* may be seen at or near the optic disc in 10–20% of normal people and can be made manifest by increasing the intraocular pressure by slight pressure with the finger on the eyeball. Venous pulsations are conspicuously absent in papilloedema. *Arterial pulsations* are never seen normally and are always pathological. The true arterial pulsations may be noticed in patients with aortic regurgitation, aortic aneurysm and exophthalmic goitre. True arterial pulsations are not limited to disc. While a pressure arterial pulse which is seen in patients with very high IOP or very low blood pressure is limited to the optic disc.

5. *General background.* Normally the general background of fundus is pinkish red in colour.

- Physiological variations include dark red background in black races and tessellated or tigroid fundus due to excessive pigment in the choroid.
- Following abnormal findings may be seen in various pathological states:
  - *Superficial retinal haemorrhage* may be found in hypertension, diabetes, trauma, venous occlusions, and blood dyscrasias.
  - *Deep retinal haemorrhages* are typically seen in diabetic retinopathy.
  - *Cotton wool spots (old name soft exudates)* appearas whitish fluffy spots with indistinct margins. These may occur in hypertensive retinopathy, toxaemic retinopathy

of pregnancy, diabetic retinopathy, anaemias and collagen disorders like DLE, PAN and scleroderma.

- *Hard exudates* are small, discrete yellowish, waxy areas with crenated margins. Common causes are diabetic retinopathy, hypertensive retinopathy, Coats' disease and circinate retinopathy.
- *Colloid bodies* also called *drusens* occur as numerous minute, whitish, retractile spots, mainly involving the posterior pole. They are seen in senile macular degeneration and Doyne's honeycomb dystrophy.
- *Pigmentary disturbances* may be seen in tape to retinal dystrophies, e.g. retinitis pigmentosa and healed chorioretinitis.
- *Microaneurysms* are seen as multiple tiny dot-like dilatations along the venous end of capillaries.

  They are commonly found in diabetic retinopathy. Other causes include hypertensive retinopathy, retinal vein occlusions, Eales' disease and sickle cell disease.
- *Neovascularization of retina* occurs in hypoxic states like diabetic retinopathy, Eales' disease, sickle-cell retinopathy, and following central retinal vein occlusion.
- *Tumours of fundus* include retinoblastoma, astrocytoma and melanomas.
- *Peripheral retinal degenerations* include lattice degeneration, paving stone degeneration, white areas with and without pressure.
- *Retinal holes* are seen as punched out red areas with or without operculum. These may be round or horseshoe in shape or giant tears.
- *Proliferative retinopathy* is seen as disorganized mass of fibrovascular tissue in patients with proliferative diabetic retinopathy, sickle cell retinopathy, following trauma, in Eales' disease and retinopathy of prematurity.
- *Retinal detachment:* Retina looks grey, raised and folded.

IV. VISUAL FIELD EXAMINATION

Examination of visual fields is important in many eye diseases. Technique of visual field examination is described on Chapter 16. Common types of field defects and their causes are mentioned below:

- *Altitudinal field defects:* Ischaemic optic neuropathy, optic disc disease, high myopia and optic neuritis.
- *Enlargement of blind spot:* Glaucoma, papilloedema, optic disc drusen, coloboma of optic disc, medullated nerve fibers, and myopic disc with a crescent.
- *Central scotoma:* Macular disease, optic neuritis, toxic amblyopia, tumours compressing the nerve.
- *Constriction of peripheral fields:* Glaucoma, retinitis pigmentosa, after panretinal photocoagulation, central retinal artery occlusion with cilioretinal artery sparing, and chronic papilloedema.
- *Homonymous hemianopia:* Lesion of the optic-tract, lateral geniculate body, optic radiations in temporal, parietal or occipital lobe lesions of the brain such as stroke, tumours, aneurysm and trauma.
- *Bitemporal hemianopia:* Lesions involving optic chiasma, such as pituitary adenoma, meningioma, craniopharyngioma and glioma.
- *Binasal field defects:* Tumours or aneurysm-compressing both optic nerves, or chiasma, chiasmatic arachnoiditis, bilateral occipital disease, bitemporal retinal disease (e.g. retinitis pigmentosa) and glaucoma.
- *Arcuate scotoma:* Glaucoma, optic disc drusen, high myopia, ischaemic optic neuropathy and optic neuritis.

V. COLOUR VISION TESTING

Colour sense in the ability of the eye to discriminate between colours excited by light of different wavelengths. An individual with normal colour vision is known as 'trichromate'. In colour blindness, faculty to appreciate one or more primary colours in either defective (anomalous) or about (anopia). It may be congenital or acquired.

Tests for colour vision are designed for:

1. Screening defective colour vision from normals;
2. Qualitative classification of colour blindness, i.e. proton, deutron and triton
3. Quantitative analysis of degree of deficiency, i.e. mild, moderate or marked.

Details about the colour vision and its testing are described in Chapter 2.

SPECIALISED OCULAR DIAGNOSTIC TESTS

The specialiged ocular diagnostic tests have their specific indication and are not infrequently performed. A few ommon such tests, listed below are described in separate chapters given in the parenthesis.

- Ocular fluorescein angiograhy (Chapter 28)
- Electrophysiologicats tests (Chapter.30)
  - Electro-retinography (ERG)
  - Electro-oculography (EOG)
  - Visually evoked response (VER)

IMAGING TECHNIQUES IN OPHTHALMOLOGY

Roentgen examination techniques have occupied an important place in the mark-up of an ophthalmic case. These are indespensable both for intraocular and intraoptical lesions. These described in Chapters 31 to 35, include the following:

- Plain X-ray
- Conventional tomography
- Ultrasonography
- CT scanning
- Magnetic Resonance Imaging (MRI)
- Protone.

HISTOPATHOLOGICAL STUDIES IN OPHTHALMOLOGY

In spite of the exaussive clinical mark-up and advanced ocular diagnostic tests, the exact diagnosis in many ocular lesions (especially orbital and adnexal lesions) cannot be made without the help of histopathological studies which can be accomplished by gine needle aspiration biopath incisional biopsy and excisional biopsy.

RECORD OF OPHTHALMIC CASE

Both right and left eye should be examined and findings should be recorded in ophthalmic clinical case sheet (depicted below).

OPHTHALMIC CLINICAL CASE SHEET

Name and Address

Age and Sex

Occupation

Religion

Chief Presenting Complaints

History of Present Illness

Past History

Contd...

OPHTHALMIC CLINICAL CASE SHEET (*Contd...*)

Personal History

Family History

General Physical and Systemic Examination

Facial Symmetry

Head Posture

Forehead

Ocular Examination

	Right Eye	Left Eye
Visual Acuity		
• Distance (with and without glasses)		
• Near		
Eyebrows		
• Level		
• Cilia		
Orbit		
• Inspection		
• Palpation		
Eyeballs		
• Position		
• Size		
• Alignment		
• Movements		
Uniocular		
Biocular		
Eyelids		
• Position		
• Movements		
• Lid Margin		
• Eyelashes		
• Skin of Lids		

Contd...

OPHTHALMIC CLINICAL CASE SHEET (*Contd...*)

Palpebral Aperture

- Width
- Height
- Shape

LACRIMAL Apparatus

- Puncta
- Lacrimal Sac Area
- Regurgitation Test
- Lacrimal Syringing

Conjunctiva

- Bulbar Conjunctiva
- Palpebral Conjunctiva
- Fornices

Limbus

Sclera

- Discoloration
- Nodule
- Ectasia
- Any Other Abnormality

Cornea

- Size
- Shape

TECHNIQUES OF OCULAR EXAMINATION AND DIAGNOSTIC TESTS

OBLIQUE ILLUMINATION

Oblique illumination also known as focal illumination, is a method for examination of the structures of the anterior segment of the eye. Karl Himly (1806) was the first to employ the technique of oblique illumination examination. In it, a zone of light is made to fall upon the structure to be examined so that it is brilliantly illuminated and stands out with special clarity as compared to the surroundings which remain in shadow.

There are two main methods of focal illumination:

- Loupe and lens examination
- Slit-lamp examination.

Loupe and lens examination

Optical principle. It is based on the principle that when an object is placed between a convex lens and its focal point, its image formed is virtual, erect, magnified and on the same side as the object.

Prerequisites. (1) Darkroom, (2) source of light, (3) condensing lens of +13 D, (4) corneal loupe of +41 D, made with two planoconvex lenses each of 20.5 D (×10 magnification) (Fig. 1.12).

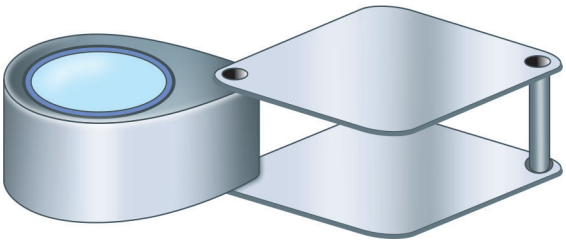


Fig. 1.12: *Corneal loupe.*

Procedure. (1) Light source is placed about 2 feet away, laterally and slightly in front of the patient's eye; (2) Light is focused on the structure to be examined with the help of +13 D condensing lens, held in one hand; (3) The examination is carried out with the help of corneal loupe. The loupe is held between thumb and forefinger of the second hand, the fourth and fifth fingers are supported on the patient's forehead, while the middle finger is used for elevating the upper lid (Fig. 1.13). The loupe is brought close to the patient's eye till the illuminated area is focused. The observer should also move his or her eyes as close to the loupe as possible to have a better view (4) By changing the position of the condensing lens and loupe, various structures of the anterior segment can be examined one by one.

Use of binocular loupe. The corneal loupe may be replaced by a binocular loupe (Fig. 1.14),

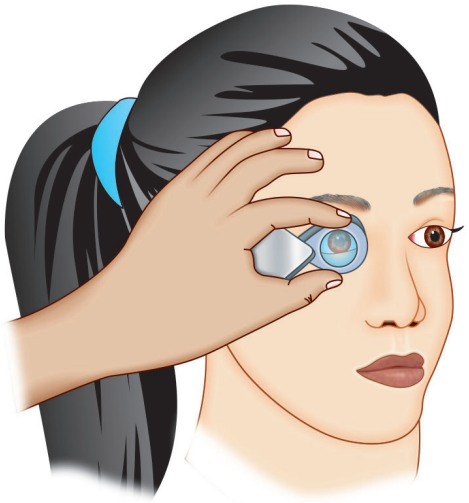


Fig. 1.13: *Technique of loupe and lens examination.*

Fig. 1.14: *Binocular loupe.*

which gives the added advantage of stereoscopic view and easy manoeuvering, as normally it is fixed to the examiner's head by a band. However, the magnification achieved with binocular loupe is much less than that of uniocular corneal loupe.

SLIT-LAMP EXAMINATION

Note: *For details see Chapter* 3.

GONIOSCOPY

Owing to lack of transparency of corneoscleral junction and total internal reflection of light (emitted from angle structures) at anterior surface of cornea it is not possible to visualize the angle of anterior chamber directly. Therefore, a device (goniolens) is used to divert the beam of light and this technique of biomicroscopic examination of the angle of anterior chamber is called *gonioscopy.*

Note: *For details see Chapter* 13.

TONOMETRY

The intraocular pressure (IOP) is measured with the help of an instrument called *tonometer.* Two basic types of tonometers available are: indentation and applanation.

Note: *For details see Chapter* 12.

TECHNIQUES OF FUNDUS EXAMINATION

A. Ophthalmoscopy
B. Slit-lamp biomicroscopic examination of the fundus by:
   - Indirect slit-lamp biomicroscopy
   - Hruby lens biomicroscopy
   - Contact lens biomicroscopy.

Note: *For details see Chapter* 4.

PERIMETRY

Visual field is a three-dimensional area of a subject's surroundings that can be seen at any one time around an object of fixation. Traquair described it as an "island of vision surrounded by a sea of darkness". The extent of normal visual field with a 5 mm white colour object is superiorly 50°, nasally 60°, inferiorly 70° and temporally 90° (Fig. 1.15). The field for blue and yellow is roughly 10° less and that for red and green colour is about 20° less than that for white. Perimetry with a red colour object is particularly useful in the diagnosis of bitemporal hemianopia due to chiasmal compression and in the central scotoma of retrobulbar neuritis.

The visual field can be divided into central and peripheral field (Fig. 1.15):

Central field includes an area from the fixation point to a circle 30° away. The central zone contains physiologic blind spot on the temporal side.

Peripheral field of vision refers to the rest of the area beyond 30° to outer extent of the field of vision.

Isopter. Visual field, i.e. the three-dimensional hill of vision can be divided into many isopters depending upon the perception sensitivity. Thus each isopter can be defined as a threshold line forming points of equal sensitivity on a visual field chart.

Scotoma refers to an area of loss of vision totally *(absolute scotoma)* or partially *(relative scotoma)* in the visual field.

Methods of estimating the visual fields

Perimetry. It is the procedure for estimating extent of the visual fields. It can be classified as below:

Kinetic versus static perimetry

Kinetic perimetry. In this, the stimulus of known luminance is moved from a peripheral non-

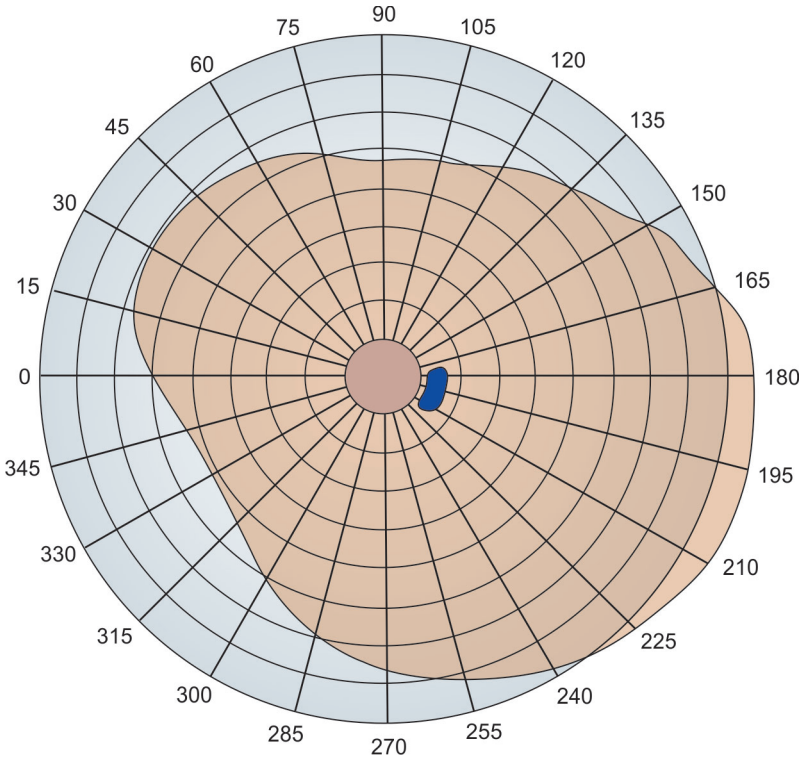


Fig. 1.15: *Extent of normal visual field.*

seeing point towards the centre till it is perceived to establish the isopters. Various methods of kinetic perimetry are: Confrontation method, Lister's perimetry, tangent screen scotometry and Goldmann's perimetry.

Static perimetry. This involves presenting a stimulus at a predetermined position for a preset duration with varying luminance in the field of vision. Various methods of static perimetry adopted are Goldmann perimetry, Friedmann perimetry, automated perimetry.

Peripheral versus central field charting

Peripheral field charting

- Confrontation method
- Perimetry: Lister's, Goldmann's and automated *central field charting*
- Campimetry or scotometry
- Goldmann's perimetry
- Automated field analysis.

Manual versus automated perimetry

- Manual perimetry
- Automated perimetry.

Note: *For details see Chapter* 16.

FUNDUS FLUORESCEIN ANGIOGRAPHY

Fundus fluorescein angiography (FFA) is a valuable tool in the diagnosis and management of a large number of fundus disorders.

Note: *For details see Chapter* 28.

ELECTRORETINOGRAPHY AND ELECTRO-OCULOGRAPHY

The electrophysiological tests allow objective evaluation of the retinal functions. These include: electroretinography (ERG), electro-oculography (EOG), and visually evoked response (VER).

Note: *For details see Chapter* 30.

OCULAR ULTRASONOGRAPHY

Ultrasonography has become a very useful diagnostic tool in ophthalmology. The diagnostic ophthalmic ultrasound is based upon 'pulse-echo' technique. Ultrasonic frequencies in the range of 10 MHz are used for ophthalmic diagnosis. Rapidly repeating short bursts of ultrasonic energy are beamed into the ocular and orbital structures. A portion of this signal is returned back to the examining probe (transducer) from areas of reflectivity. The echoes detected by the transducer are amplified and converted into display form. The processed signal is displayed on cathode ray tubes in one of the two modes: A-scan or B-scan .

A-scan (time amplitude). The A-scan produces a unidimensional image and echoes are plotted as spikes.

Interpretation of A-scan.

i. *Distance between the two echo spikes* provides an indirect measurement of tissue such as eyeball length or anterior chamber depth and lens thickness.

ii. *The height of the spike* indicates the strength of the tissue sending back the echo. The cornea, lens and sclera produce very high amplitude spikes, while the vitreous membrane and vitreous haemorrhage produce lower spikes.

B-scan (intensity modulation). B-scan produces two-dimensional dotted section of the eyeball. The location, size and configuration of the structures is easy to interpret.

Clinical uses of ocular ultrasound

A-scan is used for measurement of:

- Axial length, mainly for IOL power calculation (biometry)
- Anterior chamber depth and other intraocular distances
- Thickness of the intraocular mass.

B-scan is used for:

- Assessment of posterior segment in the presence of opaque media
- Study of intraocular tumours, orbital tumours, and other mass lesions
- Localization of intraocular and intraorbital foreign bodies.

Note: *For details see Chapter* 32.

OPTICAL COHERENCE TOMOGRAPHY

Optical coherence tomography (OCT) is a diagnostic tool that can perform cross-sectional

or tomographic images of biological tissues within less than 10 mm axial resolution using light waves. The operation of OCT is analogous to USG B-mode imaging or radar except that light is used rather than acoustic or radiowaves. OCT is specially suited for diagnostic applications in ophthalmology because of the ease of optical access to the anterior and posterior segment of the eye. The information provided by OCT is akin to *in vivo* histopathology of the structure.

Principle. *OCT* utilizes the interferometry and low coherence light in near infrared range.

OCT machine comprises: Fundus viewing unit, interferometric unit, computer display, control panel and colour inkjet printer.

OCT machine is available as:

- Anterior segment OCT machine
- Posterior segment OCT machine
- Combined anterior segment and posterior segment OCT machine.

Types of OCT machines are:

- Time domain OCT (TD-OCT)
- Frequency domain OCT (FD-OCT)
- Specially encoded frequency domain OCT (SEFD-OCT)
- Time encoded frequenc y domain OCT (TEFD-OCT).

Note: *For details see Chapters* 14 and 29.

BIBLIOGRAPHY

1. Keeney AH. Ocular examination: basis and techniques. 2nd ed. St. Louis: CV Mosby, 1976.
2. Newell FW. Ophthalmology: principles and concepts. 6th ed. St. Louis: CV Mosby, 1986.
3. Paton D, Goldberg MF. Injuries of the eye, the lids, and the orbit. Philadelphia: WB Saunders, 1968.
4. Robinett DA, Kahn JH. The physical examination of the eye. Emerg Med ClinNorth Am. 2008 Feb;26(1):1–16.
5. Scheie HG, Albert DM. Textbook of ophthalmology. 9th ed. Philadelphia: WB Saunders, 1977:169–98.
6. Stein HA, Slatt BJ. Ophthalmic assistant. 4th ed. St. Louis: CV Mosby. 1982.
7. Vaughan D, Asbury T. General ophthalmology. 11th ed. Los Altos: Appleton and Lange, 1986.

CHAPTER

2

Evaluation of Visual Acuity, Contrast Sensitivity, and Colour Vision

Chapter Outline

VISUAL ACUITY

GENERAL CONSIDERATIONS

The vision or visual perception is a complex integration of light sense, form sense, contrast sense and colour sense. ***Visual acuity*** is considered a measure of form sense, so it refers to the spatial limit of visual discrimination. Technically speaking, visual acuity measurement involves the determination of a threshold. In terms of visual angle, the visual acuity is defined as the reciprocal of the minimum resolvable visual angle measured in minutes of arc for a standard test pattern. Therefore, to understand visual acuity, the knowledge about visual angle is essential.

VISUAL ANGLE

Visual angle is the angle subtended at the nodal point of the eye by the physical dimensions of an object in the visual field (Fig. 2.1). Visual angle is a useful and convenient mode of specifying the spatial extent of objects or elements in the visual field.

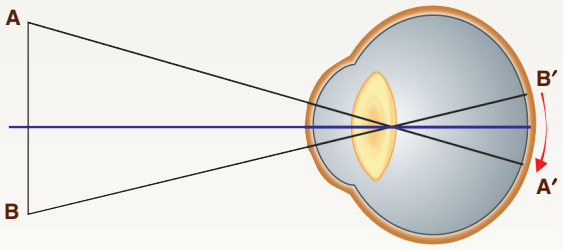


Fig. 2.1: *Visual angle (ANB) subtended at the nodal point by the physical dimensions (AB) of the object.*

It has been observed that the two adjacent points can be seen clearly and discretely only when these two points (say A and B in Fig. 2.1) produce a visual angle not less than 1 minute. The dimensions of the visual angle depend upon the size of the object as well as its distance from the eye. Therefore, to be seen clearly either the object should be large enough or it should be placed near the eye (at an appropriate distance). In terms of the length of the retinal image, it has been seen that the two points (A and B) will be seen clearly when their image size (A'B') is more than 4.5 μ. This is so, because the diameter of individual cone stimulated by the image points A' and B' is 1.5 μ each and at least one cone in between (of 1.5 μ diameter) must be unstimulated. The retinal image size for a given visual angle may vary slightly with changes in viewing distance and associated changes in accommodation of the lens, but this effect is relatively small.

COMPONENTS OF VISUAL ACUITY

In clinical practice, measurement of the threshold of discrimination of two spatially separated targets (a function of the fovea centralis) is termed visual acuity. However, in theory, visual acuity is a highly complex function that consists of the following components:

- Minimum visible,
- Resolution,
- Recognition, and
- Minimum discriminable.

MINIMUM VISIBLE

The ability to determine whether or not an object is present in an otherwise empty visual field is termed *visibility* or *detection.* This kind of task is referred to as the *minimum visible* or *minimum detectable.*

RESOLUTION (ORDINARY VISUAL ACUITY)

Discrimination of two spatially separated targets is termed resolution. The minimum separation between the two points, which can be discriminated, is known as *minimum resolvable.* Measurement of the threshold of discrimination is essentially an assessment of the function of the fovea centralis and is termed *ordinary visual acuity.* The distance between the two targets is specified by the angle subtended at the nodal point of the eye. The normal angular threshold of discrimination for resolution measures approximately 30–60 seconds of an arc; it is usually called the minimum angle of resolution (MAR). The clinical tests determining visual acuity measure the form sense or reading ability of the eye. Thus, broadly, resolution refers to the ability to identify the spatial characteristics of a test figure. The test targets in these tests may either consist of letters (Snellen's chart) or broken circles (Landolt's ring). More complex targets include gratings and checkerboard patterns.

RECOGNITION

It is that faculty by virtue of which an individual not only discriminates the spatial characteristics of the test pattern but also identifies the patterns with which one has had some experience. Recognition is thus a task involving cognitive components in addition to spatial resolution. For recognition, the individual should be familiar with the set of test figures employed in addition to being able to resolve them. The most common example of recognition phenomenon is identification of faces. An average adult can recognize thousands of faces.

MINIMUM DISCRIMINABLE OR HYPERACUITY

Minimum discriminable refers to spatial distinction by an observer when the threshold is much lower than the ordinary acuity. The best example of minimum discriminable is *vernier acuity*, which refers to the ability to determine whether or not two parallel and straight lines are aligned in the frontal plane. The threshold values of vernier acuity (Fig. 2.2) are in the range of only a few seconds (2–10) of arc. Hyperacuity should not be confused with the threshold for the minimum visible, where merely the presence or absence of a target is being judged. The mechanism subserving hyperacuity is not clearly known, but so much is clear; no contradiction is involved with the optical and receptor mosaic factors that limit ordinary visual acuity.

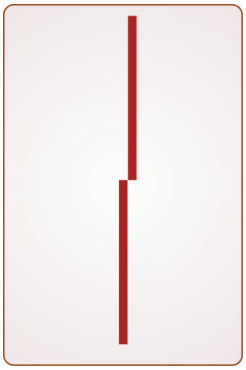


Fig. 2.2: *Typical target configuration for detecting vernier acuity.*

MEASUREMENT OF VISUAL ACUITY

As discussed earlier, the visual acuity is a highly complex function that consists of:

- *Minimum visible*, i.e. detection of presence or absence of stimulus,
- *Minimum separable*, i.e. judgement of location of a visual target relative to another element of the same target, and
- *Minimum resolvable* (ordinary visual acuity), i.e. the ability to distinguish between more than one identifying feature in a visible target.

In clinical practice, the measurement of visual acuity is considered synonymous with the measurement of 'minimum resolvable'. (However, in theory, it is not so, as is clear from the above.) The threshold of the minimum resolvable is between 30 seconds and 1 minute of arc. Therefore, all the clinical tests employed to measure the visual acuity are designed taking into consideration the threshold of the one minimum resolvable. Based on this basic principle, many visual acuity charts have been developed.

MILESTONES IN DEVELOPMENT OF VISION

Before discussing the various methods of visual assessment in infants, children, and adults, it will be worthwhile to have a quick look on the visual development. Important milestones in development of vision are summarized in Table 2.1.

TESTS FOR VISUAL ACUITY ASSESSMENT

Various visual acuity tests available can be grouped as follows:

I. *Detection acuity tests.* These assess the ability to *detect* the smallest stimulus without recognizing correctly. Common detection acuity tests are:

1. Dot visual acuity test
2. Catford drum test
3. Boek candy bead test
4. STYCAR graded ball's test
5. Schwarting metronome test

II. *Recognition acuity tests.* These are designed to assess the ability to recognize the stimulus or to distinguish it from other competing stimuli. These include:

A. *Direction identification tests*

1. Snellen's E-chart test
2. Landolt's C-chart test
3. Sjögren's hand test
4. Arrows test

B. *Letter-identification tests*

1. Snellen's letter chart test
2. Sheridan's letter test
3. Flook's symbol test
4. Lipman's HOTV test

C. *Picture identification charts (miniature toy test)*

1. Allen's picture cards test
2. Beale Collins picture charts test
3. Domino cards test
4. Lighthouse test
5. Miniature toy test of Sheridan

D. *Tests based on picture identification on behavioural pattern*

1. Cardiff acuity cards test
2. Bailey Hall cereal test

III. *Resolution acuity tests*

1. Optokinetic nystagmus (OKN) test
2. Preferential looking test (PLT)
   i. Two-alternative forced choice test
   ii. Operant variation looking test
   iii. Teller acuity cards test
3. Visually evoked response (VER)

Table 2.1 *Milestones in the development of vision*

Age	*Visual milestone*	*Visual acuity*
Newborn	• Pupillary reaction to light • Blinking to light stimulus • Conjugate horizontal gaze developed	6/360 to 6/120 (by OKN)
1 week	• Vestibulo-ocular reflex	
2 weeks	• Small saccades develop • Follows horizontal moving objects	
1 month	• Fixation developing • Can watch mother's face for prolonged time	6/480–6/120 (by PL tests)
2 months	• Bifoveal fixation • Large saccades • Pursuits and convergence movements • Conjugate vertical gaze developed	6/120–6/60
3 months	• Watches movements of own hands and reaches out towards interesting objects • Prefers photographs to patterns	
4 months	• Foveal differentiation complete • Sensory fusion and accommodation begins to develops	6/120–6/30
5 months	• Blink response to visible threat (menace response) • Grasps and explores objects • Stereopsis begins to develop	6/90–6/24 6/12–6/6 (by VER)
6 months	• Accommodation well-developed • Fusionalvergence well-developed	6/90–6/24 6/12–6/6 (by VER)
9 months	• Visual differentiation of objects • Picks up small objects	6/48–6/12 6/6 (by VER) 18
18 months	• Visual acuity at adult levels on paediatric acuity card • Myelination of optic nerve completed	6/18–6/7.5
2–3 years	• Best visual acuity approaches near adult levels, but may not be 6/6 • Can play picture or letter recognition games • Can respond to some binocular vision tests • Contrast sensitivity well-developed	6/12–6/6 (36 months)
5 years	• Stereopsis fully developed	6/6–6/5
8–10 years	• Critical period of monocular deprivation ends	6/6–6/5

Tests employed for visual acuity assessment at various age groups are summarized in Table 2.2.

MEASUREMENT OF VISUAL ACUITY IN INFANTS

ASSESSMENT OF VISUAL ACUITY FROM BIRTH TO 3 MONTHS

At birth,visual acuity is 1/60 which improves very fast to 2/60 at 1 month and 6/60 at 4 months. With 1/60 vision, the child is able to fix a face moving within one metre. The fixation reflex and following reflexes take about 6–8 weeks to develop before which an infant may fix for a few seconds and give up. There are a few bizarre movements which appear till the development of definite fixation reflex. Neonates have sporadic jerky movements made up of saccadic eye movements without smooth pursuit. So, visual acuity in a newborn and infant up to 3 months of age can be determined by the tests given below:

1. Blink reflex test. Blink reflex is present since birth (after 30 weeks of gestational age). It is

Table 2.2 *Commonly used visual assessment tests at various age groups*

Age	*Tests for assessment of vision*	*Type of visual acuity*
Birth–3 months	• Blink reflex • Pupillary light reflex • Vestibulo-ocular reflex test • Eye popping test • OKN • VER	Resolution acuity
3–6 months	• Fixation and following of objects or small toys • CSM (central, steady and maintained) fixation • Response to occlusion • OKN • VER	Resolution acuity
6–12 months	• Preferential looking tests (Teller acuity tests) • Catford drum test	Resolution acuity Detection acuity
1–3 years	• Cardiff acuity tests • Marble game test • TYCAR ball test • E game test • Boeck candy test	Resolution + Recognition acuity Detection acuity
3 –5 years	• Broken wheel test • Landolt C test • Isolated hand figure test • Pictorial vision chart tests • Tumbling E test • HOTV test • Snellen's numbers • Snellen's letters	Recognition acuity
Above 5 years	• Snellen's numbers • Snellen's letters chart • LogMAR chart	Recognition acuity

occasionally present in decorticate infants as well. When bright light is shown, a normal infant should respond by blinking.

2. Pupillary light reflex test. Presence of pupillary light reflex indicates intact afferent visual neurologic pathways to the level of the brachium of the superior colliculus and efferent pathways to the iris sphincter. This reflex is present in premature babies over 29–31 weeks of gestational age. *This is most reliable test to determine presence of vision except in cortical blindness.* The test is best performed in a semi-darkened room because the infant's pupils are smaller than that of a normal adult and constrict in the presence of bright light in the room. In the semi-dark room, the pupil comes to a state of semi-dilatation that reacts briskly. The light used should be small, well-focused and bright. Visualization in very young children sometimes requires a magnifying glass, as their pupils are smaller than those of the older children (because of decreased sympathetic tone) and the light responses are of small amplitude.

3. Vestibulo-ocular reflex. The vestibulo-ocular reflex (VOR) is generally tested by turning the newborn's head on his/her long axis and observing for the doll's eyes response (the eyes deviate opposite to the direction of head rotation).

4. Eye popping test. Another behaviour that is unique to babies is *eye popping*. Sometimes, for a variety of reasons, very young infants do not show any distinguishable visual behaviour at all. In this case, the eye popping reflex indicates at least the baby's ability to detect changes in the room illumination. When the room lights are suddenly dimmed, the baby's upper eyelids should pop open wide for a moment. The baby will often close its eyes when the lights are brought up back, but will again pop its eyes open when the lights are dimmed. This behaviour is documented as 'positive eye popping'.

5. Optokinetic nystagmus (OKN) test. It is an objective method of visual assessment in infants and uncooperative children as well as adults. In this test, nystagmus is elicited by passing a succession of black and white stripes by means of OKN drum of the size 10 × 8 inches diameter, which is rotated at 8–10 rpm through the patient's field of vision (Fig. 2.3). Eyes respond with a slow movement in the direction of drum lasting about 0.2 sec and fast phase in the reverse direction of 0.1 sec. The visual angle subtended by the smallest strip width that still elicits an eye movement (minimum separable) is a measure of visual acuity. The only cooperation required in this test is that the infant be awake and should hold both eyes open. It is reported that OKN acuity is at least 6/120 in the newborns and improves fairly rapidly during the first few months of life, reaching to a level of 6/60 at 2 months, 6/30 at 6 months and 6/6 by 20–30 months. OKN is asymmetric in newborns and becomes symmetric by 4–6 months of age.

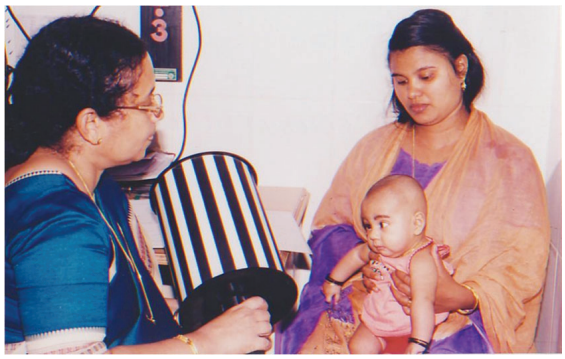


Fig. 2.3: *Optokinetic nystagmus test for visual acuity (Courtesy: Dr Elizabeth Joseph).*

6. Visual evoked response (VER). It refers to electroencephalographic (EEG) recording made from the occipital lobe in response to visual stimuli. VER is the only clinically objective technique available to assess the functional state of the visual system beyond the retinal ganglion cells. It is quite useful in assessing visual function in infants. It reflects acquity from the central retina and thus forms a good macular function test.

Flash VER is usually preformed in very young children or those incapable of fixing on a target. It just tells about the integrity of the macular and visual pathway.

Pattern reversal VER is recorded using some patterned stimulus, as in the checkerboard (Fig. 2.4). In it, the pattern of stimulus is changed (e.g. black squares go white and white become black), but the overall illumination remains the same. The pattern reversal VER depends on form sense and thus gives a rough estimate of the visual acuity. VER studies have shown visual acuity in infants to be 6/120 at the age of 1 month, which reaches to 6/60 at 2 months and 6/6–6/12 at the age of 6 months to 1 year.

Drawbacks of VER include:

- Expensive
- Time consuming
- Limited availability
- Not standardized
- Little clinical relevance

Note: The discrepancy between estimated visual acuity values with optokinetic nystagmus, preferential looking test and visually evoked response at 6 months of age must be kept in mind while performing these tests (Table 2.3).

ASSESSMENT OF VISUAL ACUITY FROM 3 TO 6 MONTHS

Since the fixation develops to moving objects by 3–4 months of age, the visual acuity in this age group can be assessed, in addition to the above mentioned tests, the help of following tests based on fixation behaviour of the infant.

1. Fixation behaviour test. Ability of the child to fix and follow the face of the examiner, toys or interesting object. The test is done first with both eyes open followed by monocular testing by

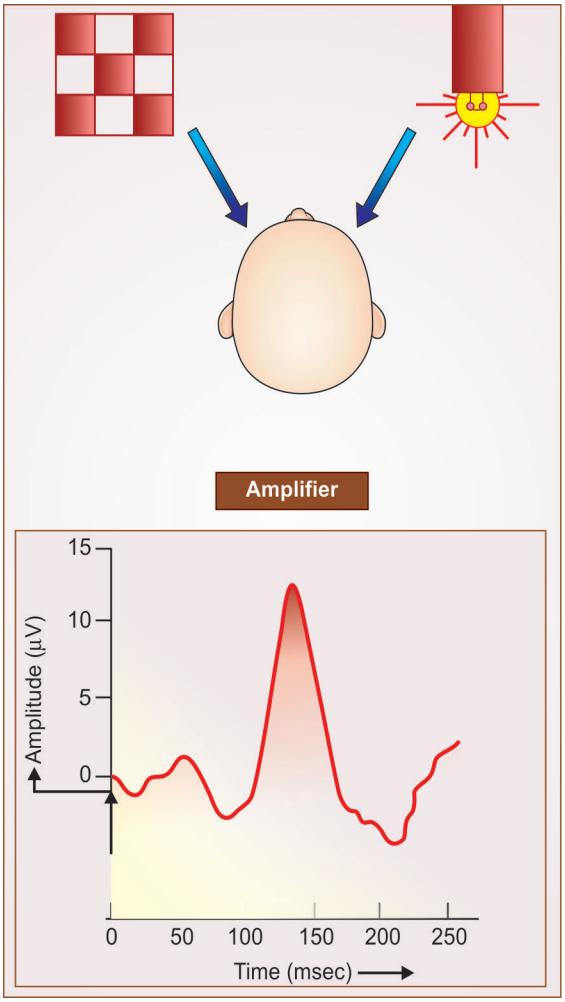


Fig. 2.4: *Technique of recording visually evoked response (VER) and record of normal VER pattern.*

occluding the other eye by hand. If the child habitually fixates with one eye, it indicates poor vision in the non-fixating eye and hence he or she will violently resist occlusion of the better eye.

2. Central, steady, maintained (CSM) method. CSM method is a useful test in this age groups. It implies:

- *Central.* The infant is asked to fixate on penlight and then the examiner looks at the corneal light reflex from a fixation light which is falling at the centre of the pupil. The reflex is considered central, if it falls in the same location in both the eyes in monocular condition.
- *Steady.* This is tested with a small target (thumb-sized toy) which is coupled with light held in front of the child and moved slowly. Nystagmus or oscillation results in unsteady fixation.
- *Maintained.* The ability to keep the eye fixed when either eye is covered.

Results of this test can be interpreted as below:

- CSM: 6/9 to 6/6
- CSNM: 6/36 to 6/60
- Unsteady central fixation: <6/60

3. Brückner's red reflex test. Brückner's reflex is helpful in children uncooperative to the cover test when an assessment is being carried out for small angle strabismus. In this test, fixation and binocular comparison of the red reflex is done. The examiner should stay far enough to illuminate both pupils by the same direct ophthalmoscope beam. The examination should be carried out in dim illumination and the child's attention to be fixed at a distance. Assess the red reflex both before and after dilatation to see how much of the pupillary space is obscured. An overall whitening of the red reflex across the entire pupil of one eye indicates strabismus or anisometropic amblyopia. While the absence of a Brückner reflex is not a good indication of alignment, the presence of a Brückner reflex is considered a positive result, and is a good indication of strabismus, even of small amounts.

4. Menace reflex test. Menace reflex, i.e. reflex closure of the eyes on the approach of an object, is usually present after the age of 5 months, if vision is normal.

Table 2.3 *Estimated visual acuity at different ages*

Age (months)	*Optokinetic nystagmus*	*Preferential looking test*	*Visually evoked response*
1	6/120	6/120	6/120
2	6/60	6/60	6/60
6	6/30	6/30	6/6–6/12
Age (months) at which 6/6 is achieved	20–30	24–36	6–12

5. Cover test. By 3–6 months, infants have adequate refixation reflex to permit cover test. This test is needed, if there is a concern about strabismus. In patients with normal vision, both eyes look at an object at the same time. Therefore, if one eye is occluded, the opposite eye should not move. In patients with strabismus, one eye is deviated. If the straight eye is covered, the other eye will make a movement to line up the visual target. If a patient is exotropic, the eye will make an inward movement. If an eye is esotropic, it will make an outward movement.

ASSESSMENT OF VISUAL ACUITY FROM 6 TO 12 MONTHS

In addition to the above mentioned tests, the tests described below are more useful in 6–12 months age group.

1. Preferential looking test (PLT). This test is based on the observation that when presented with two adjacent stimulus fields, one of which is striped and the other is homogeneous, the infant will tend to look at the striped pattern for a greater portion of the time. Test procedures have been developed in which an examiner is hidden behind a screen on which one projects a homogeneous surface on one side and black and white stripes on the other side. These two stimuli are alternated randomly. The observer is able to look at the eyes of the infant through a hole in the screen but is unaware of which target, stripes or homogeneous field is presented on which side of the screen.

Teller acuity cards (TAC) test. This is the most commonly used preferential looking test in clinical practice. TAC is recommended to test visual acuity in infants from 1 month to 1 year of age. This test is modification of preferential looking test. This is simple to perform and very reliable and efficient test. The testing distance varies with age of the child, like the test being performed at 36 cm in infants and toddlers, at 54 cm in children up to 3 years and at 84 cm in adults. Estimates of visual acuity, using the TAC grating targets, show a rapid increase in acuity during the first six months of life from 1.0 cycle per degree at one month of age to five cycles per degree by six months of age, then a gradual increase to 40 cycles per degree. Adult like levels are reached at 5 years of age. The results are obtained in *cycles* which can be converted to *Snellen's equivalent*. There are 17 cards, on one half of each card is a set of vertical black-and-white bars of varying size which form the pattern stimulus and on the other half, a uniform gray background which is the blank target (Fig. 2.5). In the centre of each card, there is a small hole through which the examiner observes the infant's fixation. In this by varying the spatial frequency of the bars shown, the finest bar which can no longer be resolved by the infant is used to determine the vision as the infant no longer shows the preference for patterned stimulus. This test can be used effectively on neurologically impaired children.

Visual acuity determined with this method has been reported to range from approximately 6/240 in the newborns to 6/60 at 3 months and 6/6 at 36 months of age. It must be well understood that grating acuity testing cannot automatically be equated with acuity testing based on recognition task, such as naming pictures or Snellen's letters. In normal children, grating acuity is better than recognition acuity. Further, it has been suggested that different neural processing mechanisms in the brain are involved with spatial discrimination and recognition tasks. Hence, it is not advisable to equate grating acuity with recognition acuity (Snellen's).

Limitations. TAC are relatively expensive and less cost effective. Therefore budget versions of FPL acuity testing have emerged in the form of spatial frequency paddles.

2. Catford drum test. It is a *detection acuity test*, useful in infants and children less than 2 years

Fig. 2.5: *Teller acuity cards test (a type of preferential looking test).*

Fig. 2.6: *Catford drum for visual acuity.*

of age. In this test, the child is made to observe an oscillating drum with black dots of varying sizes ranging from 0.5 to 15 mm in diameter representing vision between 6/6 and 2/60 (Fig. 2.6). Rotation of disc at a distance of 60 cm evokes pendular movements. The smallest dot that evokes pendular eye movements (not an OKN) denotes the level of visual acuity. This test is unreliable since it overestimates the vision.

ASSESSMENT OF VISUAL ACUITY FROM 1 TO 3 YEARS

Above 1 year of age, the child is able to visually differentiate the small objects and is able to reach out for toys. So, in addition to the above-mentioned tests, the following detection acuity tests are more useful in this age group.

1. *Cardiff acuity cards test*. Cardiff acuity cards test or vanishing optotypes test (Fig. 2.7) is used to measure visual acuity in this age group. The principle is that as long as the child can see the optotype (line drawings of pictures of fish, car, etc.), the child will show a preference for the picture as compared with the plain grey background. The black and white lines forming the pictures become finer with each set of three cards, until the picture cannot be seen (vanishing optotype) and the preference for fixation to the picture is lost. The pictures are presented on cards with the optotype appearing either on the top or the bottom of the card. The rest of the card is a homogeneous grey that matches with the mean luminance of the picture. A total of 11 sets of cards are available, with acuity values ranging from 20/400 to 20/20, which have been calibrated for two presentation distances—0.5 m and 1 m. The patient is presented with one sets of cards at a particular acuity equivalence, one card at a time. By observing the child's eye movements and fixations, the examiner must decide if the optotype is on the top or bottom of the card.

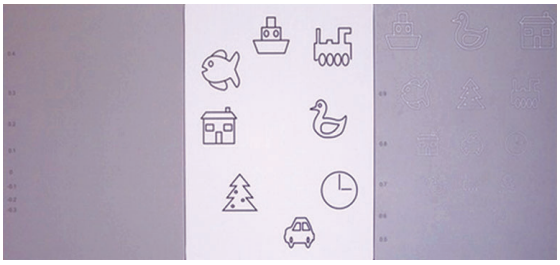


Fig. 2.7: *Cardiff acuity cards test.*

The acuity is determined by the narrowest white band for which the target is visible to the child and correct response is obtained at least 75% of the time when the particular finest line drawing is shown to the child.

Advantages include:

- It is an excellent way to determine minimum separable acuity in a child 1–3 years of age, unless the child can respond to recognition acuity chart.
- The fixations of the child to the pictures on the Cardiff cards are relatively easy to assess.
- CAC is a child friendly test.

Limitations include:

- May miss some cases of visually significant refractive errors.
- TAC is more dependable test to assess amblyogenic conditions despite the use of gratings.

1. *Marble game test.* In children of 6–12 months of age, reaching or placing games can be used to estimate visual function. One such game is the 'marble game'. In it, the child is asked to place marbles in the holes of a card or in a box. This test is not intended to measure visual acuity

of each eye, but rather to compare the functioning of the child's eye when one or the other is closed. The vision of an eye is then noted as being 'useful' or 'less useful'.

2. ***Sheridan's ball test.*** Mary Sheridan (1960) used a series of styrofoam balls of progressively smaller sizes. One records the smallest ball that the infant can fixate and follow at a distance of 10 feet. Rolling the ball on a white or grey background and asking the child to pick it up, and noting the smallest size to which the child gives a good response is a rough way of estimating visual acuity.

3. ***Worth's ivory ball test.*** Ivory balls ranging in size from 0.5 to 2.5 inches in diameter are rolled on the floor in front of the child who is asked to retrieve each ball. Acuity is estimated on the basis of smallest size of the ball for the test distance.

4. ***Dot visual acuity test.*** Child is shown an illuminated box with black dots of different sizes printed on it. The smallest dot identified denotes the visual acuity of the child.

5. ***Coin test.*** In this test, the child is asked to identify the two faces of coins of different sizes held at different distances.

6. ***Miniature toy test.*** In this test, the child is shown a miniature toy from a distance of 10 ft and is asked to name or pick the pair from the assortment.

MEASUREMENT OF VISUAL ACUITY IN PRESCHOOL CHILDREN (3–5 YEARS)

At this age, the child is able to verbalize and recognize well, so in addition to the above mentioned test, the following tests (based mainly on recognition acuity) are more useful for visual assessment.

1. ***Landolt C test.*** This test attempts to test minimum separable acuity in young children who can understand the concept of break in the circle. Landolt Cs are presented with the opening of the optotype at 3, 6, 9 or 12 o'clock. The child has to tell where the opening is. The separation at the break in the C represents 1 minute of arc and the entire C subtends 5 minutes of arc at the eye for 20/20. (For further details *see* page 42).

2. ***Broken wheel test.*** This test is another subjective assessment of visual acuity in toddlers and preschoolers who are not able to perform matching tasks. A pair of cars in progressively smaller sizes, one of which has a wheel cut across, like Landolt C (broken wheel), is shown to the child and the child is asked to identify the one with the broken wheel (Fig. 2.8).

The car represents on seven pairs of cards designed to use at 10 feet, providing Snellen's equivalents from 20/20 to 20/100 (shown in Fig. 2.8) presented in a forced choice paradigm without the need for verbal responses. The visual acuity tester holds up one pair of cards at a time and asks the child to point towards the car with the broken wheels. The child should correctly score four out of four responses and then, the next smaller set of cards is used until the child can no longer consistently identify the car with broken wheels.

Advantages include:

- The child has to simply locate the broken wheel and need not to identify the direction of the opening.
- The broken wheel and Snellen tests are highly correlated and that acuities measured with this test is equivalent to Snellen chart with a certainty of 94%, if using four-of-four criterion.

3. ***Illiterate E-cutout test***. This test is useful in children between 2½ and 3 years of age. The child is given a cutout of an E and asked to match this E with isolated Es of varying sizes. The first trial is not always successful. The mother may

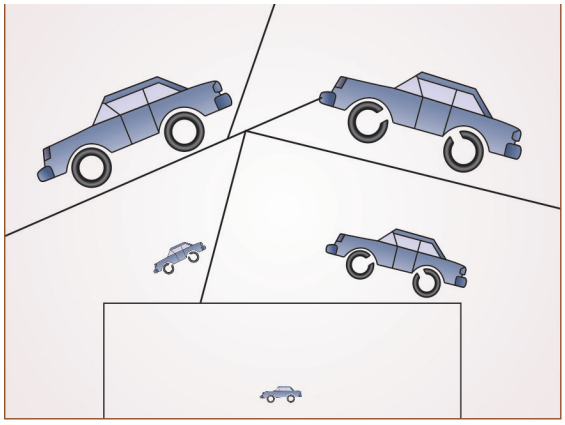


Fig. 2.8: *Broken wheel test.*

Fig. 2.9: *Tumbling E-pad test. Printed with large 20/200 E on one side and a series of five 20/20 tumbling Es on the other—calibrated to a 20 feet distance.*

be instructed to teach E-game at home. When the child starts understanding the orientation of E, a visual acuity chart consisting of Es oriented in various directions may be used.

4. *Tumbling E-pad test.* It consists of different sizes of E in one of the four positions (right, left, upward and downward) on a dice (Fig. 2.9). Basically, it is similar to E-cutout test.

5. *Isolated hand-figure test*. Sjögren has replaced the E with the isolated figure of a hand, and in some children it works better than Es.

6. *Sheridan–Gardiner HOTV test* is another test similar to E-cutout test (Fig. 2.10). This is an initiative test, used to test vision in the age group of 2–5 years. The child is handed a card with HOTV and is asked to match the letters on the chart. Snellen's equivalent of 6/6–6/60 can be estimated using this method.

7. *Pictorial vision charts*. When the child is able to verbalize, visual acuity chart showing pictures, rather than symbols, may be used. Many such charts have been devised, and one should be chosen that presents pictures of objects with which the child is likely to be familiar. Pictorial vision charts include Kay picture test, Allen cards test, Lae symbols test and BUST.

- *Allen cards test* (Fig. 2.11). In this test, seven optotypes are presented to the child for recognition at a test distance of 15 feet (20/40) at 3 years of age and 20 feet (20/30) at 4 years of age.
- *Kay pictures* (Fig. 2.12) is another picture optotype developed to assess visual acuity in

Fig. 2.10: *Sheridan–Gardiner single letter optotypes.*

Fig. 2.11: *Allen cards test.*

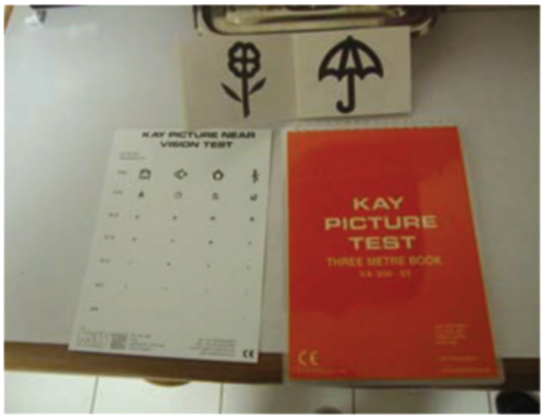


Fig. 2.12: *Kay picture test.*

young children at distance as well as at near. The figures are child friendly with matching cards for children who cannot speak. The individual elements subtend a visual angle of 1 minute of arc and the total figure subtends 10 minutes of arc at the eye. The available test booklets are for 6 m and 3 m distance. The 3 m booklet used for younger children who will not be attentive at 6 m. Near point cards are also available to assess near visual acuity.

- *Lea symbols test* (Fig. 2.13) was developed by Dr Lea Hyvärinen, a Finnish paediatric ophthalmologist, who developed a vast array of testing devices that have been standardized using four pictures—circle, square, house and apple. Lea numbers were developed in 1993 and calibrated in 1994. These optotypes can be presented as single characters, as a wall chart at a distance of 10 to 20 feet. They can be presented on a video display terminal screen or in the form of a flip book. With the Landolt C type being the reference optotype since 1988, earlier to which Snellen E chart was the reference optotype, the size of the 1.0 (20/20,6/6) optotypes was reduced from 7.5 to 6.84 minutes of arc.

  Lea symbols now have two important basic features of good optotypes that they blur equally and are calibrated against the Landolt C. This is a good way of testing individuals who do not use the western alphabet. Hence, it eliminates the problem with language barriers.
- *BUST is* another picture test designed to test visual acuity of children with vision impairment and developmental handicaps. BUST is an acronym for the Swedish words for 'visual acuity and picture perception test'. The range of visual acuity for distance acuity measurement values goes from 0.02 to 1.6 (20/1000 to 20/10).

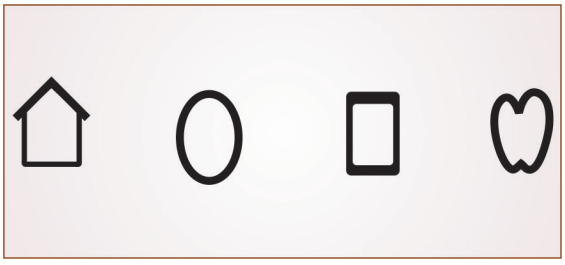


Fig. 2.13: *Lea symbols test.*

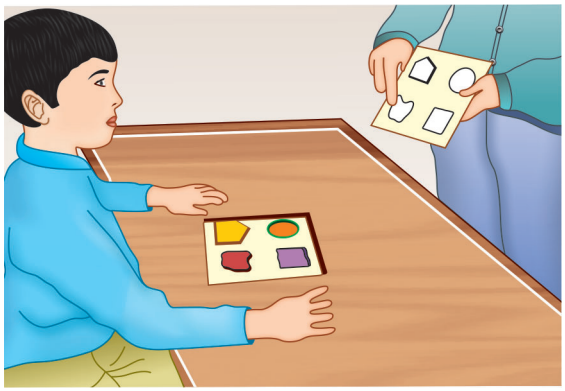


Fig. 2.14: *Light home picture cards.*

7. *Boek candy bead test.* The child is asked to match beads at 40 cm. Snellen's visual acuity equivalent of 20/200 is estimated by this method.

8. *Light home picture cards.* A chart containing an apple, a house and an umbrella (Fig. 2.14), arranged in Snellen's equivalents of 20/200–20/10 is used, and the child is asked to identify the pictures along the lines. The test is carried out at 10 feet.

MEASUREMENT OF VISUAL ACUITY IN SCHOOL CHILDREN (ABOVE 5 YEARS) AND ADULTS

- *Snellen's visual acuity charts* are most commonly employed in this age group. Illiterates E charts and Landolt's C charts are used as alternative to Snellen's test types.
- *LogMAR charts* enable a more accurate estimate of acuity as compared to other charts. Because of high accuracy, these are the most commonly used charts in research settings/clinical trials.

1. Snellen's test types

The distant central visual acuity is usually tested by Snellen's test types. The fact that two distant points can be visible as separate only when they subtend an angle of 1 minute at the nodal point of the eye forms the basis of Snellen's test types. It consists of a series of black capital letters on a white board, arranged in lines, each progressively diminishing in size. The lines comprising the

letters have such a breadth that they will subtend an angle of 1 minute at the nodal point. Each letter of the chart is so designed that it fits in a square, the sides of which are five times the breadth of the constituent lines. Thus at the given distance, each letter subtends an angle of 5 minutes at the nodal point of the eye (Fig. 2.15). The letter of the top line of Snellen's chart (Fig. 2.16) should be read clearly at a distance of 60 m. Similarly, the letters in the subsequent lines should be read from a distance of 36, 24, 18, 12, 9, 6, 5 and 4 m.

Landolt's test types. It is similar to Snellen's test types except that in it instead of the letter the broken circles are used. Each broken ring subtends an angle of 5 minutes at the nodal point and is constructed similar to letter of Snellen's test types (Fig. 2.17).

With Snellen's letters, the end point consists of letter recognition; with Landolt's rings, it consists of the detection of the orientation of the break in the circle. Each method has advantages and disadvantages. Letter targets represent a practical visual test. However, the ability to recognize the target is influenced by literacy and past experience, even if the targets are somewhat blurred. Landolt's rings were designed to eliminate these factors and present a more objective test. However, since the gap can be placed in only four positions (up, down, left and right), guessing becomes an important factor. Also letter tests remain much less confusing for the patient and the examiner, since the identification of letters is both immediate and unequivocal.

Procedure of testing. For testing distant visual acuity, the patient is seated at a distance of 6 m from the Snellen's chart, so that the rays of light are practically parallel and the patient exerts minimal accommodation. The chart should be properly illuminated (not less than 20 foot-candle). The patient is asked to read the chart with each eye separately and the visual acuity is recorded as a fraction, the numerator being the distance of the patient from the letters and

Fig. 2.16: *Snellen's test types.*

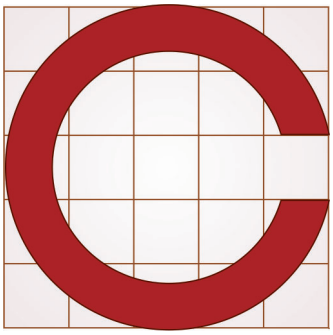


Fig. 2.17: *Construction of Landolt's visual acuity target.*

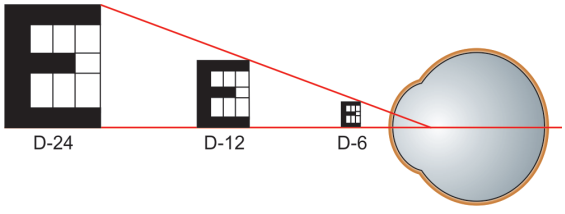


Fig. 2.15: *Principle of Snellen's test types.*

the denominator being the smallest letters accurately read.

When the patient is able to read up to 6 m line, the visual acuity is recorded as 6/6, which is normal. Similarly, depending upon the smallest line that the patient can read from the distance of 6 m, his or her vision is recorded as 6/9, 6/12, 6/18, 6/24, 6/36 and 6/60. If one cannot see the top line from 6 m, he or she is asked to slowly walk towards the chart till one can read the top line. Depending upon the distance at which one can read the top line, the vision is recorded as 5/60, 4/60, 3/60, 2/60 and 1/60.

If the patient is unable to read the top line even from 1 m, he or she is asked to count fingers (CF) of the examiner. His or her vision is recorded as CF-39, CF-29, CF-19 or CF close to face, depending upon the distance at which the patient is able to count fingers. When the patient fails to count fingers, the examiner moves his or her hand close to the patient's face. If one can appreciate the hand movements (HM), visual acuity is recorded as HM positive. When the patient cannot distinguish the hand movements, the examiner notes whether the patient can perceive light (PL) or not. If yes, vision is recorded as PL positive and if not it is recorded as PL negative.

2. LogMAR visual acuity charts

LogMAR stands for **Log**arithm of the **M**inimum **A**ngle of **R**esolution. A LogMAR chart comprises rows of letters and has equal number of letters in each line (Fig 2.18). It is used at a distance of 4 meters. It is designed to enable a more accurate estimate of acuity as compared to other charts (e.g. the Snellen chart), for this reason, it is recommended in research settings.

Fig. 2.18: *LogMAR visual acuity chart.*

An observer who can resolve details as small as 1 minute of visual angle scores LogMAR 0, since the base-10 logarithm of 1 is 0; an observer who can resolve details as small as 2 minutes of visual angle (i.e. reduced acuity) scores LogMAR 0.3, since the base-10 logarithm of 2 is 0.3; and so on.

Visual acuity equivalents in different notations

Table 2.4 indicates different ways for specifying visual acuity levels, viz. Minimal angle of resolution (MAR), Snellen's acuity, efficiency rating, Snellen's fraction (that is the reciprocal of the MAR) and the logarithm of Snellen's fraction.

MEASUREMENT OF VISUAL ACUITY FOR NEAR

Near vision is tested by asking the patient to read a near vision chart which consists of a series of different sizes of 'printer types' arranged in decreasing order and marked accordingly.

Near vision charts

Commonly used near-vision charts are as follows:

1. ***Jaeger's chart.*** Jaeger, in 1867, devised the near vision chart that consisted of the ordinary printers' fonts of varying sizes used at that time. Printers' fonts have changed considerably since then; however, it is now a general custom to use various sizes of modern fonts that approximate Jaeger's original choice. In this chart, prints are marked from 1 to 7 and accordingly patient's acuity is labelled as J1–J7, depending upon the print one can read.

2. ***Roman test types.*** The Jaeger's charts made from the modern fonts deviate considerably from the original standard, but they are probably sufficiently accurate for all practical purposes. However, to overcome this theoretical problem, the Faculty of Ophthalmologists of Great Britain in 1952 devised another near vision chart. It consists of 'Times Roman' type fonts with standard spacing (Fig. 2.19). According to

Table 2.4 *Visual acuity equivalents in different notations*

MAR or minimum angle of resolution (minutes of arc)	*Snellen's visual acuity*		*Snell-Sterling visual efficiency (%)*	*Loss of central vision (%)*	*Snellen's fraction acuity relative 20/20*	*LogMAR acuity relative to*
	ft	*m*				
0.5	20/10	6/3	109	0	2.0	0.3
0.75	20/15	6/4.5	104	0	1.33	0.1
1.00	20/20	6/6	100	0	1.0	0
1.25	20/25	6/7.5	96	4	0.8	–0.1
1.5	20/30	6/9	91	9	0.67	–0.18
2.0	20/40	6/12	84	16	0.5	–0.3
2.5	20/50	6/15	76	24	0.4	–0.4
3.0	20/60	6/18	70	30	0.33	–0.5
4.0	20/80	6/24	58	40	0.25	–0.6
5.0	20/100	6/30	49	50	0.2	–0.7
6.0	20/120	6/36	41	60	0.17	–0.78
7.5	20/150	6/45	31	70	0.133	–0.88
10.0	20/200	6/60	20	80	0.10	–1.0
20.0	20/400	6/120	3	90	0.05	–1.3

this chart, the near vision is recorded as N5, N6, N8, N10, N12, N18, N36 and N48.

3. ***Snellen's near vision test types.*** Snellen introduced the so-called 'Snellen's equivalent for near vision' on the same principles as his distant types. The graded thickness of the letters of different lines is about 1/17th of the distant vision chart letters. In this event, the letters equivalent to 6/6 line subtend an angle of 5 minutes at an average reading distance (35 cm/14 inch).

The unusual configuration of letters of this chart, however, cannot be constructed from the available printers' fonts. It can only be reproduced by a photographic reduction of the standard Snellen's distant vision test types to approximately 1/17th of their normal size. Further, such a test has never become popular. The graded sizes of pleasing types of passages from literature, the reading of which helps in the interpretation, are habitually employed.

4. ***Lea near vision cards.*** This test assesses a child's functional vision at near distances. It can also be used to familiarize child with testing procedure before introducing a distance test. It consists of cards measuring 8" × 10" (20.3 × 25.4 cm) which contain proportionally spaced (logMAR) lines on one side and more tightly-spaced symbols on the opposite side. Line sizes range from 20/400 to 20/10 (6/120 to 6/3) equivalent, 0.05 to 2.00. Response key is printed on test card. Testing distance is about 16 inches/40 cm.

Procedure of testing

For testing the near vision, the patient is seated in a chair and asked to read the near vision chart kept at a distance of 25–35 cm, with a good illumination thrown over his or her left shoulder. Each eye should be tested separately. The near vision is recorded as the smallest type that can be read comfortably by the patient. A note of the approximate distance at which the near vision chart is held should also be made. Thus near vision (NV) is recorded as:

- NV 5 J_1 at 30 cm (in Jaeger's notation)
- NV 5 N_5 at 30 cm (in Faculty's notation)

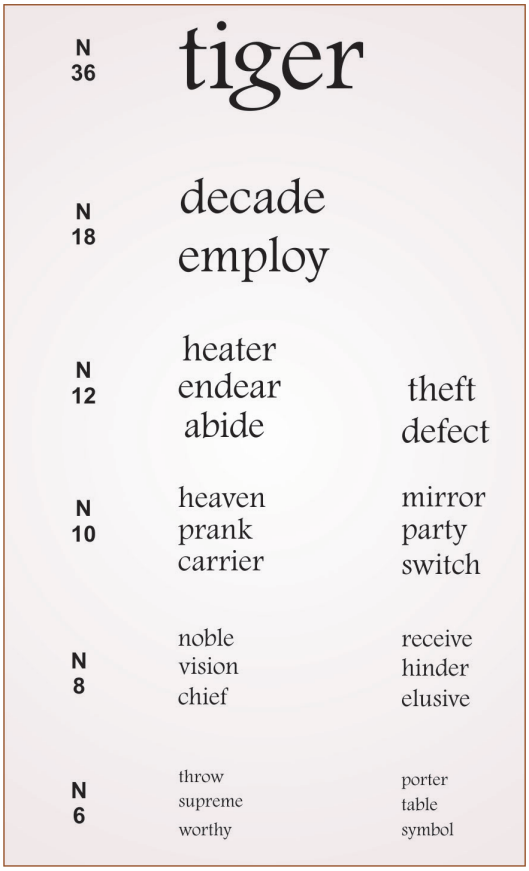


Fig. 2.19: *Near vision chart.*

Near vision equivalents in different notations

These are shown in Table 2.5.

CONTRAST SENSITIVITY

INTRODUCTION

Contrast sensitivity is the ability to perceive slight changes in luminance between regions that are not separated by definite borders and is just as important as the ability to perceive sharp outlines of relatively small objects. It is only the latter ability that is tested by means of the Snellen's test types. In many diseases, loss of contrast sensitivity is more important and disturbing for the patient than is the loss of visual acuity. Further, contrast sensitivity may be impaired even in the presence of normal visual acuity.

TYPES OF CONTRAST SENSITIVITY

1. Spatial contrast sensitivity

Spatial contrast sensitivity refers to detection of striped patterns at various levels of contrast and spatial frequencies. In its measurement, patient is presented with sine wave gratings of parallel light and dark bands (Arden gratings) and is asked to tell the minimum contrast at which the bars can be seen at each frequency. The width of the bars is defined as spatial frequency which expresses the number of pairs of dark and light bars subtending an angle of 18 at the eye. A high spatial frequency implies narrow bars, whereas a low spatial frequency indicates wide bars.

Table 2.5 *Equivalent visual acuity notations for near*

Visual angle (minutes)	*Snellen equivalent*	*American Medical Association notation*	*Decimal notation*	*Jaeger notation*	*Faculty's Roman test types notation*	*Metre notation (m)*	*Central visual efficiency for near (%)*	*Vision loss (%)*
5.00	20/20	14/14	1.00	J1	N5	0.37	100	0
6.25	20/25	14/17	0.80	J1	N6	0.43	100	0
7.50	20/30	14/21	0.66	J2	N8	0.50	95	5
10.00	20/40	14/28	0.50	J4	N10	0.75	90	10
12.50	20/50	14/35	0.40	J6	N12	0.87	50	50
15.00	20/60	14/42	0.33	J8	N14	1.00	40	60
20.00	20/80	14/56	0.25	J10	N18	1.50	20	80
25.00	20/100	14/70	0.20	J1	N24	1.75	15	85
50.00	20/200	14/140	0.10	J17	N36	3.50	2	98

2. Temporal contrast sensitivity

Here the contrast sensitivity function is generated for time-related (temporal) processing in the visual system by presenting a uniform target field modulated sinusoidal in time, rather than as a function of spatial position.

Both temporal and spatial contrast sensitivity testing yield significantly more complete and systematic data on the status of visual performance than the conventional tests.

MEASUREMENT OF CONTRAST SENSITIVITY

When a subject is presented with the grating frequencies and contrast below which resolution is impossible, it indicates the threshold level; and the reciprocal of this contrast threshold gives the contrast sensitivity.

Contrast sensitivity is measured as $(L_{max}$ 2 $L_{min})/(L_{max}$ 1 $L_{min})$, where L is the luminance recorded by photocells scanning across the gratings.

VARIABLES IN THE MEASUREMENT

There are three variables in the measurement of contrast sensitivity:

1. *Average amount of light reflected* depends on illumination of paper and darkness of ink.
2. *Degree of blackness* in relation to the white background, i.e. contrast.
3. *Distance between the grating periods* or cycles per degree of visual angle.

METHODS OF MEASUREMENT

Various methods have been developed to measure contrast sensitivity. Bodis-Wollner, introducing contrast sensitivity measurement in clinical practice, suggested the name *visuogram*, analogue to an *audiogram*, to describe a patient's 'contrast sensitivity curve'. The deficits were expressed in terms of decibels, and three types of deficits were described:

1. *High-frequency type* characterized by increasing loss at high frequency.
2. *A level-loss type* characterized by a similar loss for all spatial frequencies.
3. *A selective-loss type* characterized by deficits of spatial frequencies in a narrow band.

In general, the methods recommended to measure contrast sensitivity include: simple plates, cathode ray tube display on a screen, letter acuity charts, laser interferometer (LI) which produces grating on the retina, visual field testing using low contrast rings on stimuli, pattern discrimination test, prototype for forced choice printed test, visually evoked cortical potentials to checkerboard pattern reversal dependent contrast threshold measurement, two-alternative forced choice test and many more.

Some of the simple, inexpensive but reliable methods of measuring contrast sensitivity are described in brief in the following text.

1. Arden gratings. Arden, in 1978, introduced a booklet containing seven plates: one *screening plate* (No. 1) and six *diagnostic plates* (No. 2–7). The contrast changes from top to bottom and covers a range of approximately 1.76 log units. The plates are studied at 57 cm, with spatial frequency increasing from 0.2 cycles/degree to 6.4 cycles/degree, each being double the frequency of the previous one. A score of 1–20 is assigned to each plate, depending upon the amount of plate uncovered. Sum of six plates with an upper limit of 82 was established for normal subjects together with an interocular difference of less than 12.

2. Cambridge low-contrast gratings. Cambridge low-contrast gratings consist of a *set of ten plates* containing gratings in a spiral bound booklet. To perform the test, the booklet is hung on a wall at a distance of 6 m. The pages are presented in pairs, one above the other. One page in each pair contains gratings and the other is blank (Fig. 2.20), but the pages have the same mean reflectance. The subject is simply required to choose which page, top or bottom, contains the gratings. The pages are shown in order of descending contrast and are stopped when the first error is made. Four descending series are shown separately to each eye. When no error is made at plate 10, then a score of 11 is given. Depending upon the total score of the patient from four series, the contrast sensitivity is noted from the conversion table (Fig. 2.21).

Fig. 2.20: *Cambridge low-contrast gratings.*

CAMBRIDGE LOW CONTRAST GRATINGS
SCORE SHEET

Patient's Name ..... Date of Birth .....
Record Number..... Date of testing .....
Examined by .....

Summary of procedure

1. Test each eye separately.
2. Show demonstration pages and instruct patient to choose which page ("top" or "bottom") contains the stripes.
3. Show subsequent pairs of pages in numerical order.
4. Encourage patient to respond, guessing if necessary.
5. Stop when the first error occurs (or at No. 10).
6. Note number on which error occurred in the table below; enter 11 if no errors.
7. Go back four plates from where you stopped (or to demonstration).
8. Repeat steps 3–7 until four series have been completed.
9. Add the four scores together and enter total in table below.
10. Convert total score to contrast sensitivity using conversion table.
11. Repeat steps 3–10 for the other eye, beginning the first series with stimulus No. 1.

Left eye Error on :	Right eye Error on :
Series 1	Series 1
Series 2	Series 2
Series 3	Series 3
Series 4	Series 4
Total	Total

Contrast Sensitivity

Conversion table

Total score	Contrast sensitivity
4	10
5	13
6	16
7	20
8	24
9	28
10	33
11	37
12	43
13	49
14	55
15	62
16	70
17	78
18	88
19	99
20	110
21	120
22	130
23	140
24	150
25	170
26	180
27	190
28	210
29	230
30	250
31	270
32	290
33	310
34	340
35	370
36	400
37	440
38	480
39	520
40	560

Percentile limits of normal performance on the published version of the Cambridge Low Contrast Gratings

Age range	90th percentile	95th percentile	97.5th percentile
10–19	24	22	20
20–29	29	27	28
30–39	29	28	27
40–49	28	25	24
50–59	21	18	18
60–80	24	23	22

Total scores lower than those tabulated may be considered abnormal, i.e. poorer than those expected from 90, 95 and 97.5% of the normal population.

Fig. 2.21: *Cambridge low-contrast gratings score sheet and conversion table.*

3. Pelli-Robson contrast sensitivity chart. This chart consists of letters that subtend an angle of 38 at a distance of 1 m. The chart is printed on both the sides. The two sides have different letter sequence but are otherwise identical. The letters on chart are organized as triplets, there being two triplets in each line (Fig. 2.22A). The contrast decreases from one triplet to the next. The log contrast sensitivity varies from 0.00 to 2.25.

To perform the test, the chart is hung on the wall, so that its centre is approximately at the level of the subject's eye. The chart is illuminated as uniformly as possible, so that the luminance of the white areas is between the acceptable range of 60 and 120 cd/m, which corresponds

0.00	H	S	Z	D	S	N	0.15
0.30	C	K	R	Z	V	R	0.45
0.60	N	D	C	O	S	K	0.75
0.90	O	Z	K	V	H	Z	1.05
1.20	N	H	O	N	R	D	1.35
1.50	V	R	C	O	V	H	1.65
1.80	C	D	S	N	D	C	1.95
B 2.10	K	V	Z	O	H	R	2.25

Fig. 2.22: *Pelli-Robson contrast sensitivity chart. (A) Photograph; (B) Log contrast sensitivity score of each triplet.*

Fig. 2.23: *Measurement of contrast sensitivity with Pelli-Robson chart.*

to a photographic exposure between 1/15 and 1/30 second at f/5.6 with an ASA of 100. The luminance is determined with the help of a light meter.

While recording, the subject sits directly in front of the chart at a distance of 1 m (with the best distance correction) (Fig. 2.23). The subject is made to name or outline each letter on the chart, starting from the upper left corner and reading horizontally across the line. Subject is made to guess, even when he or she believes that the letters are invisible. The test is concluded when the subject guesses two of the three letters of the triplet incorrectly. The subject's sensitivity is indicated by the finest triplet for which two of the three letters are named correctly.

4. The Vistech chart. This chart consists of sine wave gratings and is used at a distance of 3 m from the subject. In this test, contrast is assessed at several spatial frequencies (distance of the separation of the grating bars) and the subject has to identify the orientation of the grating, i.e. whether vertical or 158 clockwise, or anti-clockwise.

5. Vector vision chart. Vector vision CSV 1000 (USA) chart test frequency of 3,6,12 and 18 cpd.

6. Fact CS chart. The fact CS chart tests for 1.5, 3, 6, 12 and 18 cpd.

TESTS FOR COLOUR VISION

It is useful to group these tests into several different categories based on design. Pseudoisochromatic plates, arrangement tests, anomaloscopes, and lanterns represent the most widely used designs. Different tests are appropriate for different circumstances (Table 2.6).

PLATE TESTS

J. Stilling first introduced pseudoisochromatic designs in 1873. Today, they are the most commonly used screening tests for colour deficiency in clinical practice. These tests are inexpensive, durable, and readily available. Most tests provide very efficient (90–95%) screening of congenital red-green defects. On the other hand, the tests have distinct limitations. They must be administered under the standard viewing conditions for which they were designed. They are not effective in grading the severity of the colour defect and thus tell us limited information about the extent or type of deficiency. In short, plate tests are best used as screening tools.

Plate tests come in several forms; however, the principle of construction is the same. Ishihara test is the prototype of this category. The test consists of a series of cards on which a figure is printed in multiple colours against a multicoloured back-

Table 2.6 *Categories of colour vision tests*

Test type	*Function*	*Example*
Screening tests	Quick diagnosis	Pseudoisochromatic plates, e.g. Ishihara test
Grading tests	Assess severity of the defect	FM 100-hue test
Diagnostic tests	Precisely classify a defect	Anomaloscope
Vocational tests	Simulate environment encountered on the job	Lantern test

ground (Fig. 2.24). The figure is recognizable to normal trichromats, but camouaged to those with colour defects. The figure used in the test is usually an easily identifiable number, letter, or shape. Figures and background are drawn in dots. The size of the dots used in plate design can be varied or uniform; however, the only difference between the figure and the background is the colour. Saturation and lightness are accounted for, such that detection of the figure in ways other than hue is unlikely.

Ishihara test

The Ishihara test is published in a full 38-plate edition, an abridged 24-plate edition and a 14-plate edition for quick screening. Scoring instructions for the Ishihara plates accompany each test. In the 38-plate edition, for example, a normal score permits four or fewer errors. In the 24-plate edition, two errors or less are considered normal. The 16-plate edition also puts two errors or less in the normal range. It does not matter which edition is used because the fail criterion is three or five errors and total number of errors has no diagnostic significance. The Ishihara can be used in children as young as 5 years. The colour differences between the figure and the background are chosen to separate normal trichromats from mild anomalous trichromats. If the differences in colour are too large, anomalous trichromats will be able to identify the hidden figure. Small differences may cause normal trichromats to fail some screening plates.

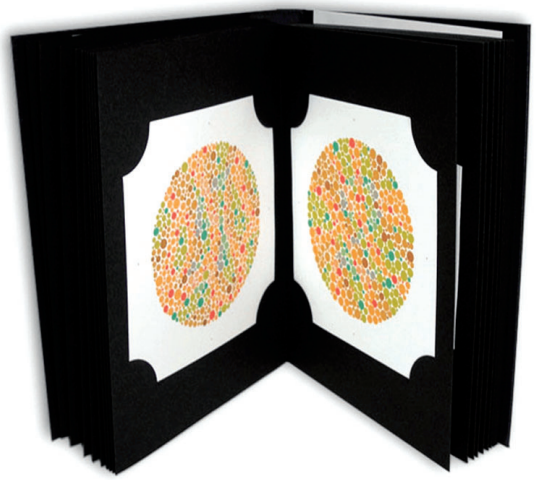


Fig. 2.24: *Ishihara's pseudoisochromatic plates.*

How to test colour vision by Ishihara chart

- Room should be adequately lit by daylight.
- Nature of the test should be explained to the patient.
- Full refractive correction is worn.
- It is preferable to do the test before pupillary dilatation.
- One eye is first occluded and the other eye is tested.
- The plates are kept at a distance of 75 cm from the subject with the plane of the paper at right angle to the line of vision.
- The standard time taken to answer each plate is 3–5 seconds.

Interpretation of Ishihara chart test

Interpretation of Ishihara chart, consisting of 25 plates, is summarised in Table 2.7.

ARRANGEMENT TESTS

Modern arrangement tests were first put into popular use in the 1940s and 1950s by Dean Farnsworth. Farnsworth originally designed the Farnsworth-Munsell 100-hue test (FM 100-hue test) and the Farnsworth Dichotomous test for colour blindness (Farnsworth Panel D-15). The principle of design for these tests is coloured caps of fixed chroma and value selected from the hue circle. The patient is asked to arrange randomly placed caps in what he/she perceives to be a natural order. The colour differences between adjacent caps on the FM 100-hue test were designed to be very small. Good colour vision as well as chromatic discrimination ability is needed to perform well on this test. Farnsworth Panel D-15 was designed to have larger colour differences, but, unlike the FM 100-hue test, only one box containing 15 caps is presented to the patient.

ANOMALOSCOPES

An anomaloscope is an instrument that uses the principle of colour matching to test colour vision. It serves as a clinical standard for

Table 2.7 *Intepertation of Ishihara chart test*

Plate number	*Normal*	*Points with redgreen defects*		*Inference*
1	12	12		Both subjects with normal and defective colour vision read plate 1 as 12.
2	8	3		
3	6	5		
4	29	17		Subjects with red-green defects read these plates as those in abnormal column. Totally colour blind are unable to read.
5	57	35		
6	5	2		
7	3	5		
8	15	17		Majority of subjects with colour vision deficiency read these plates incorrectly
9	74	21		
10	2	X		
11	6	X		Subjects with normal colour vision do not see any number. Those with redgreen deficiency read the numbers given in the abnnormal column
12	97	X		
13	45	X		
14	5	X		
15	7	X		Subjects with protanopia read these plates as given in abnormal column (1), those with deutranomaly read them as given in column (2).
16	16	X		
17	73	X		
18	X	5		
19	X	2		
20	X	45		
21	X	73		
		Protan	Deutran	
22	26	6	2	
23	42	2	4	
24	35	5	3	
25	96	6	9	

diagnosing and classifying congenital colour deficiency. The use and maintenance of an anomaloscope can be challenging and requires the expertise of a trained technician. For this reason, anomaloscopes are not used as frequently as other clinical tests.

The Nagel (model I) anomaloscope is the most common and accurate of these and uses the Rayleigh equation to diagnose red-green colour vision defects. The subject views a circular field through a telescopic barrel. This field is divided into two parts, each of which is filled with light of different spectral wavelengths. The lower half of the field is filled with spectral yellow at 589 nm. According to the Rayleigh match, the subject should be able to match the 'colour' of the upper to the lower field by adjusting the mixture of red and green light. The luminance knob is particularly useful in distinguishing deutan from protan defects. The subject is asked to comment on whether the upper and lower fields are the same colour. Normal and dichromatic individuals will accept this as a normal or near-normal match. Deuter-anomalous trichromats will state that the upper field is too red and protanomalous trichromats will state that the upper field is too green. Scoring of an anomaloscope examination begins by recording the values at which a match was made.

LANTERN TESTS

Lantern tests are simple devices geared towards measuring a subject's competency to perform a specific task, namely recognize coloured light signals. Lanterns are used in the

maritime, air, and railway industries to screen employees. The subject is asked to name the colours of the light signals that are presented to him. Two types of lanterns exist: those that present single colours and those that present pairs of lights together. The speed and sequence of colour presentation is important to the efficacy of the test. Individuals with defective colour vision make characteristic mistakes in naming the colours presented to them; how ever, most lantern tests are not meant to screen or categorize colour defectives for clinical purposes.

BIBLIOGRAPHY

1. Alpern M. Accommodation. In Davson H (Ed): The Eye, Vol 3. Muscular Mechanisms. New York, Academic Press, 1962, pp 191–229.
2. Arden GB, Jacobson JJ. A simple grating test for contrast sensitivity. Preliminary results indicate value in screening for glaucoma. Invest Ophthalmol Visual Sci 1978;17:23–32.
3. Arden GB. Testing contrast sensitivity in clinical practice. Clin Vis Sci 1988;2(3):213–24.
4. Arden GB. Visual loss in patients with normal visual acuity. Trans Ophthalmol Soc UK 1978; 98:219–23.
5. Arundale K. An investigation into variation of contrast sensitivity with age and ocular pathology. Br J Ophthalmol 1978;62:213–5.
6. Bahrick HP, Bahrick PO, Wittlinger RP. Fifty years of memory for names and faces: a cross-sectional approach. J Exp Psychol Gen 1975;104: 54–75.
7. Barlett NR. Thresholds as dependent on some energy relations and characteristics of the subject. In: Graham CH(ed). Vision and Visual Perception. New York, Wiley, 1965, pp 154–84.
8. Berlyne DE. The influence of the albedo and complexity of stimuli on visual functions in the human infant. Bt J Psychol 1958;49–315.
9. Bodis Wollner L. Visual acuity and contrast sensitivity in patients with cerebral lesions. Science 1972;178:769–71.
10. Brown JL, Black JE. Critical duration for resolution of acuity targets. Vision Res 1976;16: 309–15.
11. Brown JL, Mueller CG. Brightness discrimination and brightness contrast. In: Graham CH (Ed). Vision and Visual Perception. Wiley, New York, 1965, pp 208–50.
12. Butler T, Westheimer G. Interference with stereoscopic acuity: spatial, temporal and disparity tuning, Vision Res 1978;18:1387.
13. Campbell FW, Green DG. Optical and retinal factors affecting visual acuity. J Physiol 1965; 181:576–93.
14. Campbell FW, Robson JG. Application of Fourier analysis to the visibility of gratings. J Physiol 1968;197:551–6.
15. Dala Sala S, Bertoni G, Somazzi L. Impaired contrast sensitivity in diabetic patients with and without retinopathy. A new technique for rapid assessment. Br J Ophthalmol 1985;69: 136–42.
16. Ditchburn RW, Ginsborg BL. Vision with a stabilised retinal image, Nature 1952;170:36–37.
17. Dobson V, Teller D. Visual acuity in human infants: a review and comparison of behavioral and electro-physiological sutdies, Vision Res 1978;18:1469.
18. Dobson V, Teller D, Lee CP, Wade B. A behavioral method for efficient screening of visual acuity in young infants. I. Preliminary laboratory development. Invest. Ophthalmol Vis Sci 1978; 17:1142.
19. Drum B, et al. Pattern discrimination perimetry. A new concept in visual field testing. Doc Ophthalmol Proc Ser 1987;49:433.
20. Emsley HH. Irregular astigmatism of the eye. Effect of correcting lenses, Trans Opt Soc Lond 1925;27:28.
21. Fantz R. Pattern vision in young infants, Psychol, Rec 1958;8:43.
22. Flom MC, Weymouth FW, Kahneman D. Visual resolution and contour interaction. J Opt Soc Am 1963;53:1026.
23. Hartridge H. The visual perception of fine detail. Philos Trans R Soc Lond (Biol Sci) 1947;232; 519–671.
24. Hecht S, Mintz EV. The visibility of single lines at various illuminations and the retinal basis of visual resolution. J Gen Physiol 1939;22: 593–612.
25. Hecht S, Ross S, Mueller CG. The visibility of lines and squares at high brightnesses. J Opt Soc Am 1947;37:500–7.
26. Hecht S. Vision. II. The nature of the photoreceptor process. In: Murchison C (Ed). A Handbook of General Experimental Psychology, Worcester MA, Clark University Press, 1934; 704–828.
27. Howe JW, Mitchell KW, Mahabateswara M, Abdel-Katek MN. Visual evoked potential

latency and contrast sensitivity in patients with posterior chamber intraocular lens implants, Br J Ophthalmol 1986;70:890–4.
28. Hoyt CS, Nickel BL, Billson FA. Ophthalmological examination of the infant: developmental aspect, Surv Ophthalmol 1982;26:177.
29. L Schade O. Optical and photoelectric analogue of eye. J Opt Soc Am 1956;46:721–39.
30. Leibowitz H: The effect of pupil size on visual acuity for photometrically equated test fields at various levels of luminance, J Opt Soc Am 1952; 42:416.
31. Lempert P, Hopcroft M, Lempert Y. Evaluation of posterior subcapsular cataracts with spatial contrast acuity. Ophthalmology 1987;94(S): 14–8.
32. Lythgoe RJ. The measurement of visual acuity. Med Res Council Sp Rep Ser, No. 173, 1932.
33. Marg E, Freeman DN, Peltzman P, Goldstein P. Visual acuity development in human infants: evoked potential measurements. Invest. Ophthalmol 1976;15:150.
34. Mayer L, Fulton A, Rodier D. Grating and recognition acuities of pediatric patients, Ophthalmology 1984;91:947.
35. Pelli DG, Robson JG, Wilkin AJ. The design of a new letter chart for measuring contrast sensitivity. Clin Vis Sci 1988;2(3):187–99.
36. Pirenne MH, Marriott FHC, O'Doherty EF. Individual differences in night-vision efficiency. Med Res Council Sp Rep Ser, No 294, 1957.
37. Regan D, Neima D. Low contrast letter charts as a test of visual function. Ophthalmology 1983;90:1192.
38. Riggs LA, Ratliff F, Cornsweet JC, Cornsweet EF. The disappearance of steadily fixated visual test objects. F. opt. Soc. Amer. 1953;43,495–501.
39. Riggs LA. Visual acuity. In Graham CH (Ed). Vision and Visual Perception. New York, Wiley, 1965, pp 321–49.
40. Rodieck RW. The Vertebrate Retina. San Francisco, WH Freeman and Co, 1973.
41. Shlaer S. The relation between visual acuity and illumination. J Gen Physiol 21:165–88, 1937.
42. Skalka WH. Effect of age on Arden grating acuity. Br J Ophthalmol 1980;84:21–3.
43. Sokol S. Measurement of infant visual acuity from pattern reversal evoked potentials, Vision Res. 1978;18:33.
44. Teller DY, Movshon JA. Visual development, Vision Res. 1986;26:1483.
45. Teller DY. The forced choice preferential looking procedure. A psychophysical technique for use with human infants, infant Behav Dev 1979; 2:135.
46. Tomlinson E, Martinez D. The measurement of visual acuity: comparison of Teller acuity cards with Snellen and MBL results, Am. Orthopt. J. 1988;38:130.
47. Vaegan F, Halliday BL. A forced choice test improves clinical constrast sensitivity testing. Br J Ophthalmol 1982;66:477–91.
48. Weale RA. The Aging Eye. London, Leis, 1963.
49. Westheimer G, Hauske G. Temporal and spatial interference with vernier acuity, Vision Res. 1975;15:1137.
50. Westheimer G, McKee SP. Visual acuity in the presence of retinal-image motion, J Opt Soc Am 65:847, 1975.
51. Wilcox WW, Purdy DM. Visual acuity and its physiological basis. Br J Psychol 1933;23: 233–61.
52. Wilkins AJ, Delia SS, Somazzi L, Smith N. Age related norms for the Cambridge low contrast gratings, including details concerning their design and use. Clin Vision Sci 1988;2(3): 201–12.
53. Wolf E, Gardiner JS. Studies on the scatter of light in the dioptic media of the eye as a basis of visual glare. Arch Ophthalmol 1965;74: 338–45.
54. Woodson WE. Human Engineering Guide for Equipment Designs. Los Angeles, University of California Press, 1954.
55. Wulfing EA. Uber den Kleinsten Gesichts-winkel. Z Biol 1892;29:199.
56. Yamazaki H, Adachi-Usami E, Chiba J. Contrast thresholds of diabetic patients determined by VECP and psychophysical measurements. Acta Ophthalmol 1982;60:386–92.

CHAPTER

3

Slit-lamp Biomicroscopy

Chapter Outline

INTRODUCTION

Slit-lamp is the most important piece of equipment in the present day ophthalmologist's armamentarium. Modern slit-lamp with its auxiliary devices not only provides magnified views of every part of the eye from cornea to retina, but also allows quantitative measurements (intraocular pressure, endothelial cell counts, pupil size, corneal thickness, anterior chamber depth, etc.) and photography of every part for documentation.

The term slit-lamp is basically a misnomer, since slit is only one of the various other diaphragmatic openings present in the instrument. Therefore, Mawas in 1925 introduced the term *biomicroscopy* and defined it as examination of the living eye by means of a corneal microscope and a slit-lamp.

HISTORICAL LANDMARKS IN THE DEVELOPMENT AND EVOLUTION OF SLIT-LAMP

These can be summarized as:

- *Purkinje,* in 1823, attempted to develop a type of slit-lamp by using one hand-held lamp to magnify an another hand-held lens to focus strong oblique illumination. However, it was not until almost 100 years later that a version of the slit-lamp appeared that is recognizable today.
- *De Wecker*, in 1863, devised a portable *ophthalmomicroscope* that combined a small monocular microscope which rested against the face of the patient with an attached condenser lens. It lacked stereoscopic view.
- *Albert* and *Greenough*, in 1891, developed a binocular microscope which provided stereoscopic view.

- *Czapski*, in 1897, modified the binocular corneal microscope, which is still found in many modern slit-lamps.
- *Gullstrand*, in 1911, introduced the illumination system which had for the first time a slit-diaphragm in it. Therefore, Gullstrand is credited with the invention of the slit-lamp.
- *Henker*, in 1916, developed the prototype of the modern biomicroscopy by combining the Gullstrand's slit-illumination system with the Czapski's binocular corneal microscope.
- *Hans Goldmann*, in 1933, improvised the biomicroscope in which all the vertical and horizontal adjustments for both the lamp and the slit-beam were placed on a single mechanical stage. The slit-lamp designed by Goldman was marketed in 1937 as the *Haag–Streit model 360 slit-lamp.*
- *Littmann*, in 1950, introduced the new optical principle for the biomicroscope. He incorporated the rotatory magnification changer based on the principle of Galilean telescope. The slit-lamp designed by Littmann is the forerunner of the current Zeiss slit-lamp series.
- *Modern slit-lamps* have achieved a very high degree of refinement.

PARTS OF A SLIT-LAMP

A slit-lamp (Fig. 3.1) is composed of three basic parts:

1. Observation system (microscope)
2. Illumination system
3. Mechanical support system

Fig. 3.1: *A slit-lamp.*

1. OBSERVATION SYSTEM (MICROSCOPE)

The observation system (Fig. 3.2) is essentially a compound microscope which is composed of two optical elements, an objective and an eyepiece. It presents to the observer an enlarged image of a near object. The slit-lamp microscope is designed to have a long working distance, i.e. the distance between the microscope's objective and the patient's eye.

- Objective lens consists of two planoconvex lenses with their convexities put together, providing a composite power of 122 D.
- Eyepiece has a lens of 110 D. To provide a good stereopsis, the tubes are converged at an angle of 10–15°.
- Prisms. To overcome the problem of inverted image produced by the compound

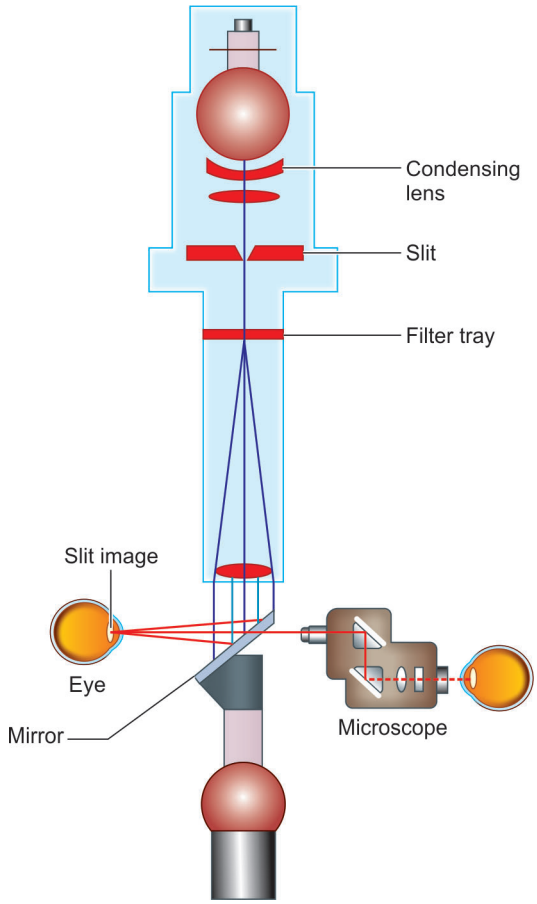


Fig. 3.2: *A cross-section of the observation system of a modern slit-lamp.*

microscope, slit-lamp microscope uses a pair of prisms between the objective and the eyepiece to reinvert the image (Fig. 3.2).

Magnification systems

Most slit-lamps provide a range of magnification from 6 to 40X. The modern slit-lamps use one of the following three systems to produce a range of magnification.

i. *Czapskiscope with rotating objectives.* This is one of the oldest and possibly still the most frequently used techniques for obtaining different magnifications. The different objectives are usually placed on a turret type of arrangement that allows them to be fairly rapidly changed during the examination.

The Haag–Streit model, the Bausch and Lomb and the Thorpe are the examples of the slit-lamps using this system.

ii. *The Littmann–Galilean telescope principle.* The Galilean magnification changer (G), as developed by Littmann (1950), is a completely separate optical system that sits neatly between the objective and eyepiece lenses and does not require either of them to change. It provides a large range of magnifications, typically five, via a turret arrangement which is completely enclosed within the microscope's body. It is called a Galilean system because it utilizes the Galilean telescopes to alter the magnification. Galilean telescopes have two optical components, a positive lens and a negative lens. It fits within the standard slit-lamp microscope along with a relay lens (R) and the prism erector (P) in the manner shown in Fig. 3.3.

The Zeiss, the Rodenstock and the American optical slit-lamps are the examples of slit-lamps using the Littmann–Galilean telescopic system.

iii. *Zoom system.* Some slit-lamps (e.g. Nikon photo slit-lamp and Zeiss-75 SL) have been produced with zoom system that allows a continuously variable degree of magnification. The Nikon slit-lamp contains the zoom system within the objective of the microscope and offers a range of magnification from 7 to 35X.

2. ILLUMINATION SYSTEM

The Gullstrand's illumination system is designed to provide a bright, evenly illuminated, finely focused adjustable slit of light at the eye. It comprises following components (Fig. 3.4):

i. *Light source.* Originally a Nernst lamp was used as a light source which was followed by Nitra lamp, arc lamp, mercury vapour lamp and finally halogen lamps. It provides an illumination of 2×10^5 to 4×10^5 lux.

ii. *Condenser lens system.* It consists of a couple of planoconvex lenses with their convex surfaces in apposition.

iii. *Slit and other diaphragms.* The height and width of the slit can be varied using two knobs provided for this purpose. In addition, there are some stenopaeic slits of 2.0 and 0.5 mm to provide conical beam of light.

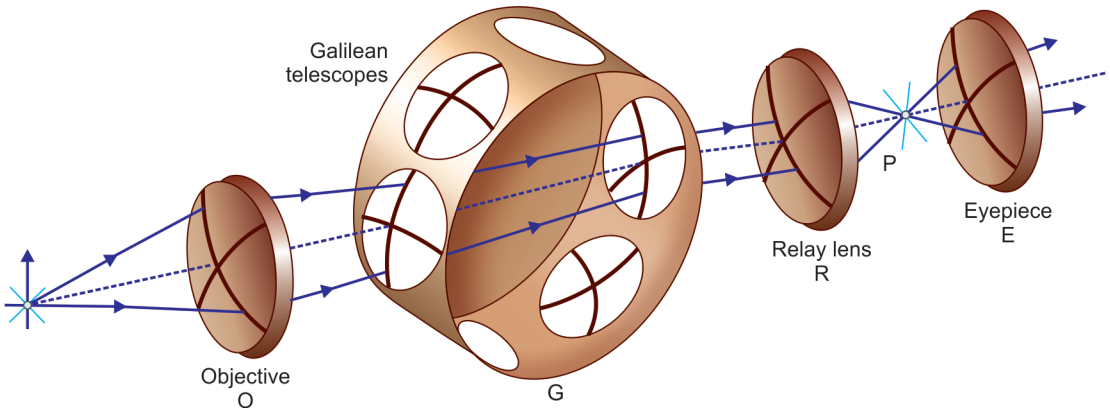


Fig. 3.3: *Galilean magnification changer (G) is placed between the slit-lamp objective (O) and the relay lens (R) which focuses the light through a prism erector (P) into the eyepiece (E).*

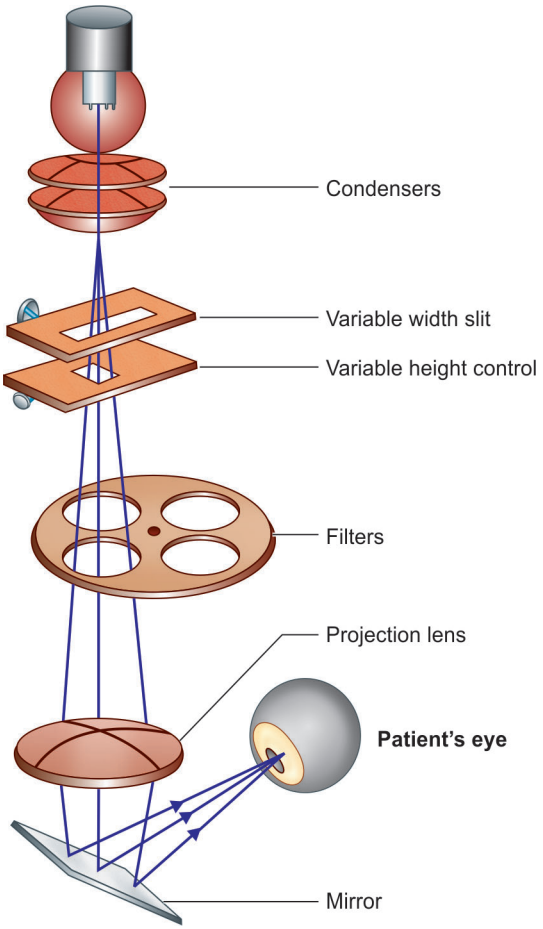


Fig. 3.4: *Typical slit-lamp illumination system.*

There is a facility to rotate the slit away from the vertical meridian and also the ability to tilt the projection system about a horizontal axis that is provided. These two additional degrees of freedom are included to assist in the examination of the fundus and the angle of anterior chamber.

iv. ***Filters.*** Different filters can be inserted into the illumination beam. Cobalt blue and red-free filters are provided in most of the models.

v. ***Projection lens.*** It forms an image of the slit at the eye. The diameter of the projection lens is usually fairly small. This has two advantages: first, it keeps the aberrations of the lens down, which results in a better quality image; second, it increases the depth of focus of the slit and thereby produces a better optical section of the eye.

vi. ***Reflecting mirror or prism.*** It forms the last component of the illumination system. The illumination system of a slit-lamp has to be able to pass relatively easily from one side of the microscope to the other. To allow this, the projection system is normally arranged along a vertical axis, with either a *mirror* or *prism* finally reflecting the light along a horizontal axis. The use of a narrow prism or mirror means that when necessary, such as in examination of the fundus, the illumination axis can be made to, without obstructing the field of view, almost coincide with the viewing axis.

Optics of the illumination system

The Koeller illumination system has been adopted in slit-lamps. Optically, it is identical to that of a 35 mm slide projection with the exception that a variable aperture slit takes the place of the slit and the projection lens has a much shorter focal length. In the Koeller illumination system, as shown in Fig. 3.4, the filament of the light source is imaged by the condenser lenses at or close to the projection lens which in turn forms the image of the slit in the patient's eye.

3. MECHANICAL SUPPORT SYSTEM

Although mechanical support system is least glamorous, a brief review of the instrument's history reveals that the optical principles upon which the modern slit-lamp is based have changed little over the years, whereas the ease of examination, characteristics of all modern slit-lamps, is due to the indigenous mechanical design.

Salient features of most of the mechanical support systems are as follows:

i. ***Joystick arrangement.*** Movement of the microscope and illumination system towards or away from the eye and from side to side is usually achieved via a joystick arrangement.

ii. ***Up and down movement arrangement.*** The up and down movement is obtained via some sort of screw device that moves the whole illumination and viewing system up and down relative to the chin rest.

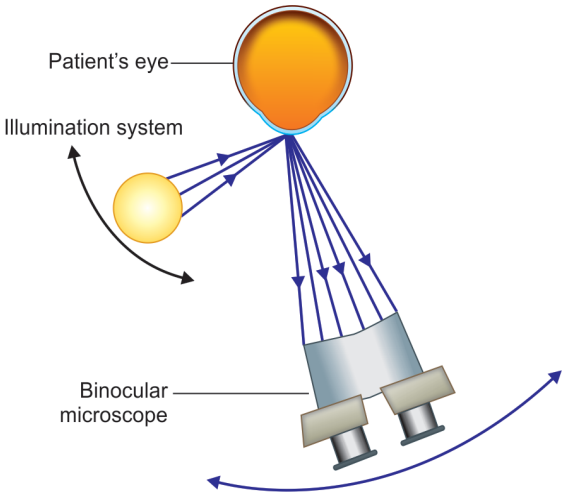


Fig. 3.5: *Mechanical coupling of the microscope and illumination system allows their focusing on the same point.*

iii. *Patient support arrangement.* A vertically movable chin rest and the provision to adjust the height of the table has been made to accommodate the persons of all sizes.

iv. *Fixation target.* A movable fixation target greatly facilitates the examination under some conditions.

v. *Mechanical coupling.* The mechanical system not only provides a support but also a coupling of the microscope and the illumination system along a common axis of rotation that coincides their focal planes. This arrangement ensures that light falls on the point where microscope is focused. It allows either the microscope or the illumination system to be rotated around this axis without changing the focus (Fig. 3.5).

The coupling of the microscope and illumination system in this way has advantages when using the slit-lamp for routine examination of the anterior segment of the eye. However, when certain accessories, such as gonioscope or the three-mirror fundus lens, are used, this can be a disadvantage, since the slit and the microscope optics frequently do not reach a common focal point under those conditions, leaving the observer with the choice of suffering under suboptimal images or refocusing the eyepieces.

TECHNIQUE OF BIOMICROSCOPY

SLIT-LAMP BIOMICROSCOPY ROUTINE

While performing slit-lamp biomicroscopy, following routine may be adopted:

1. ***Patient adjustment.*** The patient should be positioned comfortably in front of the slit-lamp with his or her chin resting on the chin rest and forehead opposed to head rest (*see* Fig. 3.1).

2. ***Instrument adjustment.*** The height of the table housing the slit-lamp should be adjusted according to patient's height. The microscope and illumination system should be aligned with the patient's eye to be examined. Fixation target should be placed at the required position.

3. ***Beginning slit-lamp examination.*** Some points to be kept in mind are:

i. Examination should be carried out in semidark room so that the examiner's eyes are partially dark-adapted to ensure sensitivity to low intensities of light.

ii. Diffuse illumination should be used for as short a time as necessary.

iii. There should be a minimum exposure of retina to light.

iv. Medications like ointments and anaesthetic eyedrops produce corneal surface disturbances which can be mistaken for pathology.

v. Low magnification should be first used to locate the pathology and higher magnification should then be used to examine it.

METHODS OF ILLUMINATION

Berliner described seven basic methods of illumination using the slit-lamp. A few guidelines for the set-up for each method of illumination are described briefly.

1. Diffuse illumination (Fig. 3.6)

The *set-up* is as given:

- Angle between microscope and illumination system should be 30–45°.
- Slit width should be widest.
- Filter to be used is diffusing filter.

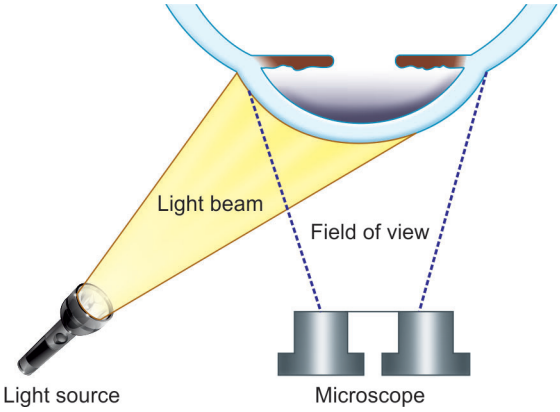


Fig. 3.6: *Set-up for diffuse illumination.*

- Magnification used is low to medium.
- Illumination should be medium to high.

Diffuse illumination is used for:

- General view of the anterior eye and the palpebral conjunctiva
- Contact lens fitting

2. Direct focal illumination. In this technique, the slit-beam is regulated until it coincides with the exact focus of the microscope (Fig. 3.7). Light is directed as a narrow slit at an oblique angle (30–45°). Heterogenous tissues like cornea and lens disperse light and become visible as bright objects against a dark background.

The direct illumination examination is carried out utilizing three slit-beam effects on the transparent structures of the eye, i.e. optical section, parallelopiped and a conical beam effect.

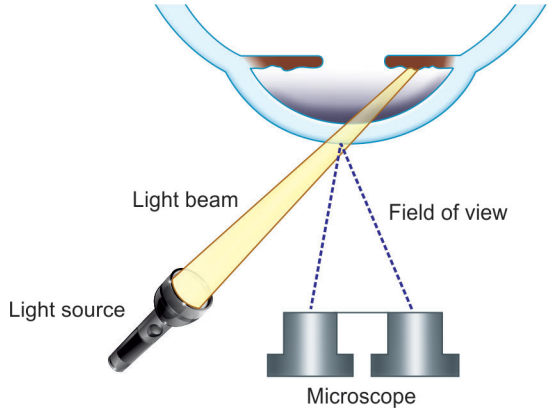


Fig. 3.7: *Set for direct illumination.*

i. *Optical section* (Fig. 3.8) is produced by a very narrow slit-beam focused obliquely. The optical section produced resembles a knife-like histological section of the tissue focused (cornea, lens and anterior part of vitreous). The whole tissue can be examined by moving the slit-beam and simultaneous focus of the microscope across the surface.

■ *Corneal optical section* (Fig. 3.9) consists of a segment of an arc with following concentric zones:

- Tear layer is seen as a bright *anterior most* zone.
- Epithelium is seen as a dark line immediately behind the tear layer.
- Bowman's membrane is seen as a bright line.
- Stroma is focused as a wider granular and greyer zone.
- Descemet's membrane and endothelial layers are seen as *posterior most* bright zone.

Examination of the optical section of the cornea gives useful information about:

- Changes in corneal curvature
- Changes in corneal thickness
- Depth of the corneal pathologies, e.g. location of a foreign body
- Anterior chamber angle grading by van Herrick method can be done by the use of corneal optical sections at the nasal and temporal periphery.

■ *Optical section of the lens* (Fig. 3.10) seen with slit-lamp microscope shows stratification of the lens into following layers (from front to backwards):

- Anterior capsule (Ca)
- Subcapsular clear zone (first cortical clear zone $C_1\alpha$)
- A bright narrow scattering zone of discontinuity (first zone of disjunction $C_1\beta$)
- Second cortical clear zone (C_2)
- Light scattering zone of deep cortex (C_3)
- Clear zone of deep cortex (C_4)
- Nucleus (N) which follows the clear zone of cortex represents the prenatal part of the lens. It shows further stratification with a central clear interval which has been termed the embryonic nucleus.

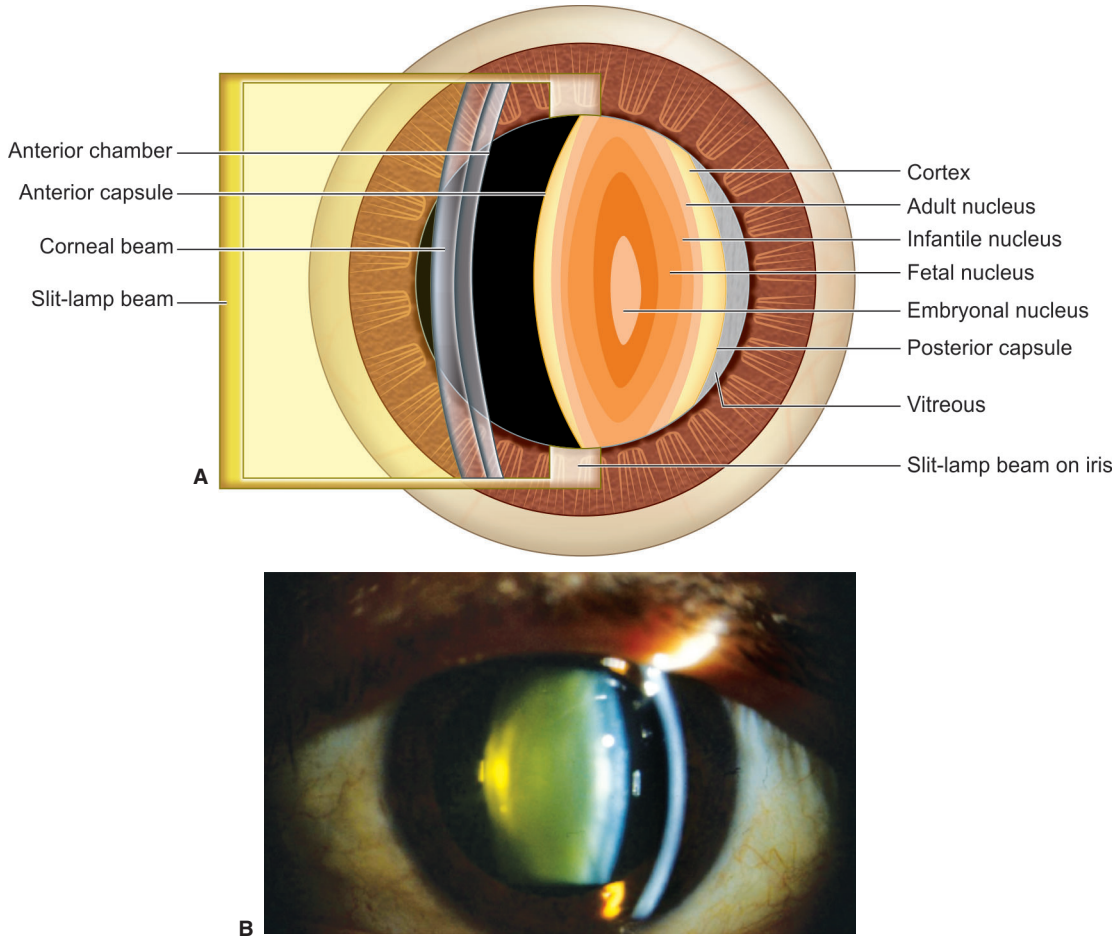


Fig. 3.8: *Optical section of the cornea, lens and anterior vitreous seen on slit-lamp examination: (A) Diagrammatic; (B) Clinical photograph.*

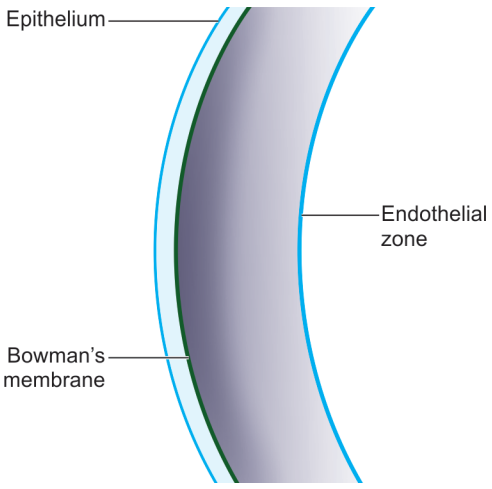


Fig. 3.9: *Corneal optical section.*

The entire optical section of the lens cannot be focused in one field and thus, the microscope needs to be shifted forward to focus more posterior layer. The location and extent of lenticular opacities can be easily made in the optical section of the lens.

- *Optical section of the anterior one-third* of the vitreous can be studied with slit-lamp beam.

ii. *Parallelopiped* of the cornea (Fig. 3.11) is observed using a 2–3 mm wide focused slit. Pathologies of epithelium and stroma are better studied under this illumination. Corneal scars or infiltrates appear brighter than surroundings because they have more density. Water clefts have decreased optical density, and so appear black in optical block.

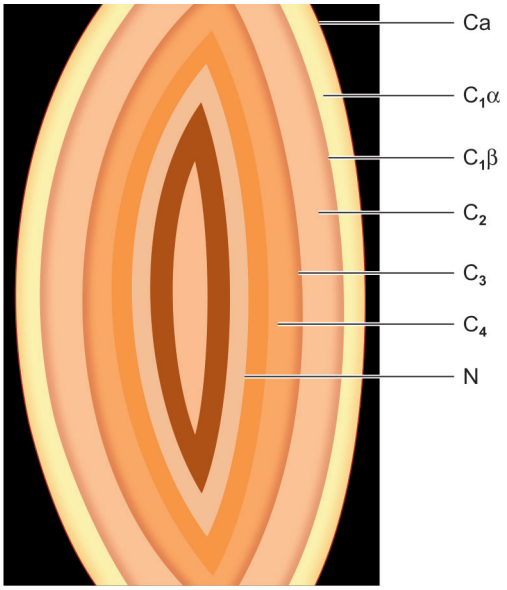


Fig. 3.10: *Optical section of the lens.*

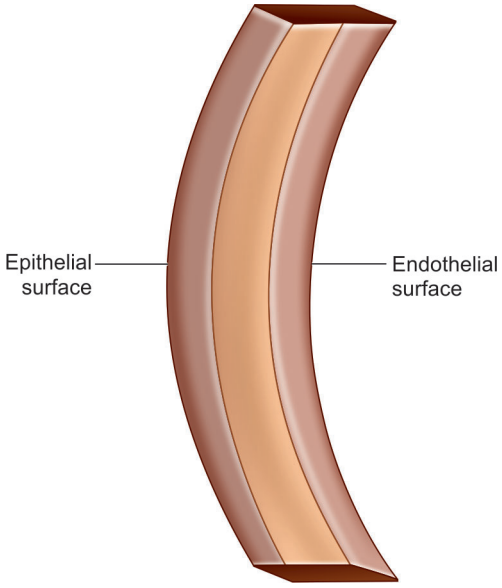


Fig. 3.11: *Parallelopiped of cornea seen on slit-lamp.*

Cells and flare in the anterior chamber can be graded by using a parallelopiped 2 mm wide 34 mm high.

iii. ***Conical beam*** (Fig. 3.12) is a small circular beam used to examine the presence of aqueous flare. Settings for examination of aqueous flare are as follows:

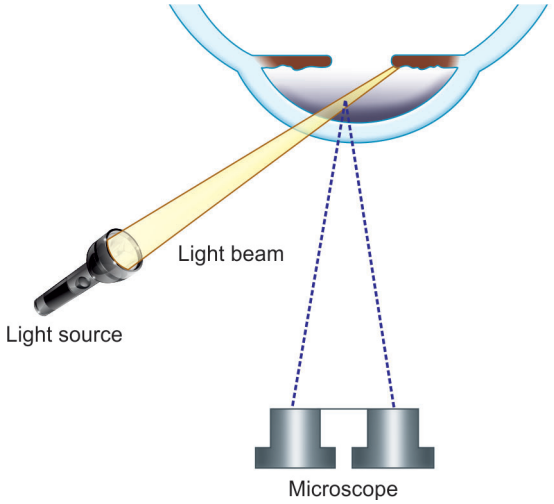


Fig. 3.12: *Conical beam used to examine the presence of aqueous flare.*

- Beam—small circular pattern
- Light source 45–60° temporally and directed into the pupil
- Biomicroscope—directly in front of the eye
- Magnification—high (16–20X)
- Focusing. Beam is focused between the cornea and anterior lens surface, and the dark zone between cornea and lens is observed. This zone is normally optically empty and appears black. Flare appears grey or milky and cells are seen as white dots. Locating the cells may be facilitated by gently oscillating the illuminator.

3. Indirect illumination. The slit-beam is focused on a position just beside the area to be examined (Fig. 3.13). The *set-up* required is as given:

- Angle between slit-lamp and microscope should be 30–45°.
- Beam width used is moderate.
- Illumination used is low, medium or high.
- Slit-lamp can be offset.

Indirect illumination is *useful* to observe:

- Corneal infiltrates
- Corneal microcysts

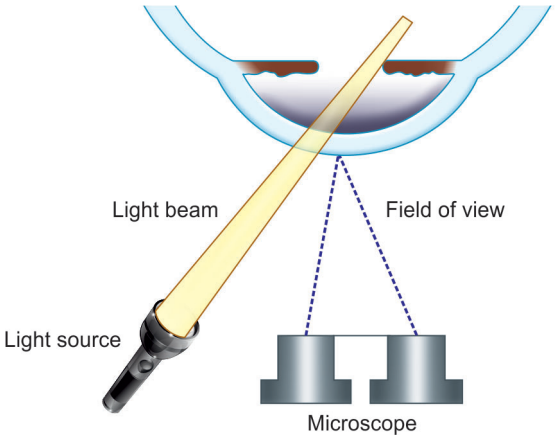


Fig. 3.13: *Set-up for indirect illumination.*

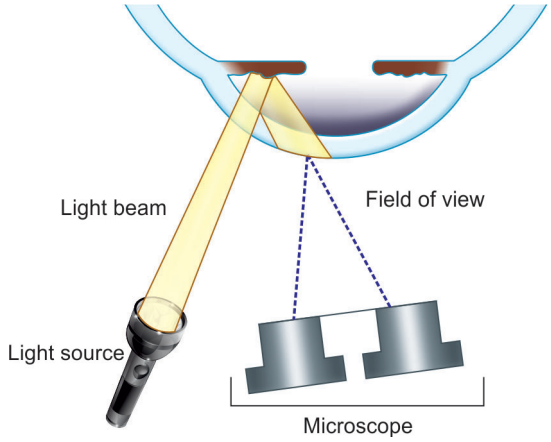


Fig. 3.14: *Set-up for retroillumination.*

- Corneal vacuoles
- Epithelial cells

4. Retroillumination. Light is reflected off the iris or fundus, while the microscope is focused on the cornea (Fig. 3.14). Graves divided retroillumination as direct and indirect, depending on the angle between observer and light.

a. *Direct:* Observer is in direct pathway of light reflected from structures. The pathology is seen against an illuminated background (Fig. 3.15).

b. *Indirect:* Observer is at right angle to the observed structure and, therefore, not in line with light, so pathology is seen against a dark, non-illuminated background (Fig. 3.16).

Based on the optical properties, Graves divided the pathologies as:

- *Obstructive.* These are opaque to light and seen as dark against a bright background, e.g. pigment or blood-filled vessel.
- *Respersive.* These scatter light but do not obstruct light completely. The pathology is seen brightly against a dark background, e.g. epithelial oedema, precipitates. Infiltrates are relucent in direct focal illumination but respersive in direct retroillumination.
- *Refractile.* These refractile pathologies distort the view of junction of illuminated and dark areas because their refractive index is different from surroundings, e.g. vacuole.

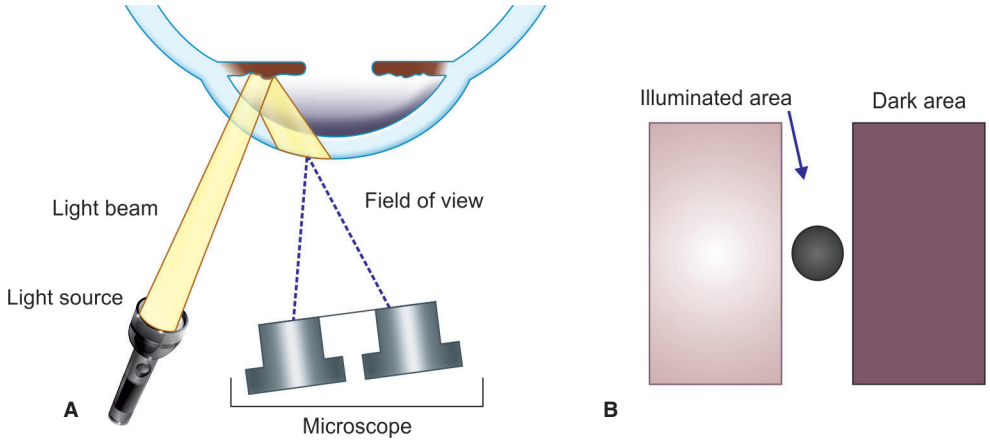


Fig. 3.15: *Direct retroillumination: (A) Cross-sectional view; (B) A keratic precipitate is seen as dark against illuminated background.*

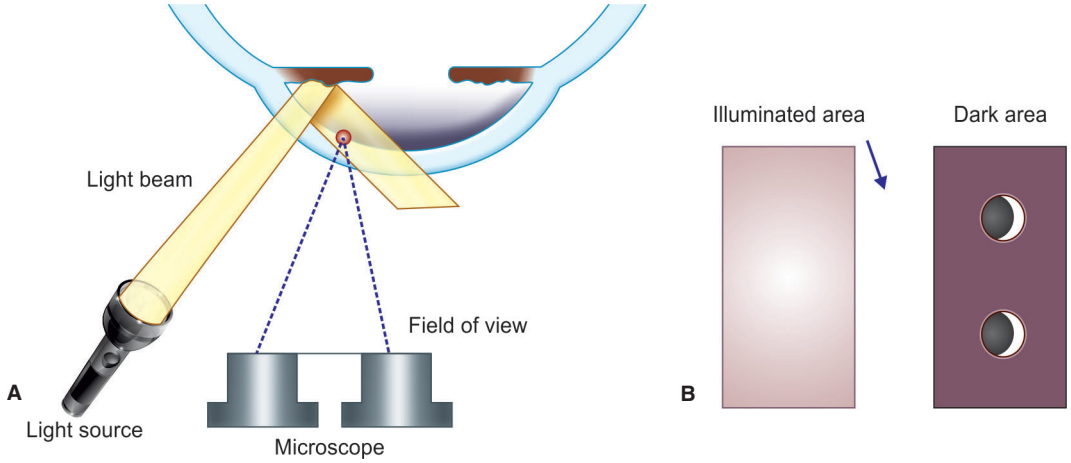


Fig. 3.16: *Indirect retroillumination: (A) Cross-sectional view; (B) A keratic precipitate seen as dark with lighted crescent on the border away from illuminated side (reversed illumination) and seen against a dark background.*

A vacuole is seen as an illuminated area bordered by dark line in direct retroillumination but in indirect retroillumination it appears as black area with a bright surface towards the illuminated area (unreversed illumination). A solid or opaque precipitate will be seen as dark area in direct retroillumination but under indirect retroillumination it will show reversed illumination; that is, its side away from the illuminated area will be bright.

Thus retroillumination can provide information regarding not only the form but also the refractive index and consistency of the pathology.

Retroillumination from the fundus. This technique is used to observe media clarities and opacities. The pupil is dilated and the slit-beam and microscope are made coaxial. The light is directed so that it strikes the fundus and creates a glow behind the opacity in the media. The media opacity creates a shadow in the glow. The microscope is then focused on the pathology directly and 10–16X magnification is used. Cornea, lens and vitreous pathologies are examined by this technique. Retroillumination of crystalline lens is required to classify and grade both cortical and posterior subcapsular cataracts using LOCS II (lens opacity classifying system II).

5. Specular reflection. Reflection of light occurs when a beam of light is incident on an optical surface, which is called *zone of discontinuity*. Such zones may be found in cornea and lens. When an observer is placed in the pathway of reflected light, a dazzling reflex will be seen which is called specular reflection. The surface from which reflection is obtained is called zone of specular reflection. Surface pathologies will scatter the light irregularly and, therefore, create dark areas in the reflex.

To get specular reflection, the patient is asked to look 30° temporally. Light beam is directed from opposite side. Optical block is focused under high magnification, 3–4 mm from limbus. Towards the side of light source, a shining reflex is seen on the cornea. When the light source is rotated still temporally, the optical block will approach the reflex. When the angle between microscope and slit-beam is about 60°, i.e. when the angle of incidence becomes equal to the angle of reflection (Fig. 3.17) at this point, dazzling reflex which is coming from tear meniscus will show the meniscus irregularities. At the same time, a deeper less luminous glow will be seen which when focused will show the endothelial mosaic. A parallelopiped beam with high illumination and high magnification is used in this technique. Similarly specular reflection from anterior and posterior capsule of lens can be

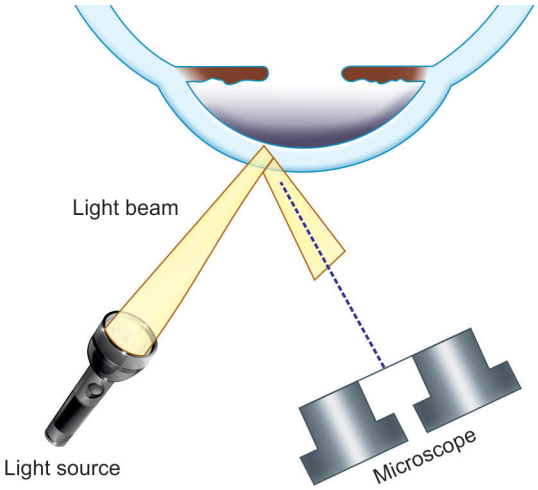


Fig. 3.17: *Set-up for specular reflection.*

obtained. Using an eyepiece reticule, endothelial cells can be measured and counted. It can also be used to study tear film details.

6. Sclerotic scatter. It is used to outline even the faintest corneal pathology. Light beam is focused at the limbus. Because of the phenomenon of total internal reflection, rays of light pass through the substance of cornea and illuminate the opposite side of limbus. If there is any pathology like corneal opacity, it becomes visible because it scatters the rays of light. A magnification of 6–10X is used and microscope is directed straight ahead (Fig. 3.18).

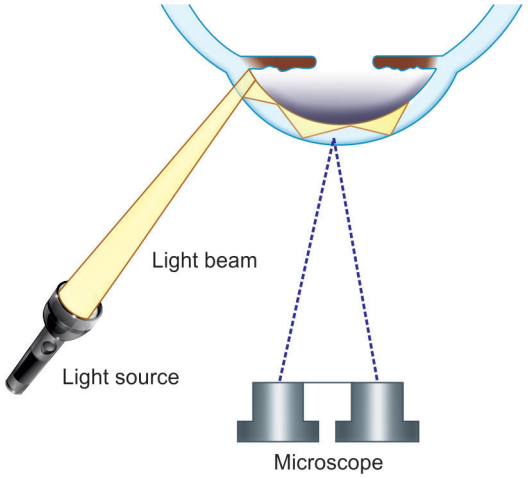


Fig. 3.18: *Set-up for sclerotic scatter.*

7. Oscillating illumination of Koeppe. In this, the slit-beam is given an oscillatory movement by which it is often possible to see minute objects or filaments especially in the aqueous which would otherwise escape detection.

ACCESSORY DEVICES

For specialized examinations with the help of a slit-lamp biomicroscope certain accessory devices that can be used with slit-lamp (78/90D examination) are given below:

- Gonioscopy
- Fundus examination with focal illumination
- Pachymetry
- Applanation tonometry
- Ophthalmodynamometry
- Slit-lamp photography
- Slit-lamp videography
- Slit-lamp as delivery system for argon, diode and YAG laser
- Laser interferometry
- Potential acuity meter test

HAND-HELD SLIT-LAMP

Hand-held slit-lamp (Fig. 3.19) is portable version of the table mounted slit-lamp which allows reasonably good examination.

Uses. It is especially suitable for:

- Bedridden patients
- Home-based examinations
- Childrens or the restless adults
- For eye camps.

Fig. 3.19: *Hand-held slit-lamp.*

BIBLIOGRAPHY

1. Hand-Held Portable Slit Lamp from Reichert. Review of Ophthalmology 2006. www.revophth.com/index.asp?page=1_1008.htm (Accessed on September 07, 2010).
2. Knoop K, Trott A. Ophthalmologic procedures in the emergency department—Part III: Slit lamp use and foreign bodies. AcadEmerg Med 1995;2:224.
3. Koppenhöfer, Eilhard. From Lateral Illumination to Slit Lamp—An Outline of Medical History, online published 2012.
4. Schwartz Gary S. The eye exam: a complete guide, pp. 109–128 Slit Lamp Biomicroscopy, SLACK Incorporated, ISBN 978-1-55642-755-8, published 2006.
5. Slit Lamp Adapters Turn Smartphones into Clinical Cameras. Ophthalmology Web May 14, 2013. http://www.ophthalmologyweb.com/Featured-Articles/136817-Slit-Lamp-Adapters-turn-Smartphones-into-Clinical-Cameras/ (Accessed on April 05, 2017).
6. Slit-Lamp Gonioscopy. Postgraduate Medical Journal 1963;39(451):310.
7. Tate GW, Safir A. The slit lamp: History, principles, and practice. In: Clinical Opthalmology, Duane TD (Ed). Vol 1. Harper & Row, New York 1981.
8. Vivino MA, Chintalagiri S, Trus B, Datiles M. Development of a Scheimpflug slit lamp camera system for quantitative densitometric analysis, Computer Systems Laboratory, National Eye Institute, National Institutes of Health, Bethesda, MD 20892. Eye (Lond). 1993;7 (Pt 6):791–8.

CHAPTER

4

Examination of Posterior Segment

Chapter Outline

INTRODUCTION

Though the conventional direct and indirect ophthalmoscopies are still the most commonly used techniques, the ophthalmic imaging technology has undergone explosive growth in the past few years. Current techniques of posterior segment evaluation and imaging have contributed significantly to the understanding of pathophysiology and treatment of a variety

of posterior segment disorders. Some of the common optical instruments and techniques for posterior segment evaluation include the following:

- Ophthalmoscopy
- Slit lamp biomicroscopic examination of the fundus
- Fundus camera
- Wide-field imaging system (retinal camera)
- Scanning laser ophthalmic techniques
  - Scanning laser ophthalmoscopy (SLO)
  - CSLO or scanning laser tomography (SLT)
  - Retinal thickness analyser
  - Scanning laser polarimetry (SLP) (retinal nerve fiber analyser)
- Optical coherence tomography
- OCT ophthalmoscopy

OPHTHALMOSCOPY

Ophthalmoscopy is a clinical examination of the interior of the eye by means of an ophthalmoscope. It is primarily done to assess the state of fundus and detect the opacities of ocular media. The ophthalmoscope was invented by Babbage in 1848; however, its importance was not recognized, till it was reinvented by *von Helmholtz* in 1850. Ophthalmoscopic methods of examination in vogue are:

- Distant direct ophthalmoscopy
- Direct ophthalmoscopy
- Monocular indirect ophthalmoscopy
- Binocular indirect ophthalmoscopy.

DISTANT DIRECT OPHTHALMOSCOPY

It should be performed routinely before the direct ophthalmoscopy, as it gives a lot of useful information (vide infra). It can be performed with the help of a self-illuminated ophthalmoscope or a simple plain mirror with a hole in the center.

Procedure

The light is thrown into the patient's eye—with the patient sitting in a semidark room—from a distance of 20–25 cm, and the features of the red glow in the pupillary area are noted.

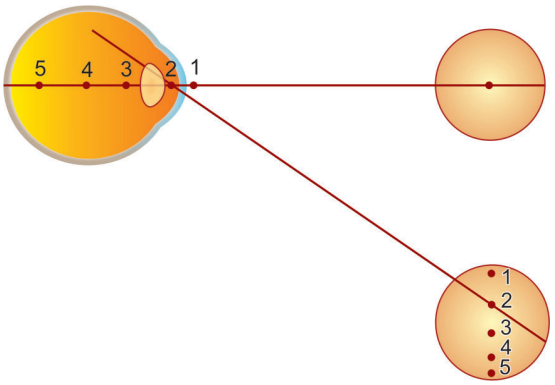


Fig. 4.1: *Parallactic displacement on distant direct ophthalmoscopy.*

Applications of distant direct ophthalmoscopy

1. ***To diagnose opacities in the refractive media.*** Any opacity in the refractive media is seen as a black shadow in the red glow. The exact location of the opacity can be determined by observing the parallactic displacement. For this, the patient is asked to move the eye up and down while the examiner is observing the pupillary glow. The opacities in the pupillary plane remain stationary, those in front of the pupillary plane move in the direction of the movement of the eye and those behind it will move in opposite direction (Fig. 4.1).

2. ***To differentiate between a mole and a hole of the iris.*** A small hole and a mole on the iris appear as a black spot on oblique illumination. On distant direct ophthalmoscopy, the mole looks black (as earlier) but a red reflex is seen through the hole in the iris.

3. ***To recognize detached retina or a tumour arising from the fundus.*** A greyish reflex seen on distant direct ophthalmoscopy indicates either a detached retina or a tumour arising from the fundus.

DIRECT OPHTHALMOSCOPY

It is the most commonly practised method for routine fundus examination.

OPTICS AND CHARACTERISTICS OF IMAGE

Optics

The modern direct ophthalmoscope (Fig. 4.2) works on the basic optical principle of glass plate

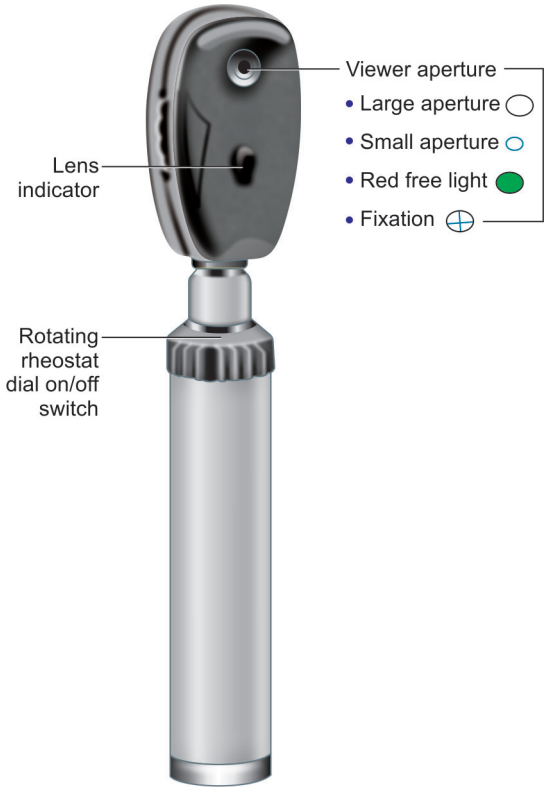


Fig. 4.2: *Direct ophthalmoscope showing viewing aperture above illuminating aperture and lens indicators.*

ophthalmoscope introduced by *von Helmholtz*. Optics of direct ophthalmoscopy is depicted in Fig. 4.3.

A convergent beam of light is reflected into the patient's pupil (Fig. 4.3, dotted lines). The emergent rays from any point on the patient's fundus reach the observer's retina through the viewing hole in the ophthalmoscope (Fig. 4.3, continuous lines). The emergent rays from the patient's eye are parallel and brought to focus on the retina of the emmetropic observer when accommodation is relaxed.

- *In a hypermetropic patient*, the emergent ray from the illuminated area of retina will be divergent and thus can be brought to focus on the observer's retina, if the latter accommodates, or by the help of a convex lens (Fig. 4.4).
- *In a myopic patient*, the emergent rays will be convergent and thus can be brought to focus on the observer's retina by the help of a concave lens (Fig. 4.5).

Therefore, if the patient or/and the observer is/are ametropic, a correcting lens (equivalent to the sum of the patient's and observer's refractive error) must be interposed (from the system of plus and minus lenses, in-built in the modern ophthalmoscopes).

Characteristics of the image formed

In direct ophthalmoscopy, the image is erect, virtual and about 14–15 times magnified

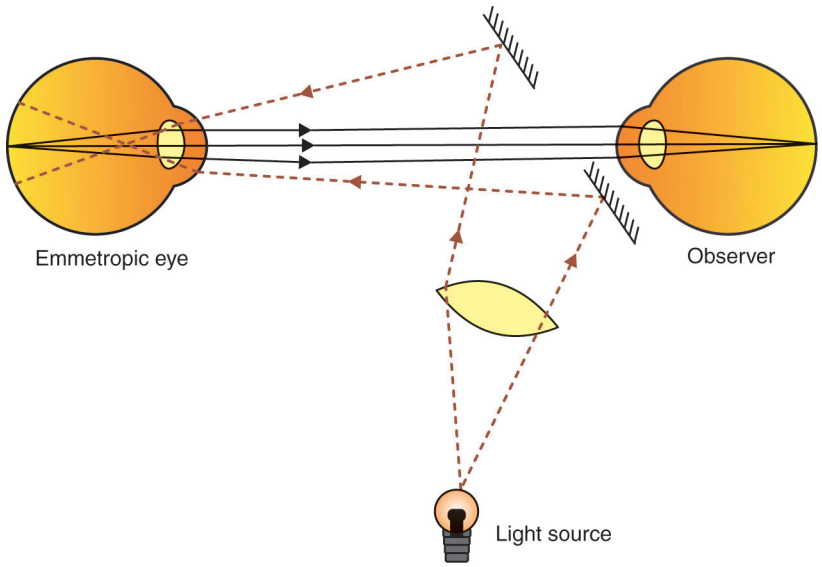


Fig. 4.3: *Optics of direct ophthalmoscopy in an emmetropic patient.*

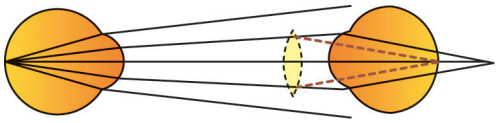


Fig. 4.4: *Optics of direct ophthalmoscopy in a hypermetropic patient.*

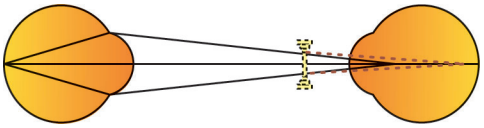


Fig. 4.5: *Optics of direct ophthalmoscopy in a myopic patient.*

(Table 4.1) in emmetropes (more in myopes and less in hypermetropes).

Magnification of the direct ophthalmoscope for an emmetropic patient viewed by an emmetropic observer is 15x. If the patient and observer have refractive errors, then the axial length and refractive power of both eyes, plus the compensating lenses of the ophthalmoscope, all influence the resultant magnification. If the patient is myopic, then the eye has plus power and the ophthalmoscope requires a minus lens for viewing a clear images. The combination results in a **Galilean telescope**, which enlarges fundus detail. The opposite effect is seen in a hyperopic eye (reverse telescope).

If neither the patient nor the observer is emmetropic, then power of a single lens in the ophthalmoscope must be equal to the mathematical sum of the patient's and the observer's refractive errors. It is important to understand that when one or both of the participants have a large refractive error or a high degree of astigmatism, it is more advantageous to use the glasses to view the fundus.

Field of view

The ophthalmoscopic field of vision (Table 4.1) is always smaller than the field of illumination in direct ophthalmoscopy. It is affected by the following factors:

- It is directly proportional to the size of the pupil of observed eye.

Table 4.1 *Magnification, field of view and characteristics of the image formed with different techniques of fundus examination*

Technique	*Magnification*	*Field of view*	*Characteristics of image*	*Principal use*
Direct ophthalmoscopy	14X	5°	Erect, virtual	Routine view of disc and surrounding area
Indirect ophthalmoscopy				
• With 114 D	4X	40°	Inverted, reversed and real	Fundus lesion inspection
• With 120 D	3X	45°	Inverted, reversed and real	Routine examination
• With 130 D	2X	50°	Inverted, reversed and real	Routine examination
Biomicroscopic examination				
• With 178 D	10X	30°	Inverted, reversed and real	Posterior pole observation
• With 190 D	7.5X	40°	Inverted, reversed and real	Posterior pole observation
• With Hruby lens	12X	10°	Erect, virtual	Optic disc and vitreous observation
• With Goldmann fundus contact lens	10X	20°	Erect, virtual	Optic disc and macula inspection
Fundus camera	2.5X	30°	Erect, virtual Photodocumentation	

- It is directly proportional to the *axial length* of the observed eye.
- It is inversely proportional to the distance between the observed and the observer's eye.
- The smaller the sight hole of the ophthalmoscope, the better the field of vision.

Technique

Direct ophthalmoscopy should be performed in a semidark room with the patient seated and looking straight ahead, while the observer standing or seated slightly over to the side of the eye to be examined (Fig. 4.6A). The patient's right eye should be examined by the observer with his or her right eye, and left with the left.

The observer should reflect beam of light from the ophthalmoscope into patient's pupil. Once the red reflex is seen, the observer should move as close to the patient's eye as possible (theoretically at the anterior focal plane of the patient's eye, i.e. 15.4 mm from the cornea).

The direct ophthalmoscope should then be focused by twirling the dial for the Reskoss disc, which has several plus- and minus-powered lasers. The optimal focusing lens on the Reskoss disc depends on the patient's refractive error, the examiner's refractive error (including unintended accommodation) and the examination distance (Table 4.2).

Once the retina is focused, the details should be examined systematically starting from disc, blood vessels, the four quadrants of the general background and the macula by utilizing the various illumination options and apertures provided in the direct ophthalmoscope (Table 4.3 and Fig. 4.6A).

Table 4.2 *Direct ophthalmoscope's refractive power versus patient's spherical equivalent while focusing**

Direct ophthalmoscope's refractive power	*Patient's refractive error*
230 D	215 D
220 D	212 D
210 D	28 D
25 D	24 D
20	2Plano
15 D	16 D
110 D	115 D

*When the examiner's eye is emmetropic or corrected and the examination distance between the ophthalmoscope and cornea is 20 mm

Note. The problem is obtaining adequate illumination of the patient's fundus as the light source only illuminates that part of the fundus which is struck directly by light; the rest of the fundus remains dark. Therefore, the fundus can be adequately viewed only if the observed areas and the illuminated areas coincide. This can take place only if the light source and the observer's pupil are closely aligned optically (Fig. 4.6B). Most direct ophthalmoscopes (Fig. 4.2) have the

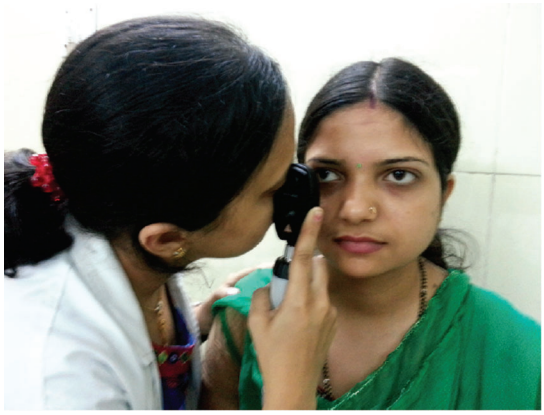


Fig. 4.6A: *Technique of direct ophthalmoscopy.*

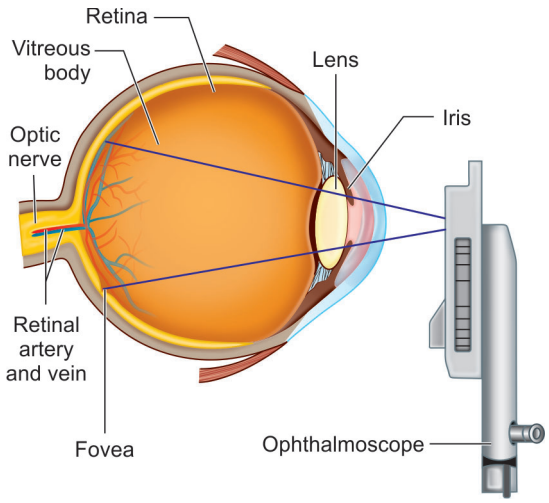


Fig. 4.6B: *The light source and the observer's pupil are closely aligned optically and that part of the fundus which is properly illuminated can be adequately viewed.*

Table 4.3 *Various apertures and illumination options with direct ophthalmoscope*

Aperture description	*Use*
Large spot	For viewing through a dilated pupil
Small spot	For viewing through a small pupil
Red-free fibre	Useful in detecting changes in the nerve fibre layer and identifying microaneurysms and other vascular anomalies
Slit	For evaluating contour of retinal lesions
Reticule or grid	For measuring vessel caliber or diameter of a small retinal lesion (marked in 0.2 mm increments)
Fixation target	For testing fixation pattern (central or eccentric)
Reskoss disc	Plus and minus lenses are for focusing the retina

illuminating beam situated below the viewing aperture. Modern ophthalmoscopes have a condensing lens to intensify the light Beam and a diaphragm and projecting lens to limit the size of the light beam.

Problems faced during viewing

Unwanted reflections. To avoid both scattering and reflection of light rays into the viewing beam, both the illuminating and viewing beams must be maximally separated so that interference and hence reflections do not occur. Therefore, separation of the two beams must be maintained through the cornea and lens, yet overlap onto the retina. Thus, with a dilated pupil, reflex-free viewing is more easily obtained.

Peripheral viewing with a direct ophthalmoscope is limited because the pupil becomes too narrow for the viewing and illumination beams. The equatorial region is usually the limit in peripheral viewing with the direct ophthalmoscope. A technique to aid in peripheral viewing has to do with the change in the pupil configuration on extreme eyes gazes. When the patient looks to the right or left, the pupil is elongated vertically. In this situation the ophthalmoscope should be held vertically to facilitate the entrance of both beams into the eye. Likewise, a horizontal elongation of the pupil results during up or down gaze, and a horizontal orientation of the scope may be helpful.

Interpretation

Generally, an ophthalmoscopic examination of the fundus starts at the optic nerve head because localization of this structure provides immediate orientation. The image is virtual and upright. The optic disc should be examined for the cup-to-disc ratio, color, clarity of margins, spontaneous venous pulsations, and any abnormalities. The tissue around the disc is studied, with emphasis placed on the blood vessels, especially the superior and inferior temporal arcades. The vessels should be evaluated for their arteriovenous ratio, color, diameter, and course. The background retinal tissue is also examined. The macula is usually examined last because of the dazzling and discomfort that is experienced by the patient. The macula should be examined for the foveal reflex, color, pigmentation, and any abnormalities.

The size of any abnormal lesion is described in terms of disc areas and distance from disc or macula is described in terms of disc diameters. For depth of the lesion a 3-D difference in focal planes for focusing the lesion in an emmetropic eye converts into a linear depth equivalent of approximately 1 mm in a phakic eye and into approximately 2 mm in an aphakic eye. This is especially useful for documenting raised lesions, e.g. disc edema.

Accessory functions of direct ophthalmoscope

Accessory functions have been built into the ophthalmoscope to widen the diagnostic capabilities.

Slit diaphragm can produce a narrow slit beam, which can be used to detect elevation or depression of retinal lesions. Here, a distortion of the beam occurs when it travels across an elevation or depression. The beam bows toward the observer on an elevated area and away from the observer in a depressed area.

Pinhole diaphragm produces a narrow beam of light that can be used to reduce reflections, which is especially helpful when viewing

through a small pupil. A small circle of light allows observation of fine retinal detail seen in the zone adjacent to the directly illuminated retina. This zone consists of areas of indirect illumination that enhance observation.

Fixation reticle can be used to discover eccentric fixation or eccentric viewing by the patient. This may be helpful in the evaluation of strabismic patients or for measuring the size of macular lesions.

Filters of different types can be very helpful while performing ophthalmoscopy. A cobalt blue filter can be used to enhance fluorescence angiography. A red free (green) filter to absorb red light; therefore, red objects appear very dark. This is helpful when studying blood vessels and hemorrhages. Defects in the nerve fiber layer and retinal edema are more easily seen with red-free light because of shorter wavelengths that are readily scattered by superficial retinal layers.

Cross polarizing filters reduce reflection because light reflected back from the cornea is depolarized and blocked by the viewing filter, but light reflected from the retina (except for the internal limiting membranes) is polarized and remains visible. The chief drawback of polarizing filters is the substantial reduction in illumination and hence less bright view of the fundus.

MONOCULAR INDIRECT OPHTHALMOSCOPY

Structural features

The monocular indirect ophthalmoscope consists of (Fig. 4.7):

- *Illumination rheostat* at its base
- *Focusing lever* for image refinement
- *Filter dial* with red-free and yellow filters
- *Forehead rest* for steady proper observer head positioning
- *Iris diaphragm lever* to adjust the illumination beam diameter.

Optics

An internal relay lens system re-inverts the initially inverted image to a real erect one, which is then magnified. This image is focusable using the focusing lever/eyepiece system (Fig. 4.7).

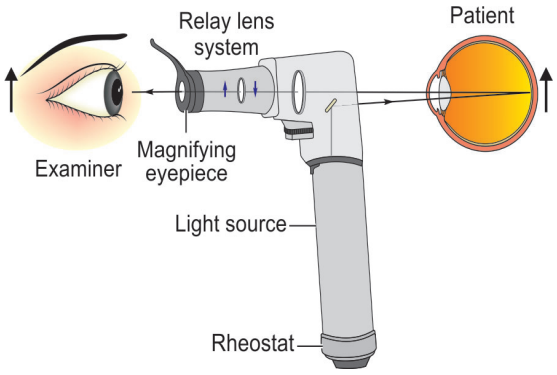


Fig. 4.7: *The optical principle of monocular indirect ophthalmoscopy, demonstrating the resultant erect magnified image.*

Indications and view of extent

Indications for use of monocular indirect ophthalmoscopy include:

- Need for an increased field of view
- Small pupils
- Uncooperative children
- Patient's intolerance of bright light of binocular indirect ophthalmoscope
- Basic fundus screening

Extent of view. Although vitreous base views are possible with monocular indirect ophthalmoscopy, its greatest effectiveness extends anteriorly to the peripheral equatorial region. The 40+ degree field of view of the monocular indirect ophthalmoscope is approximately the same as that of binocular indirect ophthalmoscope.

Advantages and disadvantages

Advantages of monocular indirect ophthalmoscopy include:

- Increased field of view similar to indirect ophthalmoscopy.
- Erect real imaging similar to direct ophthalmoscopy.

Disadvantages include:

- Lack of stereopsis
- Limited illumination
- Fixed magnification
- Fair to good resolution.

BINOCULAR INDIRECT OPHTHALMOSCOPY

Indirect ophthalmoscopy, introduced by Nagel in 1864, is now a very popular method for examination of the posterior segment. Indirect ophthalmoscopy was considered as an elementary part of examination by only the posterior segment or the retinal surgeons in yesteryears. It was the eagerness on the part of the examiner, who used only direct ophthalmoscopy, so as to come to a hasty diagnosis. He used to organize his thoughts on this cursory examination of the retina, and assumptions were made for the final diagnosis. However, in this modern era, indirect ophthalmoscopy is of great general use in ophthalmology and requires much effort and practice by the anterior as well as the posterior segment surgeons.

OPTICS OF INDIRECT OPHTHALMOSCOPY

Optical principle

The principle of indirect ophthalmoscopy is to make the eye highly myopic by placing a strong convex lens in front of patient's eye so that the emergent rays from an area of the fundus are brought to focus as a real inverted image between the lens and the observer's eye, which is then studied (Fig. 4.8A).

Optical system of binocular indirect ophthalmoscope

Optics of modern binocular indirect ophthalmoscopy is shown in Fig. 4.8B. Binocularity is achieved by reducing the observer's interpupillary distance from about 60 mm to approximately 15 mm by prisms/mirrors (Fig. 4.9). Even this artificial reduction of interpupillary distance requires larger patient's pupils for binocular viewing than those for the monocular viewing.

Field of illumination as shown in Fig. 4.10. The field of illumination is more in myopia and less in hypermetropia compared to emmetropia.

Image formation

1. ***Image formation in emmetropia.*** The emergent rays from the illuminated area of retina are parallel in emmetropic patients and are, therefore, brought to focus by the condensing lens at its principal focus (Fig. 4.11). Thus an inverted image of the retina is formed in the air between the condensing lens and the observer.

2. ***Image formation in hypermetropia.*** The emergent rays from the illuminated area of

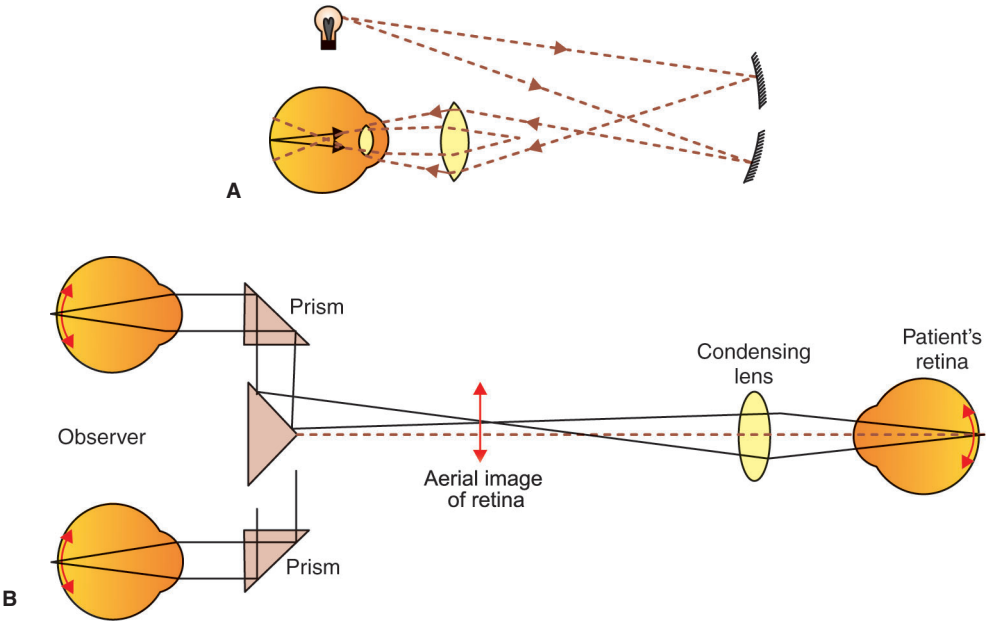


Fig. 4.8: *(A) Optics of indirect ophthalmoscopy; and (B) optical system of a modern binocular indirect ophthalmoscope.*

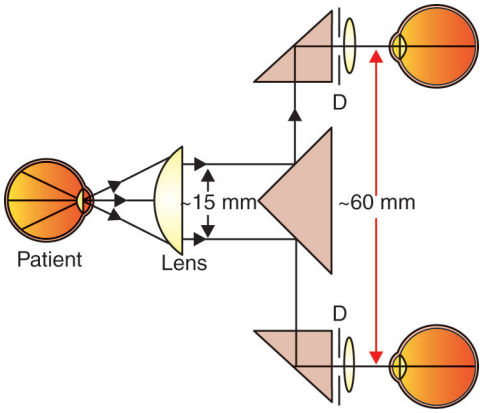


Fig. 4.9: *Stereopsis is produced by the binocular indirect ophthalmoscope. Note how the two prisms widen the incoming beams so that they are incident to the eyes of the observer.*

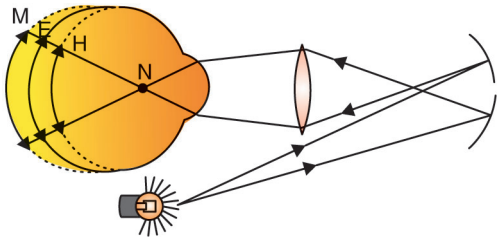


Fig. 4.10: *Field of illumination in various refractive errors.*

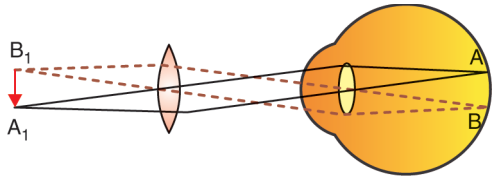


Fig. 4.11: *Image formation on indirect ophthalmoscopy in emmetropia.*

retina are divergent in hypermetropic patients and thus appear to come from an imaginary enlarged upright image situated behind the eye (Fig. 4.12). The condensing lens, therefore, uses this as an object and forms an inverted image of it. Since, the rays are divergent, the final image is situated in front of the principal focus.

3. ***Image formation in the myopic eye.*** The emergent rays from the illuminated area AB of retina in a myopic patient are convergent and, therefore, an inverted image A_1B_1 of it is formed

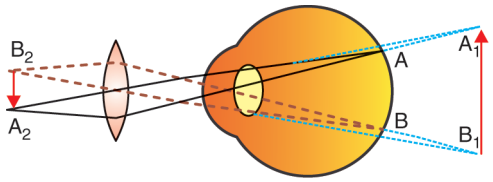


Fig. 4.12: *Image formation on indirect ophthalmoscopy in hypermetropia.*

in front of the eye. The condensing lens forms the final image A_2B_2 situated within its own focal length (Fig. 4.13).

Characteristics of the image

The image formed in indirect ophthalmoscopy is real, inverted and magnified. Magnification of image depends upon the dioptric power of the convex lens, position of the lens in relation to the eyeball and refractive state of the eyeball. About 53 magnification is obtained with a 113 D lens. With a stronger lens, image will be smaller but brighter and field of vision will be more. The important characteristics of the image formed by an indirect ophthalmoscope are as follows:

1. ***Relative position of images formed in emmetropic, myopic and hypermetropic eye.*** The relative positions of the images formed in emmetropic, myopic and hypermetropic eye, when the condensing lens used is situated at its own focal distance from cornea, are shown in Fig. 4.14.

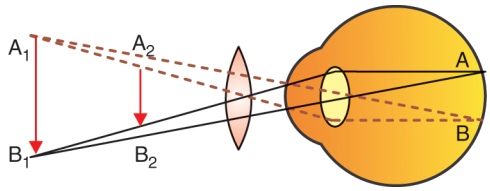


Fig. 4.13: *Image formation on indirect ophthalmoscopy in myopia.*

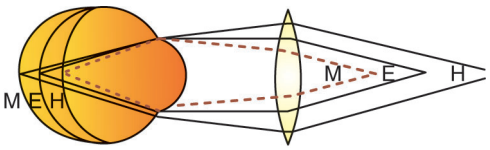


Fig. 4.14: *The relative positions of the images in indirect ophthalmoscopy in emmetropia (E), hypermetropia (H) and myopia (M).*

- *In emmetropia,* the emergent rays are parallel and thus focused at the principal focus of the lens, i.e. at E.
- *In hypermetropia,* the emergent rays are divergent and are, therefore, focused farther away from the principal focus, i.e. at H.
- *In myopia,* the emergent rays are convergent and are, therefore focused near to the lens than its principal focus, i.e. at M.

2. *Size of the image vis-a-vis refractive condition of the eye.*

i. *In an emmetropic eye,* the size of image always remains the same and is situated at its principal focus, because the rays emerging for such an eye are parallel (Figs 4.11 and 4.15).

ii. *In hypermetropia,* the size of image will be:

- *Equal to an emmetropic eye,* if the condensing lens is held at such a distance that its principal focus (f) corresponds to the anterior focus of eye (Fig. 4.15A).
- *Larger than the emmetropic eye,* if the condensing lens is held at such a distance that its principal focus (f) is nearer than the anterior focus of the eye (F) (Fig. 4.15B).

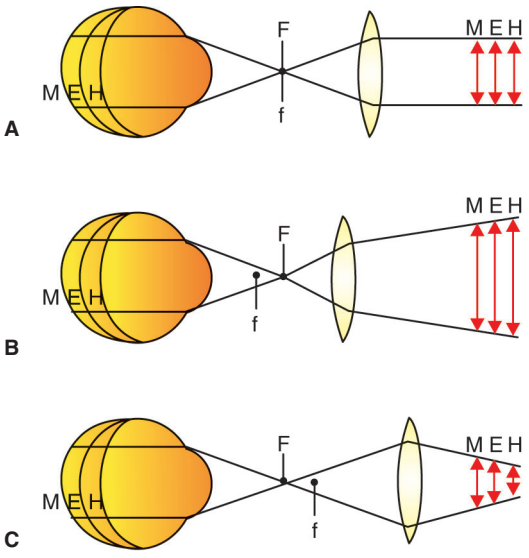


Fig. 4.15: *The size of the image in different refractive states (M: myopia; E: emmetropia; H: hypermetropia), when the condensing lens is held at such a distance that its principal focus (f): (A) Corresponds to the anterior focus of the eye (F); (B) is nearer than the anterior focus of the eye; and (C) is farther away from the anterior focus of the eye.*

- *Smaller than the emmetropic eye,* when the principal focus of the condensing lens (f) is farther away than the anterior focus of eye (Fig. 4.15C).

iii. *In myopia,* the size of image will be:

- *Equal to an emmetropic eye,* if the condensing lens is held at such a distance that its principal focus (f) corresponds to the anterior focus of eye (F) (Fig. 4.15A).
- *Smaller than the emmetropic eye,* if the condensing lens is held at such a distance that its principal focus (f) is nearer than the anterior focus of the eye (F) (Fig. 4.15B).
- *Larger than the emmetropic eye,* when the principal focus of the condensing lens (f) is farther away than the anterior focus of eye (Fig. 4.15C).

3. *Image magnification in indirect ophthalmoscopy.* Lateral (transverse, linear) magnification in an indirect ophthalmoscope is a function of the power of the condensing lens and power of the patient's eye. It may be expressed as power of the eye (60 D) to the power of the condensing lens. Therefore, a 20 D lens produces 33 lateral magnification and a 30 D lens produces 23 magnification (Table 4.1). Although the axial image remains constant in size for a given lens, if it is viewed from more than 25 cm (the reference point for the designation of magnification) the perceived magnification decreases proportionately to the viewing distance.

Field of illumination and observation

The field of observation is always larger than the field of illumination in indirect ophthalmoscopy. The size of the pupil does not affect the size of field of observation, provided it is larger than the image of the observer's pupil formed by the condensing lens in the observed pupil.

The field of observation is in fact a function of magnification and the condensing lens diameter. An X-fold decrease in magnification equals an x^2 increase in the field of observation (Table 4.1).

Practice of indirect ophthalmoscopy

Prerequisites

- Indirect ophthalmoscope
- Dark room

- Convex lens 14 D/120 D/128 D/30 D (nowadays commonly employed lens is of 120 D)
- Pupils of the patient should be dilated.

Technique

The procedure is explained to the patient and is made to lie in the supine position, with one pillow on a bed or couch and instructed to keep both eyes open. The examiner throws the light into the patient's eye from an arm's distance (with the self-illuminated ophthalmoscope). In practice, binocular ophthalmoscope with head band or that mounted on the spectacle frame is employed most frequently (Fig. 4.16). Keeping the eyes on the reflex, the examiner then interposes the condensing lens (120 D, routinely) in the path of beam of light—close to the patient's eye and then slowly moves the lens away from the eye (towards himself or herself) until the image of the retina is clearly seen. The examiner moves around the head of the patient to examine different quadrants of the fundus. He or she has to stand opposite the clock hour position to be examined, e.g. to examine inferior quadrant (around 6 o'clock meridian) the examiner stands towards patient's head (12 o'clock meridian) and so on. By asking the patient to look in extreme gaze, and using scleral indenter, the whole peripheral retina up to ora serrata can be examined.

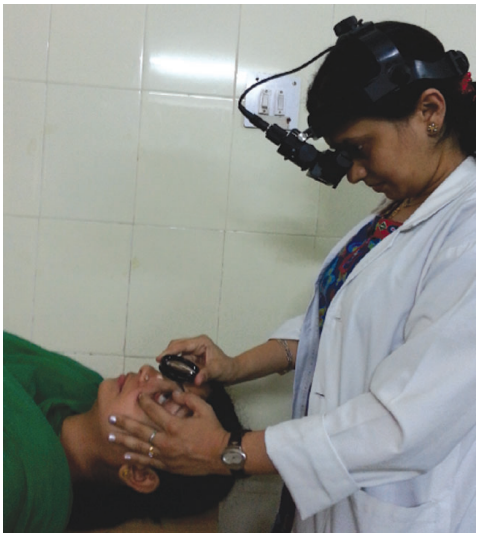


Fig. 4.16: *Technique of indirect ophthalmoscopy.*

Scleral indentation

This is done with the depressor placed on the patient's lids. This helps in making prominent the just or barely perceptible lesions. One can better appreciate the different tissue colors and densities.

- The examiner should move the scleral depressor in a direction opposite to that in which he or she wishes the depression to appear.
- The scleral depressor should be rolled gently and tangentially over the eye surface.
- The patients are most sensitive to scleral depression in superonasal quadrants.
- Sometimes a topical anaesthetic may be applied and scleral depressor is placed directly on the medial conjunctiva, causing little patient discomfort.
- The temporal part of the upper lid is sufficiently lax so that depressor can be placed inferiorly in the horizontal meridian.
- Sometimes when more posterior areas of fundus are to be examined, the examiner asks the patient to look slightly towards his or her position.

Small pupil ophthalmoscopy

In cases where the pupils do not dilate or if media opacities are enough so as to allow only few rays to enter the retina through a small clear media, small pupil ophthalmoscopy is required. Theoretically, it is possible to see the retina binocularly through 0.6 mm pupil with the 30 D lens. Indirect ophthalmoscopy can be performed through a small pupil without small pupil ophthalmoscope by using 30 D lens held as far as possible. When looking through a small pupil, it is convenient to visualize the retina, if light source is directed high in examiner's field of vision. Slight blurring can occur.

Fundus drawing

The image seen with the indirect ophthalmoscope is vertically inverted and laterally reversed; the top of the retinal chart is placed towards the foot end of the patient (i.e. upside down) (Fig. 4.17). This corresponds to the image of the fundus obtained by the examiner. The

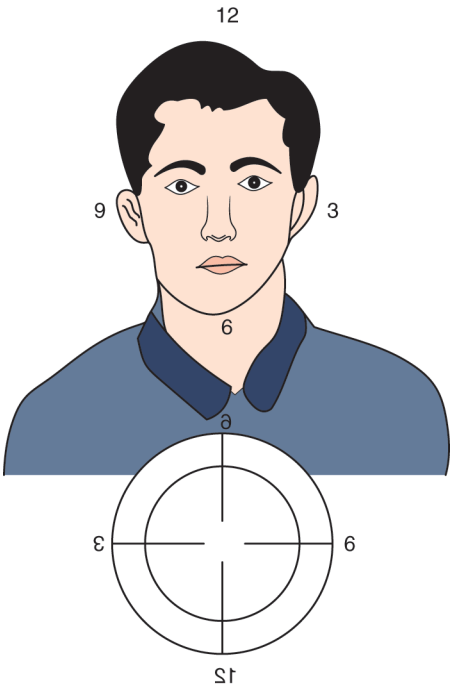


Fig. 4.17: *Position of the chart for drawing during indirect ophthalmoscopy.*

fundus drawing is made on a special Amsler's chart, which has 12 clock hours marked and has three concentric circles made on it. The innermost circle represents to the equator, the middle circle the ora serrata and the outermost circle the midpoint of pars plana.

Normal anatomical landmarks. For mapping of the finding, it is very useful to note the position of any lesion with respect to the ***normal anatomical landmarks*** on the retina (Fig. 4.18):

- *Vortex veins ampulla* are seen along the equator.
- *Long ciliary veins* may be seen at 3 o'clock and 9 o'clock positions.
- *Branching vessels* may also be used and marked to draw the pathology seen.

Symbols and colour codes used to draw the fundus, as accepted internationally (Fig. 4.19), are as below:

- *Optic disc* is always shown with red margins.
- *Arteries* are drawn as red lines.
- *Veins* are drawn as blue lines.
- *Attached retina* is shown red.

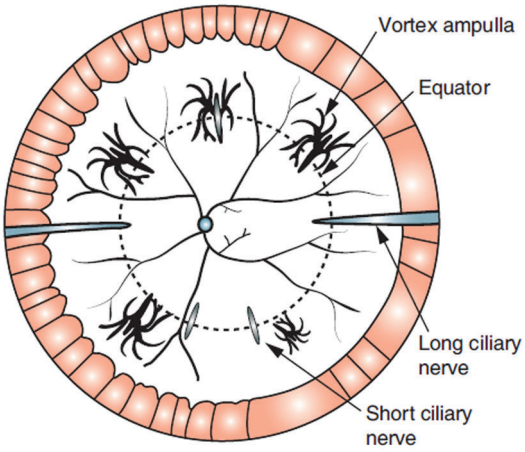


Fig. 4.18: *Normal anatomical landmarks which can be used as aids to draw the location of design seen on fundus examination.*

- *Thin retina* is indicated by red hatching outlines in blue.
- *Detached retina* is drawn with blue color.
- *Retinal tears* are shown as red with blue outline. Flap of the retinal tear is also drawn blue.
- *Lattice degeneration* is shown as blue hatchings outlined in blue.
- *Retinal pigment* is shown as black.
- *Retinal exudates* are shown as yellow.
- *Choroidal lesions* are depicted brown.
- *Vitreous opacities* are depicted as green.

APPLICATIONS, DIFFICULTIES, ADVANTAGES AND DISADVANTAGES

Applications

It is essential for the assessment and management of retinal detachment and other peripheral retinal lesions.

Difficulties during viewing

Reflections and light scatter are problems ophthalmoscopy, and binocular viewing requires a larger pupil than monocular viewing to meet Gullstrand's original ophthalmoscope design. Moving the beams closer together will facilitate viewing through a **small pupil** but will increase reflections and reduce stereopsis. The advantage of the indirect ophthalmoscope is the ability to

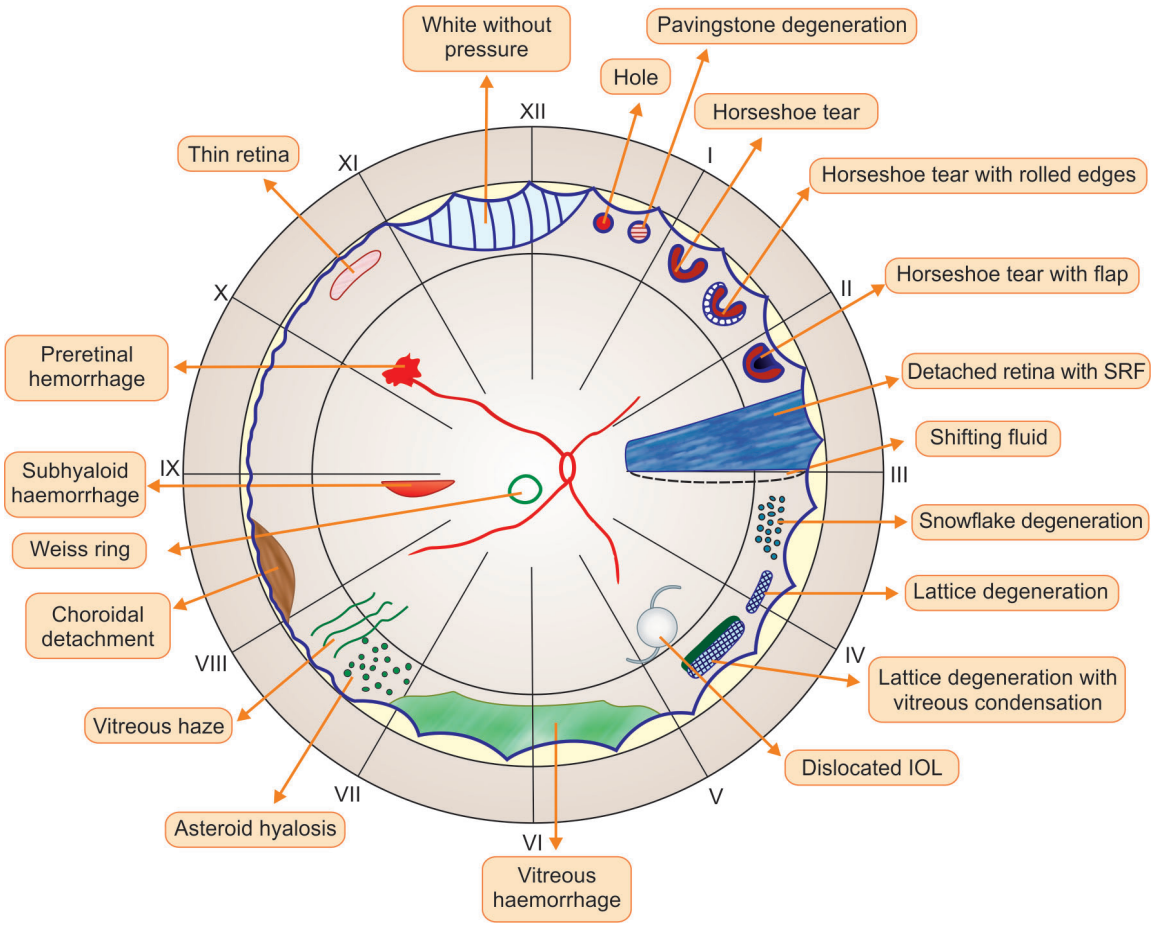


Fig. 4.19: *A sample fundus diagram showing the universal colour-coding system for a few common lesions and structures.*

change the distance between the illuminating beam and viewing beams by tilting the mirror on the scope. During indirect ophthalmoscopy, the illumination is focused in the plane of the pupil to better satisfy Gullstrand's requirements, for this will be the smallest diameter of the beam. Because a +14 D condensing lens has a longer focal length, it is held a greater distance from the eye than a +30 D lens to place the smallest diameter of the beam in the pupil.

The indirect ophthalmoscopy lens design should be to decrease **peripheral aberrations** that increase with stronger and larger lens. To overcome this problem, most condensing lenses are made of an **aspheric** design. This results in a lens with two different curves, the steeper curve on the examiner side of the lens. The illumination beam produces reflections and scatter on the condensing lens surface that can be minimized by **antireflective coatings**. If the lens is held perpendicular to the line of viewing, it produces reflections on the front and rear surfaces in the center of the lens. These reflections can be directed out of the line of light by a **slight tilt of the lens**. Observation of the reflections can be helpful for determining the **proper orientation** of the condensing lens (i.e. the steeper curvature is on the examiner's side), when facing the proper direction, the two reflections will be approximately equal in size. When opposite to this, one reflection will be significantly larger than the other. To help assist with proper orientation, modern condensing lenses have a silver or white ring painted on the edge of the lens holder's flange that faces the patient.

Excessive **lens tilt will induce astigmatic distortion** of the fundus image and should be avoided. However, this can be advantageous when viewing the peripheral fundus. By inducing astigmatism with the condensing lens at 90 degrees to the astigmatism produced during observation of the fundus periphery, it is possible to reduce peripheral optical distortions. The degree of induced astigmatism increases with greater lens tilt, and the observer can vary the tilt to obtain the clearest focus. Considerable practice is usually required before one becomes comfortable with the technique.

Peripheral viewing could be a problem**.** When viewing the periphery, the pupil becomes elliptical and much smaller in diameter along the short-axis. This may make it impossible to direct both viewing beams and the illumination beam into the patient's pupil. This can be remedied by tilting the observer's head 45 degrees, which may allow the illumination beam and one viewing beam to enter the pupil. This will eliminate stereopsis, but will allow a more peripheral view of the fundus. Also, it is helpful to increase the viewing distance when examining through a small pupil by moving farther away from the condensing lens; the closer one is to the pupil, the less the chances of intercepting the angle of exiting rays.

Advantages of indirect ophthalmoscopy

1. Larger field of retina is visible. There is a 10-fold increase in the area of retina visible as compared to direct ophthalmoscopy.
2. Lesser distortion of the image of the retina.
3. Easier to examine, if the patient's eye movements are present and with high spherical or astigmatic refractive errors.
4. Easy visualization of the retina anterior to the equator, where most retinal holes and degenerations exist.
5. It gives a 3-D stereoscopic view of the retina with considerable depth of focus.
6. It is useful in hazy media because of its bright light and optical property.

Disadvantages of indirect ophthalmoscopy

1. Magnification in indirect ophthalmoscopy is 5 times, whereas in direct ophthalmoscopy it is 15 times.
2. Indirect ophthalmoscopy is impossible with very small pupils.
3. The patient is usually more uncomfortable with the intense light of indirect ophthalmoscope and with scleral indentation.
4. The procedure is more cumbersome, requires extensive practice both in technique and in interpretation of the images visualized.
5. Reflex sneezing can occur on exposure to bright light.

Effect of prolonged indirect ophthalmoscopy on patient's eye

Does prolonged indirect ophthalmoscope viewing affect eyes of patient? This is a commonly asked question by the patients before repeated examinations. Many technical advances in light sources have been made in modern ophthalmoscopes. These light sources can deliver high-intensity light to the subject's eye. A study by Robertson and Erickson of prolonged indirect ophthalmoscopy on human eyes failed to reveal any long-term retinal damage. However, there were some **short-term changes** consisting of irregular bending and twisting of photoreceptor outer segment and transient corneal edema. Attempts have been made to reduce the infrared radiation through the use of fiberoptics, dichroic mirrors, and tinted condensing lenses such as the Volk yellow-tinted lenses that absorb light in both blue and infrared wavelengths.

BIOMICROSCOPIC EXAMINATION OF FUNDUS

Biomicroscopic examination of the fundus can be performed after full mydriasis, using a slit-lamp and any one of the following lenses.

1. HRUBY LENS BIOMICROSCOPY

Hruby lens (Fig. 4.20A) is a planoconcave lens with dioptric power 58.6 D which neutralizes the optical power of the normal eye (160 D) and forms a virtual, erect image of the fundus (Fig. 4.20B). This lens provides a small field with low magnification and cannot visualize the fundus beyond equator.

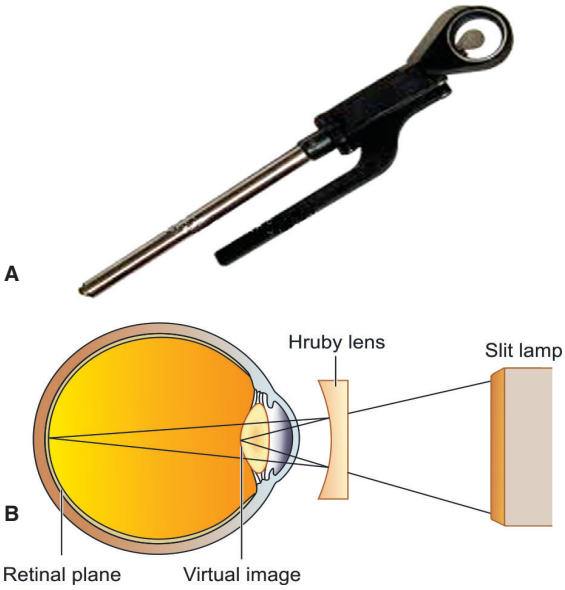


Fig. 4.20: *(A) Hruby lens; and (B) optics of Hruby lens.*

2. CONTACT LENS BIOMICROSCOPY OF FUNDUS

Contact lens biomicroscopy combines stereopsis, high illumination and high magnification with the advantages of slit-beam. Following lenses are available for contact lens biomicroscopy of the fundus.

Modified Koeppe lens examination

Modified Koeppe lens, i.e. posterior fundus contact lens (Fig. 4.21A) can be used to examine the posterior segment. It provides a virtual and erect image (Fig. 4.21B).

Goldmann's three-mirror contact lens examination

Goldmann's three-mirror contact lens (Fig. 4.21C) consists of a central contact lens and three mirrors placed in the cone, each with different angles of inclination. With this, the central as well as peripheral parts of the fundus

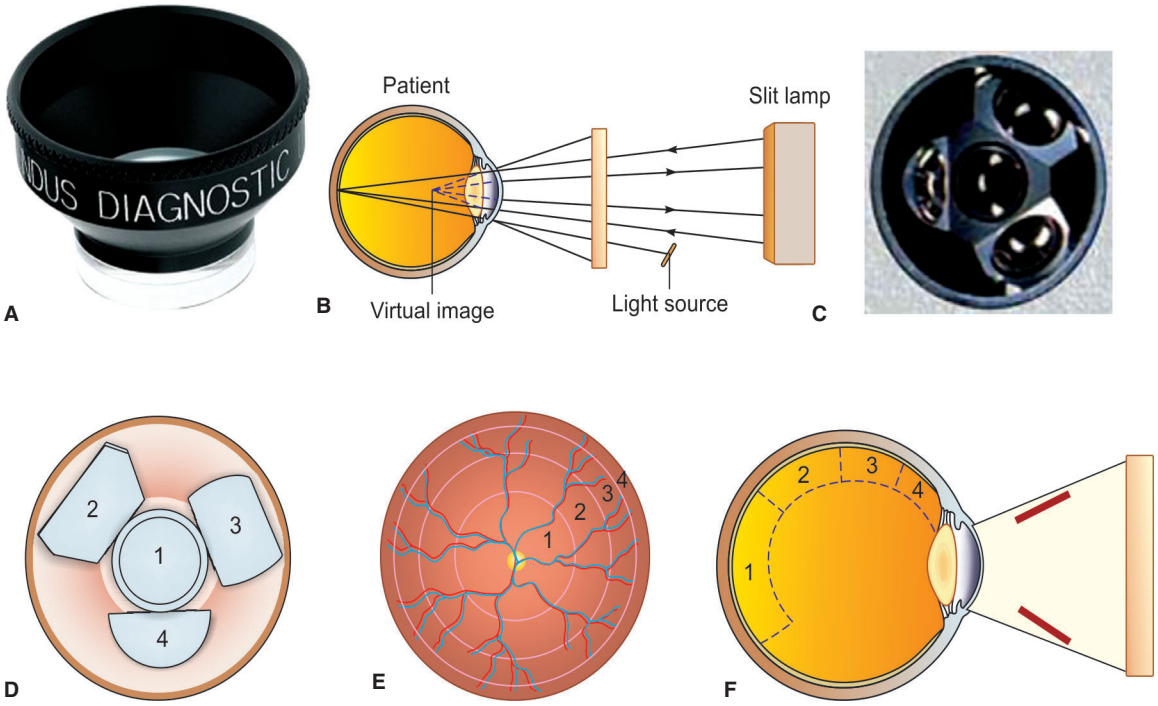


Fig. 4.21 *Contact lenses for biomicroscopy of fundus: (A) Modified Koeppe lens; (B) optics of contact lens biomicroscopy; (C) Goldmann's three-mirror contact lens; (D) front view of the Goldmann's three-mirror lens with its four optical surfaces (1, for central posterior pole; 2, for equatorial area; 3, for anterior peripheral fundus; 4, for ora serrata and pars plana); (E) diagrammatic projection of viewing range for each component of Goldmann lens; and (F) panoramic diagram of specific viewing range for each lens component.*

can be visualized. It also provides a virtual and erect image (Fig. 4.21B).

Technique

- Dilate the pupils as for indirect ophthalmoscopy.
- Instill topical anaesthetic drops.
- Insert coupling fluid into the cup of the contact lens, but do not overfill.
- Ask the patient to look up, insert the inferior rim of the lens into the lower fornix and press it quickly against the cornea.
- Always tilt the illumination column except when viewing the 12 o'clock position in the fundus (i.e. with the mirror at 6 o'clock).
- When viewing the different positions of the peripheral retina, rotate the axis of the beam so that it is always at right angles to the mirror.
- To visualize the entire fundus, rotate the lens for 3608 using the 59, 67 and 738 tilted mirrors to give views of the peripheral retina, the equatorial fundus and the area around the posterior pole, respectively (Fig. 4.21D to F).
- To obtain a more peripheral view of the retina, tilt the lens to the opposite side and ask the patient to move the eyes to the same side. For example, to obtain a more peripheral view of 12 o'clock position (with mirror at 6 o'clock), tilt the lens down and ask the patient to look up.
- Examine the vitreous cavity with the central lens, using a horizontal and a vertical slit-beam, and then examine the posterior pole.

Note. Since examination with contact lens biomicroscopy involves anaesthetising the cornea and a direct touch, so it is neither liked much by the patients nor by the examiners. Therefore, presently, fundus contact lenses are primarily used for therapeutic purposes (retinal photocoagulation, etc.) and not for diagnostic purposes except for certain special circumstances. Nowadays examination with fundus non-contact lenses is being preferred for diagnostic purposes.

Wide-field (panfundoscopic) indirect contact

Wide-field (panfundoscopic) indirect contact lenses with a field of view up to 1308 are available for fundus examination and for performing laser photocoagulation. The image produced by such lens is inverted.

3. INDIRECT FUNDUS BIOMICROSCOPY

Indirect fundus biomicroscopy, also known as non-contact fundus biomicroscopy, has become quite popular in the last decade or so—to the extent that it has become an integral part of routine eye examination. As mentioned earlier, the non-contact lenses have replaced the contact lenses for diagnostic purposes.

Fundus non-contact lenses most commonly used for indirect slit-lamp biomicroscopy are 78 D (Fig. 4.22A) and 90 D (Fig. 4.22B), but other lenses are also available (60 D, 130 D, etc.). Almost all condensing lenses used with slit-lamp are double-aspheric lenses, so it does not matter which side is held towards the patient.

Optics of indirect fundus biomicroscopy is exactly similar to that of indirect ophthalmoscopy (*see* page 72, Fig. 4.8A). Thus, a real, inverted image is formed between the condensing lens and objective lens of slit-lamp.

Magnification provided by fundus non-contact lenses is calculated by dividing power of the eye by the power of lens. For example, 90D lens provides a magnification of 60/90 = 0.66, i.e. a minification of the image. However, the magnified image is seen because of the magnification provided by the slit-lamp. Thus, 7.5X magnification seen with 90D lens (Table 4.1) is due to 10X of slit-lamp.

Field of view. High-powered lens provides larger field of view but lesser magnification, e.g. the 190 D lens provides bigger field of view but gives lesser magnification than 178D lens (Table 4.1).

Technique of indirect fundus biomicroscopy is summarized follow (Fig. 4.22C):

Tell patient about the procedure. Make patient comfortable on slit-lamp. A quick look at anterior segment is a must before any fundus examination as it could give additional information many a times. Illumination system and microscope are preferably in click position or full alignment. Adjust slit-lamp at magnification

A

B

C

Fig. 4.22: *Indirect fundus biomicroscopy: (A) 78 D lens; (B) 90 D lens; and (C) technique of examination.*

of 10X, low illumination and slit width of 2–3 mm. Give fixed target to the patient (e.g. examiner's ear for other eye). Focus slit-lamp on cornea, introduce the lens into the beam illuminating the patients eye by holding it in forefinger and thumb, using middle finger to widely open the upper lid of patient's eye or to stabilize the hand on the forehead band of the slit-lamp. Now pull slit-lamp backwards by approximately 2 inches. There is no correct direction for holding the lenses due to the aspheric nature of these lenses; either side can face the patient. Before seeing the retina vitreous must also be studied as important information can be got from it. Align the image in the center of the lens. As the image is inverted tell the patient to look in the direction opposite to the part of image what you want to view (Fig. 4.23).

Like slit-lamp biomicroscopy we can examine a lesion by direct illumination on the lesion, indirect illumination adjacent to lesion and retroillumination from reflected light from within the lesion. The contours of chorioretinal lesions are more apparent with narrow beam projected onto the lesion's surface. The contour of the thin slit gives us clue to elevation or depression for subtle lesions in addition to stereopsis (Fig. 4.24).

Start the fundus examination from the peripheral fundus to ensure patient cooperation. Inferior most part of lens corresponds to anterior most part of superior fundus. Hold the lens with index finger and thumb while the middle or ring finger is used to retract the upper lid. The suggested protocol for sequence of examination (1 to 7) of fundus is shown in Fig. 4.25. For documentation the easy way is to reverse the file and draw as you see.

To deal with reflection in line of sight we can tilt lens slightly, rotate lens around rotational

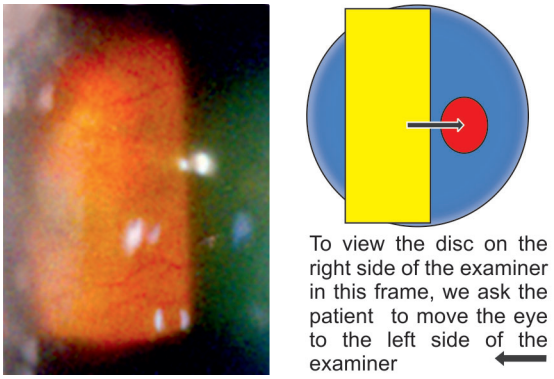


Fig. 4.23 *Align image in center of lens and to view that part of image which is not in field the patient is asked to move eye in opposite direction.*

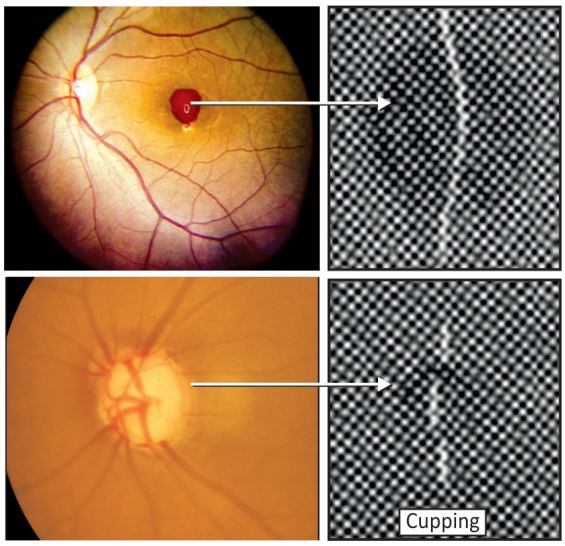


Fig. 4.24 *Kinking of narrow slit on retina helps to identify subtle contour changes in fundus.*

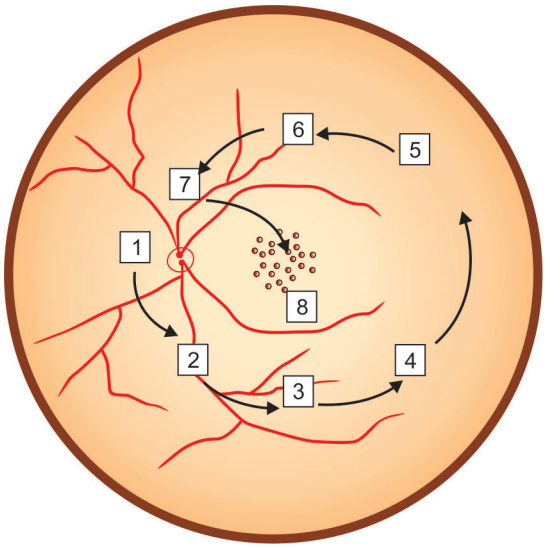


Fig. 4.25 *Suggested protocol for sequence of examination of fundus.*

axis, get illumination system slightly out of click position and further dilate the pupil (Fig. 4.26).

Certain tests like Watzke Allen sign are diagnostic for macular hole. We shine the slit of light on the hole and the patient sees kinking of slit or breaking of slit in center (Fig. 4.27).

The yellow tint lenses are also available and these filter the wavelengths below 480 nm, enhancing patient comfort and acceptance. The yellow tint may cause a slight colour shift in the appearance of the retina which could cause misinterpretation of optic nerve pallor and makes detection of the macular edema more difficult.

Interpretation

Of major importance is the description of fundus lesions, which includes colour, shape, size,

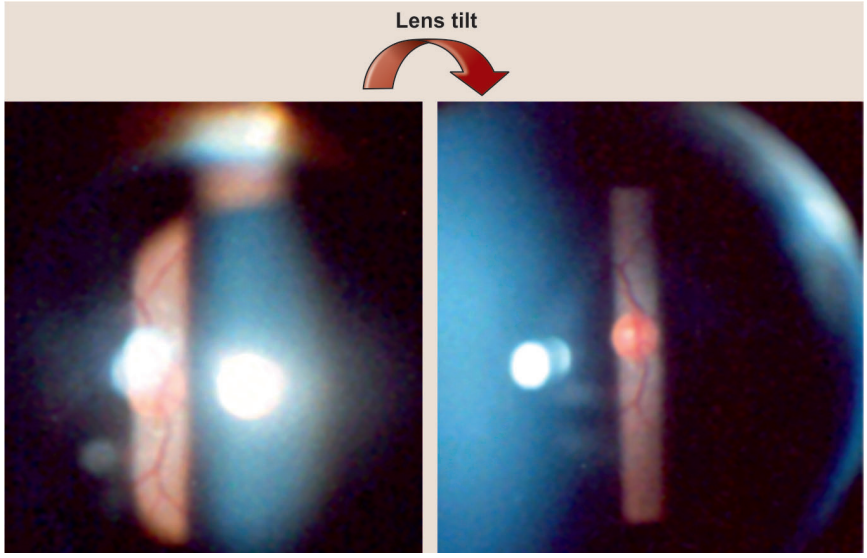


Fig. 4.26: *Demonstrating that mild lens tilt could take care of reflections causing problem in retinal examination.*

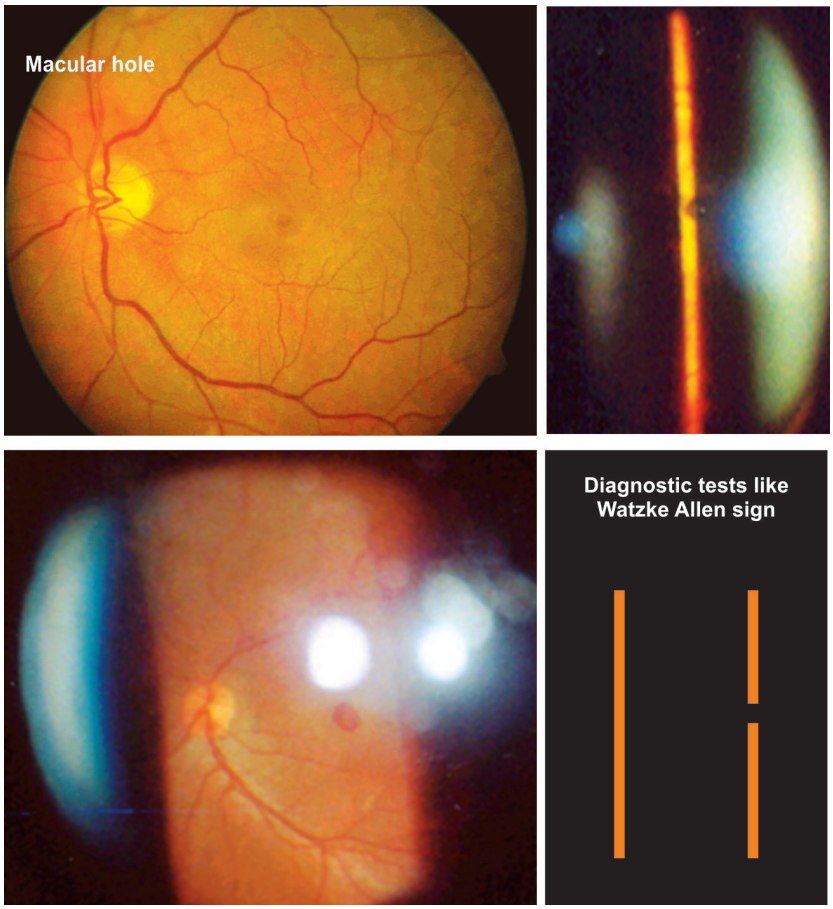


Fig. 4.27 *Watzke Allen sign in a case of macular hole could be diagnostic. The patient might identify a kink or break in continuity of the slit of light projected in the region of macular hole*

elevation, and location. Size estimation of a lesion is usually accomplished by comparing it with a structure of known dimensions, such as the optic disc.

Most fundus lesions are described relative to disc diameters (DDs) in size (e.g. a choroid nevus is "2 DDs by 3 DDs"). This is often done by viewing the optic disc first and then quickly relocating the lesion and comparing the two. Since, the horizontal diameter of a normal optic disc is 1.5 mm, it is possible to translate DDs into millimetres. For future comparison, the size of a lesion can also be compared with the reticle dimensions in direct ophthalmoscope projected on the fundus.

USES OF DIFFERENT FUNDUS EXAMINATION LENSES

Uses of different fundus examination lenses are summarised in Table 4.4.

FUNDUS CAMERA

OPTICAL PRINCIPLE

All fundus cameras are technically indirect ophthalmoscopes, and currently they are all based upon the principles of Gullstrand's ophthalmoscope. That is, the illumination and observation pathways pass through different portions of the patient's pupil to avoid reflections from the cornea and from the surfaces

Table 4.4 *Uses of different fundus examination lenses*

Lens	*To view and laser*	*Image*	*Relative mag*	*Spot mag*	*Field view*
Goldman	Macula equator periphery	Virtual erect	1.00	1.08	36°
Volk area centralis	Macula equator	Real inverted	1.13	0.95	82°
Mainster standard	Macula equator	Real inverted	1.03	1.05	90°
Mainster widefield	Equator periphery	Real inverted	0.73	1.47	125°
Volk quardr Aspheric	Equator periphery	Real inverted	0.56	1.82	130°
Volk superquad	Equator periphery	Real inverted	0.56	1.92	160°
Panfundoscope	Equator periphery	Real inverted	0.76	1.41	120°

of the crystalline lens. Also, an inverted aerial image of the fundus is formed within the fundus camera, and this aerial image, in turn, is reimaged onto the film plane.

OPTICAL SYSTEM

The optical system of the fundus camera thus consists of two major components: the illumination system and the observation and photography system. Each of these components occupies its own independent pathway within the apparatus and shares with the other only one common point, the front or ophthalmoscopic lens (Fig. 4.28).

Illumination system

The fundus cameras employ two light sources: a low-intensity incandescent lamp for viewing the fundus and focusing the instrument and a high-powered electronic flashtube for taking the

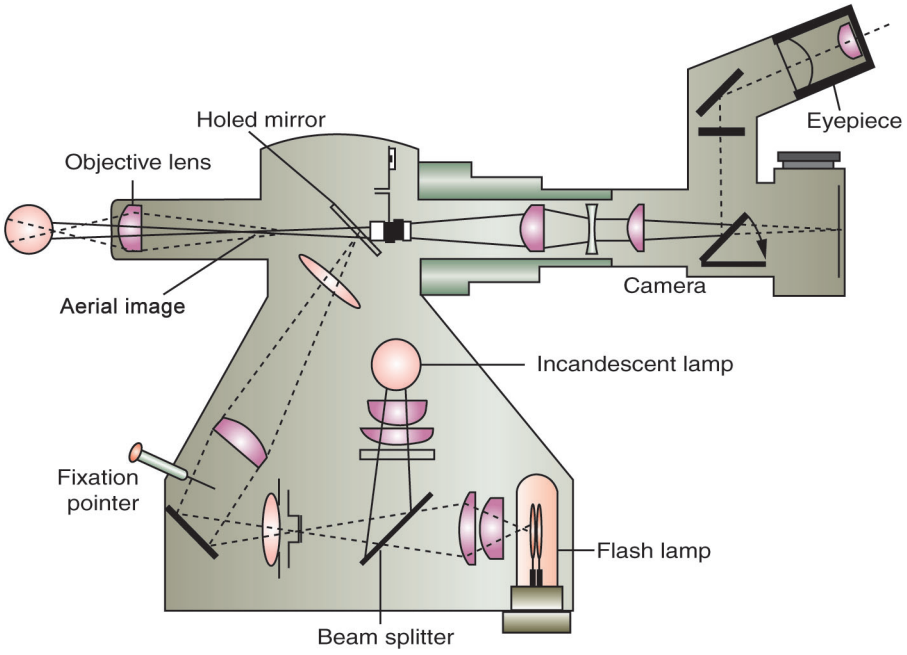


Fig. 4.28: *Schematic view of the Zeiss fundus camera to show outlines of the optical system.*

photograph. In the Zeiss fundus camera, these two light sources are optically combined through the semireflecting surface (Fig. 4.28). In most of the other commercially available fundus cameras, the incandescent lamp and electronic flashtube are mounted onto a common base, and a transillumination method is used to combine the pathway of the two lights.

From this point onwards, the light from two light sources following a common pathway passes through a diaphragm, the adjustment of which controls the size of illuminated patch upon the patient's retina. This diaphragm is imaged at the surface of a holed mirror, which is itself imaged by the ophthalmoscopic lens in the plane of the patient's pupil. These two optical elements confine the illuminating beam to an annulus (a ring of light), the width of which is controlled by the diaphragm.

Observation and photographic system

The holed mirror, which is imaged by the ophthalmoscope lens in the plane of the patient's pupil, forms the entrance pupil of the viewing system. It confines the viewing beam to central region of the pupil. It also confines the illuminating beam to an annulus that surrounds the viewing beam. The illuminating and viewing paths are, therefore, separated in the plane of the patient's pupil, thereby making the instrument reflex-free.

The ophthalmoscopic lens produces an image of the fundus between the holed mirror and the ophthalmoscopic lens. This image is viewed through the hole with a compound microscope. The objective of this microscope forms an image of the fundus, via a flip mirror, upon the ground glass screen that is placed at the focal point of the viewing eyepiece. When the photograph is taken, the flip mirror that diverts the image into the eyepiece for observation swings out of the optical pathway, thus permitting the image to be projected on to the film for photography (Fig 4.28).

The photographic component of the early instruments consisted of a small film carrier and a shutter mechanism. However, with the advent of fluorescein angiography, the simple film carrier has been replaced by a sophisticated, electronic motorized 35 mm camera system.

MODIFICATIONS IN FUNDUS CAMERA

1. ***Fluorescein angiography system.*** Fundus cameras have been modified for fluorescein angiography by addition of appropriate filters in the illumination and observation pathways (Fig. 4.29). Special power supplies are necessary to allow multiple exposures per second.

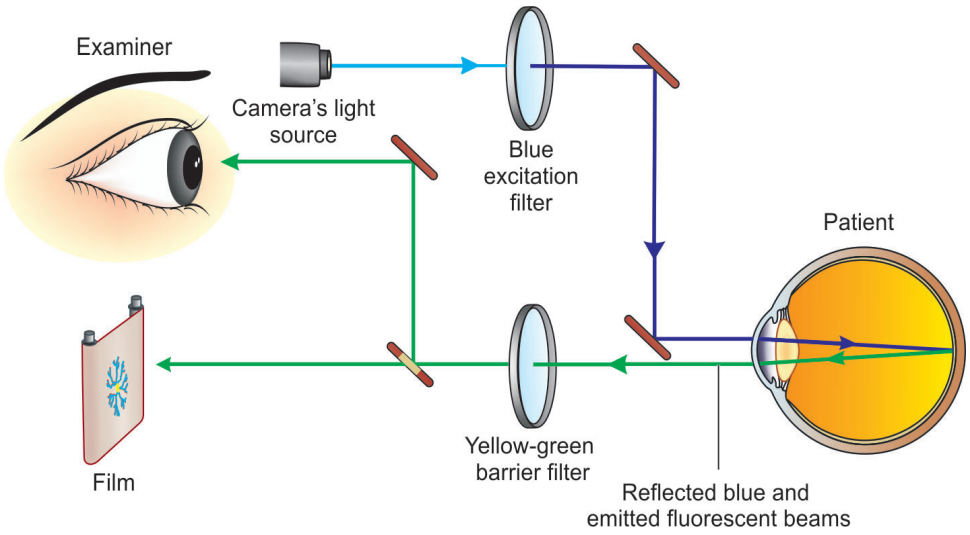


Fig. 4.29: *Blue excitation filter in the fundus camera produces blue light, which excites the unbound fluorescein molecules. The reflected blue light is absorbed by the yellow-green filter allowing only the fluoresceing particles to be recorded on the film.*

2. ***Digital fluorescein angiography system***. Recently, digital fluorescein angiography (DFA) is being used increasingly. The DFA system uses a CCD detector in the camera in place of a film. One of the commercially available digital fluorescein angiography system manufactured is shown in Fig. 4.30.

Advantages of DFA

- The images can be instantaneously viewed on a high-resolution monitor. This allows the observer to manipulate the parameters (e.g. light intensity, centration of photography) while the study is in progress to obtain the optimum image.
- The images are recorded either on a computer hard drive or CD-ROM. The electronic recording allows immediate viewing of images and permits prompt management of the disease process.
- The angiograms can be electronically transmitted or printed form the digital data.

Disadvantage of DFA

The quality of the DFA is inferior to the film-based photographs; however, it is adequate for clinical purposes.

3. ***Wide-field digital fundus fluorescein angiography*** has also been introduced, specially for use in children.

4. ***Non-mydriatic fundus cameras.*** These use infrared light and semi-automatic or automatic focusing systems to allow fundus photography without dilating drops. The infrared light is invisible to the patient, and the pupil dilates physiologically. After alignment and focusing are completed, the white light flash is triggered, and the photograph is taken before the pupil has a chance to constrict.

Fig. 4.30: *Digital fluorescein angiography system.*

5. ***Wide-angle fundus cameras*** up to 608 have appeared, having large diameter and aspheric objective lenses. Wide-angle photographs even up to 1488 are possible, but a contact type of objective lens and special illumination system are necessary for such photographs.

6. ***Television ophthalmoscopy.*** Several attempts at television ophthalmoscopy have been made, using fundus camera optics. In general, excessive illumination is required, and resolution is poor.

7. ***Scanning laser ophthalmoscopy.*** A promising new system is the SLO, where only a single spot of laser light is scanned over the fundus, with each point being recorded as it is illuminated. The primary advantage of this system is the extremely low level of total light required. (For details *see* page 74).

WIDE-FIELD RETINAL IMAGING SYSTEMS

Wide-field retinal imaging systems have been developed with the capability of capturing up to 2008 field of view with one picture as compared to only 30–608 field of view with current standard fundus photography system. The salient features of the following three commercially available wide-field retinal imaging systems are described here in brief:

- Retcam II and III
- Panoret 1000AA
- Panoramic 200

RETCAM II AND III

Retcam II (Retinal camera II) is the advanced version of Retcam 120 (manufactured by Massie Research Lab., Dublin, CA).

Components of Retcam II. It is a mobile wide-field digital imaging system comprising following major components (Fig. 4.31):

- *Three-chip CCD medical grade digital video cameras* is the heart of Retcam II. It is

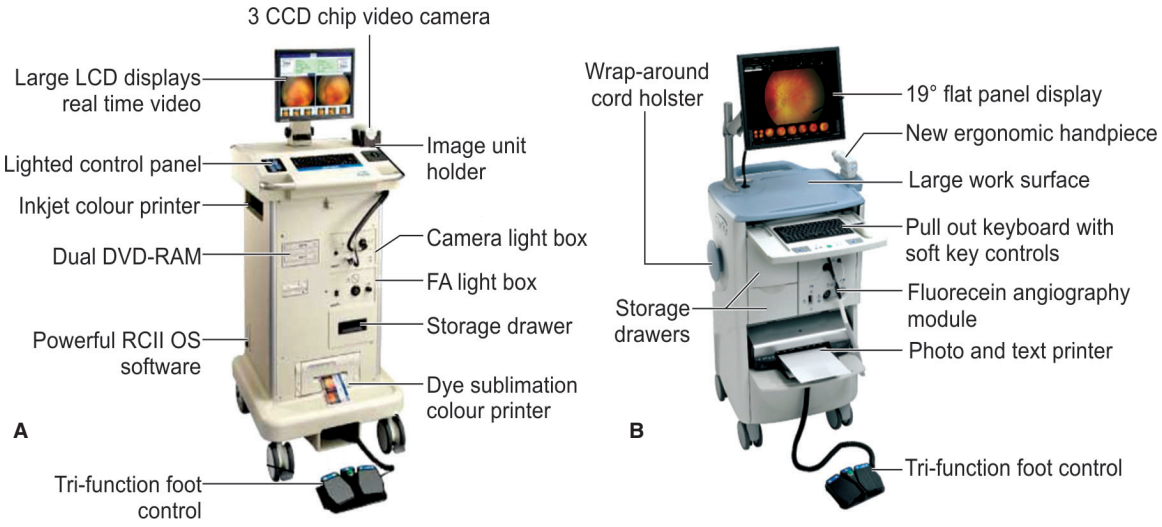


Fig. 4.31: *(A) Retcam II, the wide-field retinal imaging system; and (B) Retcam III.*

lightweight (so easy to position) and is attached to the light source and image capture unit.

- *Hand-held image capture unit* is attached with the camera by a long cable for easy patient access.
- *High-index corneal contact lenses* form the essential part of the image-capturing unit. These lenses allow capturing of oblique rays emerging from the peripheral retina. The changeable lenses (nose pieces) available to be attached to the image-capturing unit of Retcam II are as follows (Fig. 4.32):

ROP (retinopathy of prematurity) lens, for premature infants which allows 1308 field of view.

Standard children lens, a 1208 field-of-view lens for pediatric to young adult patients.

High magnification lenses, a 308 field-of-view lens for fine details.

808 *lens* for higher contrast pediatric and adult imaging.

Portrait lens or external lens for area or external imaging.

- *Image processing unit, comprises* a Windows or T computer system which gets the information from the camera. This unit is equipped with a new multipurpose software.
- *Flat LCD colour display* on 17 inch monitor allows the images to be viewed in real-time motion during acquisition.

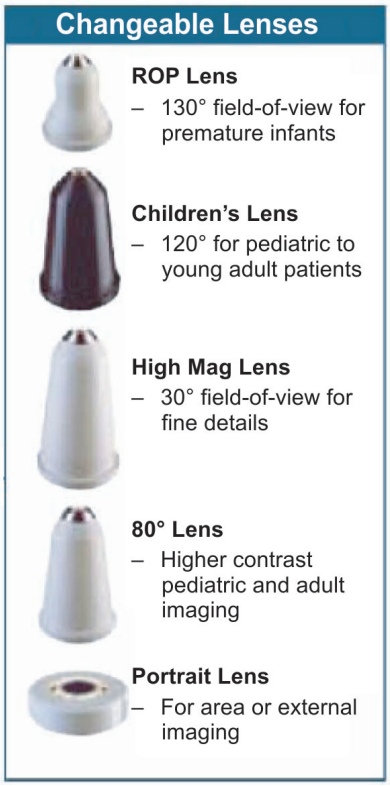


Fig. 4.32: *Changeable high-index lens available for attaching with image-capturing unit of Retcam II.*

- *Tri-function foot control* connected to the camera controls image focus, illumination and capture.

Special features of Retcam II

- *Cone-shaped lens* provided with it is very handy to hold while scanning the retina.
- *Wide, 130 and 120°, real-time image* of the fundus is particularly useful in diagnosis and documentation of diseases such as retinoblastoma and ROP.
- *Images are stored in digital format*, thus are retrievable easily.
- *Camera has a large storage device* with good facility of transferring the images in other media like CD, USB and in other DVD device. The data can be shared with others for seeking an opinion.
- *Comprehensive database* keeps track of each imaging section for the patients, allowing for later or side by side review of the cases. This is particularly useful in assessing response to treatment as in chemoreduction for retinoblastoma and laser photocoagulation for ROP.
- *Fluorescein angiography can also be performed with it*. It is another major feature of this equipment. It is provided with a barrier filter, which helps to take the angiogram by still mode and continuous video for 20 seconds.
- In-built colour printer allows the print images and the detailed case report of the patient.

Features of Retcam III

Additional features of Retcam III (Fig. 4.31B) are summarized below.

Procedure

It involves following steps:

- *Pupils* are dilated fully.
- *Anaesthesia*. Neonates and infants can be easily examined under topical anaesthesia achieved with proparacaine eyedrops. Older children may be given short-term sedation for the procedure.
- *Separation of lids* is done with the help of a pediatric lid speculum, after placing the patient in supine position.
- *Fixation of the head* is then achieved.
- *Coupling solution* like methylcellulose gel is applied to the cornea.
- *Image capture unit* with desired lens is then positioned with gentle contact to the anterior corneal surface. Illumination and focus are controlled by the operator with the foot switch. Often a quick scan of the entire retina can be performed in live video motion before acquisition of images. Once the desired field of view has been identified, the images can be captured with the foot switch control.

Limitations of retcam

- *Pupillary dilation* is extremely important for it, so not useful where pupillary dilation is a problem.
- *Other limitations* include need for camera lens–cornea contact, need for eyelid speculum and technical limitations of the camera.
- *Lack of stereopsis* and some loss of magnification of retinal field in exchange for a wide-angle field of view may also be seen as a limitation.
- *Cannot be used in adults* because with lens opacities that begin in adolescence and accumulate with age, the entering light is scattered more widely, causing decreased contrast sensitivity.

Advantages

- *Mobile, self-contained system* for use in nursery, ICU, operating rooms, etc.
- *Easy to use*—even technicians or nurses can operate.
- *Avoids stress and expertise* of indirect ophthalmoscopy and scleral indentation.
- *Interobserver variability* is eliminated.
- *Teaching tool for students*, and parents can be counselled.
- *Easy case management* with access to images, video clips, patient data, instant retrieval and side by side comparison.

Applications of wide-field imaging system

- *Paediatric retinal disorders* can be easily diagnosed, followed and objectively documented. Especially useful in ROP, retinoblastoma, shaken baby syndrome.
- *Pediatric anterior segment imaging*, gonioimaging for glaucomatous damage, iris lesions.
- *Fluorescein angiography* can also be performed with advances in the technique.

PANORET 1000 AA

Principle

This wide-field imaging system employs the principles of trans-scleral illumination propagated by Pomerantzeff.

Advantages

Because a trans-scleral light source provides diffuse illumination, so this system:

- Can be used in the presence of media opacities
- Can be used in cases where pupillary dilation is a problem
- Can also be used in adults
- Both fluorescein angiography and indocyanine green angiography can also be performed.

Limitations

- Patients with heavily pigmented uvea are not well-imaged.
- Since, it is introduced recently, so there is limited clinical experience with its use.

PANORAMIC 200 NON-MYDRIATIC SLO

Principle

It is a non-contact non-mydriatic system-based on the use of both a green (532 nm) and red (633 nm) laser to produce a digital image of 2000 by 2000 pixels. The resolution of image ranges from 20 to 40 m per pixel.

Applications

It is often used as a screening tool for diabetic retinopathy, age-related macular degeneration (ARMD) and glaucomatous disc changes.

Advantages

Field of view is 2008 in a single image.

Limitations

Being a table-mounted non-mobile unit, it cannot be used in small children and uncooperative patients.

LASER SCANNING IMAGING TECHNIQUES

- Scanning laser ophthalmoscopy
- Confocal scanning laser ophthalmoscopy
- Retinal thickness analyser
- Scanning laser polarimetry

SCANNING LASER OPHTHALMOSCOPY (SLO)

The scanning laser ophthalmoscopy was invented by Webb, Pomerantzeff and Hughes in 1979. The word scanning here refers to the illumination system, which samples the retina point by point rather than capturing the image as a whole, as is done with a conventional fundus camera.

Principle

The SLO operates essentially as an inverted indirect ophthalmoscope. This means that a small illumination aperture is used to illuminate the eye while a large viewing aperture collects all the light emitted by the eye (Fig. 4.33). The small aperture creates a very narrow moving beam of light which can bypass most ocular media opacities (i.e. corneal scars, cataracts, vitreous hemorrhage) to reach the surface of the retina and record its surface detail. A live video image of the retina is displayed on a computer monitor and test results are digitally recorded (Fig. 4.34).

Applications of SLO

1. ***Scanning laser acuity potential test.*** The letter E corresponding to different levels of visual acuity (ranging from 20/1000 to 20/60) is projected directly on the patient's retina. The examiner can direct the test letters to foveal and/or extrafoveal location within the macula and determine a subject's potential visual acuity.

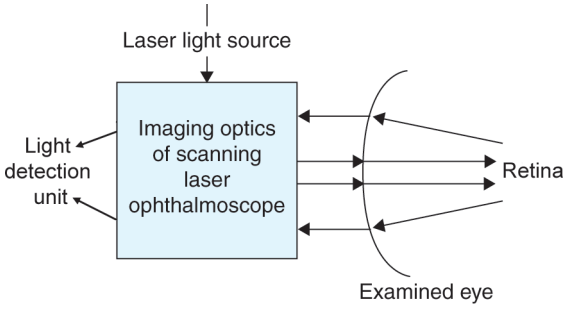


Fig. 4.33: *Optics of scanning laser ophthalmoscope as inverted indirect ophthalmoscope. Note that the light enters the eye through a small illumination aperture and the returned light is collected over a large viewing aperture.*

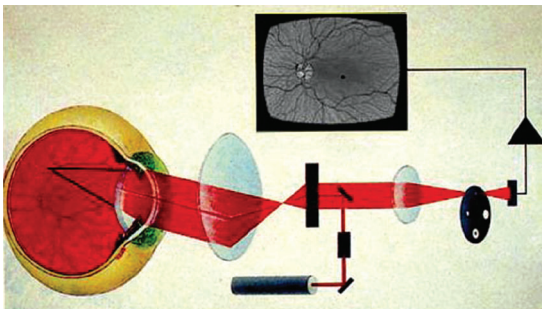


Fig. 4.34: *Optical path of recording of scanning laser ophthalmoscope (SLO).*

This may be especially helpful in individuals who have lost central fixation but who may still possess significant eccentric vision. It is also useful in separating out the component of retinal function from anterior segment contributions to overall visual dysfunction when contemplating surgical interventions.

2. ***Microperimetry/scotometry***. The SLO can visualize a particular area of the retina and test its sensitivity to visual stimuli, thereby generating a map of the seeing and non-seeing areas. If central vision is lost, the patient can potentially be trained to use an adjacent retinal site to substitute for central visual function.

3. ***Hi-Speed FA/ICG***. Fluorescein and indocyanine green angiography (FA/ICG) performed using the SLO is recorded at 30 images per second, producing a real-time video sequence of the ocular blood flow. The standard fundus camera sequence is limited by flash recycling to one to two frames per second, and is unreliable in its ability to document details of choroidal filling which occurs over a 1–2-second span of time.

The higher speed of image acquisition more completely captures the chorioretinal filling sequence, and can be used to accurately identify the choroidal feeder vessels of neovascular membranes. Guided by high-speed FA/ICG results, laser treatment of sight-threatening diseases like exudative ARMD can be carried out with pinpoint accuracy.

SLO versus conventional fundus camera

1. SLO samples the retina point by point while the fundus camera captures the image as a whole.
2. In SLO, a single point on retina is illuminated for less than 1,000,000th of a second while the conventional fundus camera illuminates the eye for several milliseconds during flash capture.
3. The SLO captures a temporal image while conventional fundus camera captures a spatial image.
4. In SLO, light source is always laser, so it can achieve white light imaging comparable to conventional white light fundus photography.

Advantages of SLO over conventional fundus camera

- Low light level
- Highly light efficient
- Continuous imaging
- Large depth of field
- Instantaneous image availability for review
- The high capture speed allows dynamic image studies such as blood flow
- Allows excellent imaging even in the presence of media opacities.

CONFOCAL SCANNING LASER OPHTHALMOSCOPY

The confocal scanning laser ophthalmoscopy, or CSLO, also known as scanning laser tomography, or SLT, was introduced by Webb and associates in 1987. The term *confocal* has been derived by combining the terms *conjugate* and *focal*, and it describes that the locations of the focal plane in the retina and the focal plane in the image sensor are located in conjugate positions. Confocality of the system is achieved by placing a pinhole in front of the detector, which is conjugate to the laser focus (Fig. 4.35). The size of the pinhole determines the degree of confocality, such that a small pinhole aperture will give a highly confocal image. Commercially available CSLOs include:

- Heidelberg Retina Tomography (HRT)
- Top SS

HEIDELBERG RETINA TOMOGRAPHY

Heidelberg retina tomography (HRT), the most popular instrument, is available in two models–the HRT I (introduced in November 1991) and

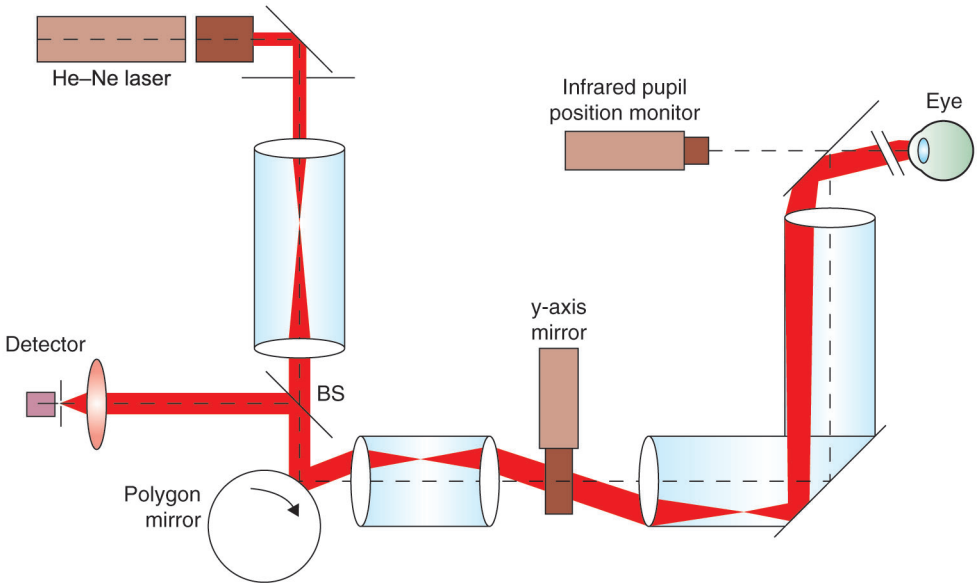


Fig. 4.35: *Optics of confocal scanning laser ophthalmoscope (CSLO).*

the HRT II C (introduced in April 1999). For both the models, the laser source is a *helium–neon diode laser* of wavelength 670 nm. The laser raster scans the x–y plane to obtain confocal optical sections of the retina. Once one plane has been scanned, the laser changes focus to scan a slightly deeper plane of the retina. This continues until a series of confocal optical sections through the depth of the fundus are obtained.

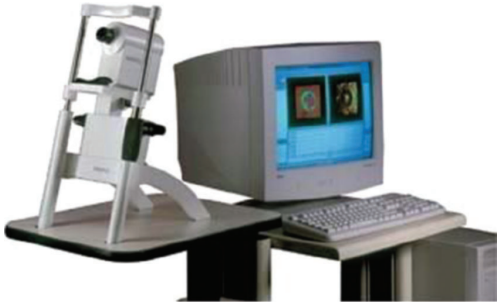


Fig. 4.36 *The Heidelberg retinal tomograph II.*

INSTRUMENT PROFILE

The instrument is small, light, portable and is table-mounted along with a notebook computer (Fig. 4.36). Press of signal button acquires optical section images within 32 milliseconds and with a repetition rate of 20 Hz two-dimensional. From the images obtained in this pre-scan of 4–6 mm depth, the software computes and automatically sets the correct location of the focal plane, the required scan depth for that eye and the proper sensitivity to obtain images with correct brightness. The Heidelberg retinal tomograph operation software automatically defines a reference plane for each individual eye. The reference plane is defined parallel to the peripapillary retinal surface and is located 50 m posteriorly to the retinal surface at the papillomacular bundle. The reason for this definition is that during development of glaucoma the nerve fibers at the papillomacular bundle remain intact longest and the nerve fiber layer thickness at that location is approximately 50 m. We can, therefore, assume to have a stable reference plane located just beneath the nerve fiber layer. All structures located below the reference plane are considered to be cup; all structures located above the reference plane and within the contour line are considered to be the rim.

ACQUISITION AND GENERATION OF TOPOGRAPHY IMAGE

HRT I

Image acquisition. The HRT I makes *32 scans through the retina resulting in a stack of optical*

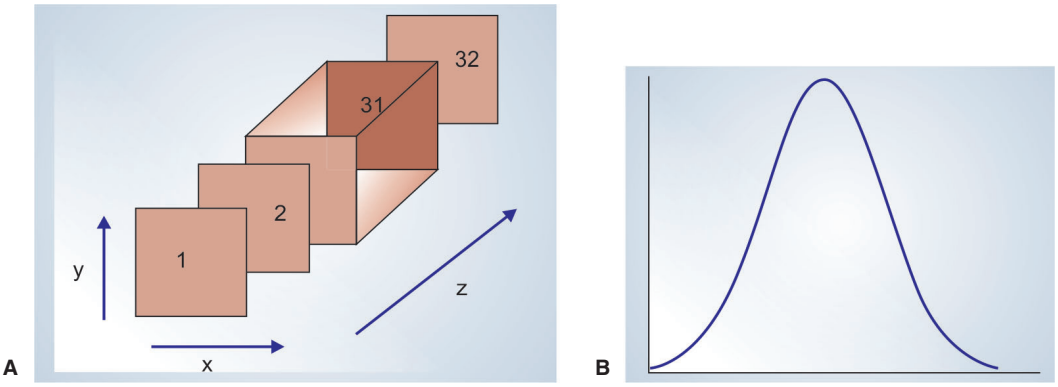


Fig. 4.37: *HRT I-image acquisition: (A) A stack of 32 image series; and (B) z-profile of pixel (x, y) in image series.*

sections which represent both an area (x–y) and depth (z) image of the retinal structure under investigation (Figs 4.37 and 4.38A). The field of view can be set to three levels—108 × 108, 158 × 158 or 208 × 208. The depth to which the laser scans varies between 0.5 and 4.0 mm in 0.5 mm steps. Thirty-two optical sections are generated at all of these depth levels, so the spacing between sections is closer at the lower depth levels and greater at the higher depth levels. The camera must be placed 15 mm from the examined eye, and the operator centers the optic disc on the monitor. The HRT I software has a quality control mechanism which informs the operator whether the image series is of good quality. Changes in focus and depth setting are advised until the series acquired is optimum. However, the operator has to examine the image series to establish whether there are any image-distorting eye movements. In such cases, the series have to be rejected. Generally, three optimum image series are obtained for each eye under examination (Fig. 4.38B). The topography images are then generated (Fig. 4.38C).

Generation of the topography image. Each confocal section of the 32-image series consists of 256 × 256 pixels. Each pixel location (x, y) has a varying brightness through the series. The distribution of reflected light intensity of each pixel through the 32 series is called the z-profile (Fig. 4.37). The z-profile is a symmetric distribution with a maximum at the location of the light-reflecting surface. By determining the position

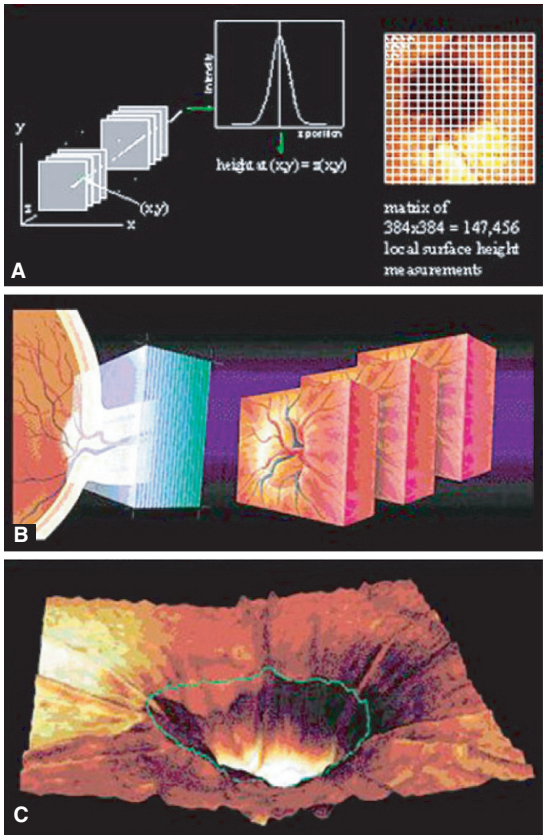


Fig. 4.38 *Principle of scanning laser tomography–concept of 3-D image composition based on 32 confocal sections: (A) A stack of 32 confocal sections (the software aligns the images but only compensates for small eye movements) the axial intensity distribution for each of the 256 × 256 pixels is plotted and the axial location of the maximum is coded into a 2-D image with 256 × 256 pixels; (B) Three separate image series acquired; and (C) 3-D image of optic nerve head.*

of the profile maximum, the height of each pixel can be determined (Fig. 4.38). The topography map is a colour-coded representation of each pixel position within the 32 series. Each of the 32 confocal sections has been designated an arbitrary red value. Section 1 is dark red, section 32 is saturated white and the sections in between decrease in redness from 1 down to 32 in equal steps.

Alongside the topography image is a reflectivity image, which gives the most visual information about the optic disc under examination similar to a fundus photo (Fig. 4.37).

HRT II

Image acquisition. The HRT II differs quite considerably from the HRT I. There is one field of view (158), and each optical section has a resolution of 384 × 384 pixels. In contrast to the HRT I, which can be used for the acquisition of both optic nerve head (ONH) and macular images, the HRT II has been designed specifically for the grabbing of ONH images alone.

In image acquisition, the operator enters the patient's details and a rough setting of the examined eye's refraction. The patient is instructed to look at an internal fixation light, which results in an automatic centration of the ONH on the monitor. The acquisition button is activated, and the CSLO proceeds with image acquisition.

An automatic pre-scan with 4–6 mm depth is performed, and from the images obtained from this pre-scan, the software computes and automatically sets the correct location of the focal plane—the required scan depth for that eye and the sensitivity to obtain images with correct brightness. Following this, the system automatically acquires three image series with the predetermined acquisition parameters. The number of image planes acquired per series depends on the required scan depth – 16 images per millimetre scan depth are acquired. There is an automatic quality control during image acquisition, and so if one or more of the acquired image series cannot be used for any reason, additional images are acquired automatically until three good quality image series have been obtained. After image acquisition, the images are saved on the hard disc and the three topography images and the mean topography image are computed automatically.

This semi-automated image acquisition of the HRT II means that in busy practice situations, staff with minimal experience of using the instrument should be able to acquire images.

IMAGE ANALYSIS AND EXAMINATION OF RESULTS

I. SLT in glaucoma

The applications of SLT in glaucoma are:

1. *Initial examination to discriminate between the normal eyes, glaucoma suspects and glaucomatous eyes*

The printout of initial report has following details (Fig. 4.39).

Topography and reflectivity image. As described earlier (Fig. 4.37), the topography image is a colour-coded map. The red areas are on the surface and the white areas are deeper in the scan (Fig. 4.39).

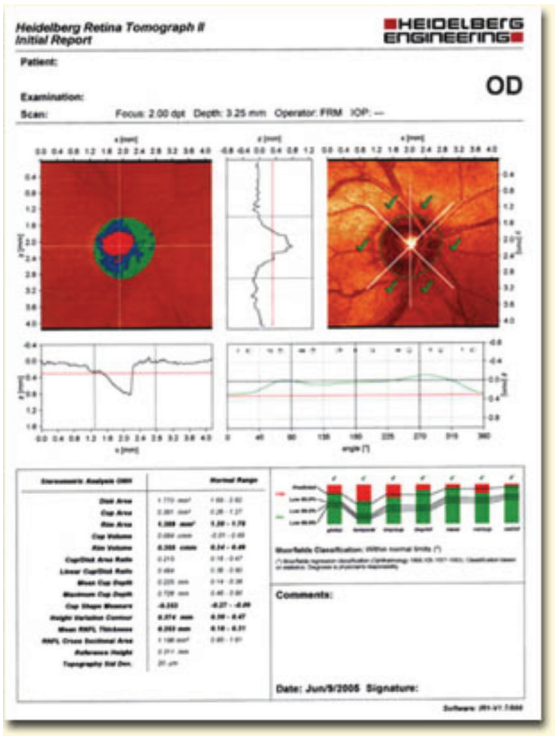


Fig. 4.39: *Initial examination report with the HRT II.*

The reflectivity image approximates a mean brightness of all images. In the reflection image, the ONH is divided into six sectors. These sectors are compared to a normal database and then classified. Moorfield's regression analysis means that the rim (green and blue) and the disc area (green, blue and red) for each sector are compared to a normal database. Depending on the patient's age and overall disc size, the eye is then statistically classified as 'within normal limit', 'borderline' or 'outside normal limit'.

Horizontal/vertical height profile, i.e. height profile along the white horizontal and the white vertical line in the tomography image. The subjacent reference line (red) indicates the location of the reference plane (separation between cup and neuroretinal rim). The two black lines perpendicular to the height profile denote the borders of the disc as defined by the contour line.

Mean height contour graph. The height difference between the reference line (red) and the height profile corresponds to the retinal nerve fiber layer (RNFL) thickness along the contour line.

Stereometric analysis of ONH. For both instruments, an operator has to define the edge of the ONH, and this is done using the mouse. Once the ONH margin, i.e. contour line which matches the inner edge of scleral ring (Elschnig's ring) has been defined, area and volumetric information about the ONH are obtained.

The result of this analysis is a set of stereometric parameters. The most important parameters are disc area, cup and rim area, cup and rim volume, and mean and maximum cup depth, a measure for the 3-D shape of the cup and for the mean thickness of the RNFL along the contour line (Fig. 4.39). Most of the stereometric parameters provided by the Heidelberg retinal tomograph change significantly with progression of glaucoma; the standard errors of the means in the visual field groups are very small, and the means differ significantly between groups. The parameters are useful, therefore, to follow the progression of the disease. But the physiologic variability of the ONH configuration is high and so are the standard deviations of the parameter values. The distributions of the parameter values of the different groups overlap each other. Hence, it is difficult (except in advanced cases) to classify an individual eye as being normal or glaucomatous, based on individual stereometric parameters.

Disc analysis with HRT II—Moorfield's analysis feature. Once the contour line has been drawn, there is the option of using the Moorfield's regression feature. This compares the optic disc imaged to a normal database and predicts the normality of the disc.

Variability in acquisition can occur due to manual contour line drawing, inter- and intratest examinations. To overcome this, Moorfield's study revealed the advantage of examining the rim area in sectors. This graphic visualizes the result of the Moorfield's regression analysis. The whole column represents the total ONH area in this specific sector. It is divided into the percentage of rim area (green) and percentage of cup area (red). The age-dependent limits of the confidence intervals are as follows:

- If the percentage of the rim is larger than or equal to the 95% limit, the respective sector is classified as 'within normal limit'.
- If the percentage of the rim is between the 95 and the 99.9% limits, the respective sector is classified as 'borderline'.
- If the percentage of the rim is lower than the 99.9% limit, the respective sector is classified as 'outside normal limit'.

2. Follow-up examination to study the progression

Glaucoma is a progressive disease, and there is significant individual variability which makes labelling an eye glaucomatous after one single test hazardous. Therefore, proven progression of the disease becomes critical to the diagnosis and management. The baseline measurements are extremely important, since those parameters alone are taken for further retesting. Therefore, the image quality (as ascertained by standard deviation) should be good and it should be ensured that ONH is centered, illumination is even, refractive error is incorporated and eye

movements are minimal. It is claimed that disc changes are more frequent than field changes. Progression requires three consecutive readings (Baseline 1 three follow-up) to perform a topographic change analysis.

Topographic change analysis can be done by two methods:

i. *Change probability maps* (Fig. 4.40) are independent of the reference plane and the contour line and are calculated automatically, comparing mean topography images.

- Red signifies 'significant' depression.
- Green signifies 'significant' elevation.
- The change is calculated by local change in surface height, measured in microns, at the location selected. A height change is considered significant:

If it is repeated in at least two (better is three) consecutive follow-up examinations.

If it is region of at least 20 connected superpixels.

ii. *Parametric change* is evaluated in the follow-up diagram that plots normalized stereometric values versus time. If average normalized parametric value decreases by more than 20.05 significant in two consecutive examinations, it is deemed 'suspected' and if it appears in three consecutive examinations, it is considered 'confirmed' progression (Fig. 4.41).

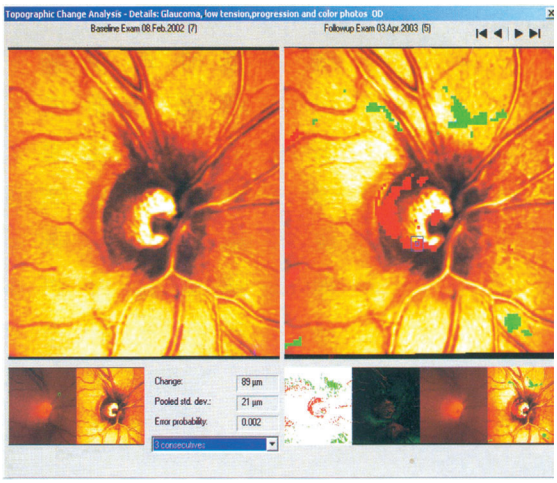


Fig. 4.40: *Change probability maps.*

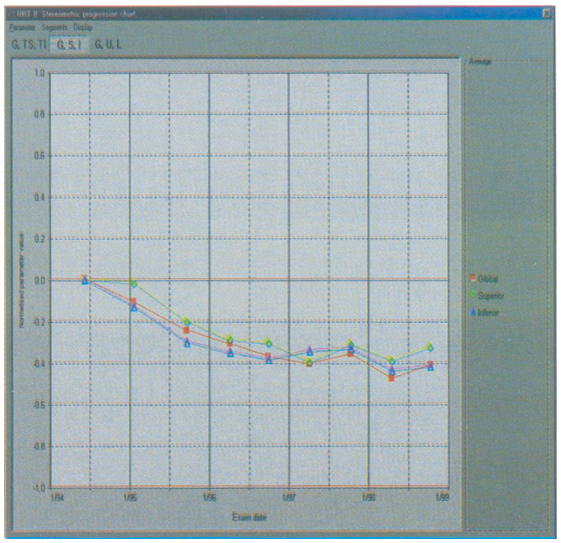


Fig. 4.41: *Parametric changes.*

Frequency of examinations. Time determines the speed of progression, and repeated examinations cannot detect disease. High-risk cases on basis of race, age, family history and raised intraocular pressure should undergo a 6 monthly examination and other patients may be followed up annually. Examinations may be done more frequently for the first 18 months in patients showing signs of clinical progression so as to start detecting statistical 'change'.

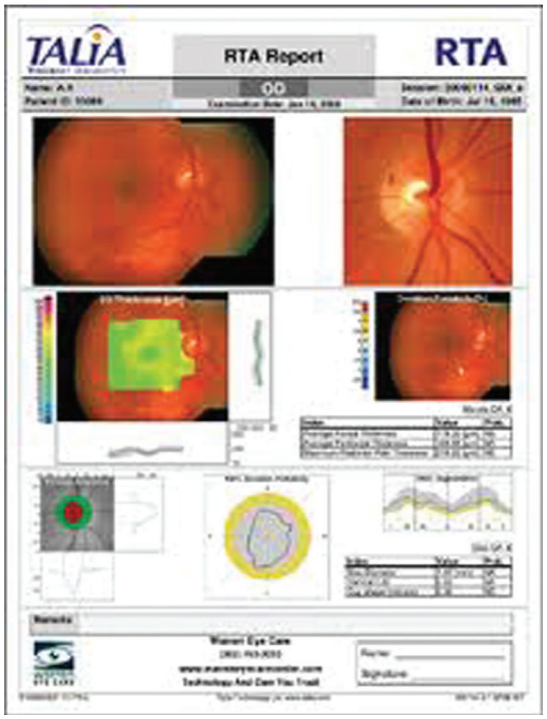
II. SLT in macular diseases

Researchers have developed a software algorithm that analyses the axial intensity distribution and computes a thickness-equivalent map of the retina. This is useful in macular pathologies such as macular edema or macular cysts. The researchers concluded that this analysis offers non-invasive, objective, topographic and reproducible index of macular retinal thickening. The scanning laser thicksness analyser using HRT II uses 147, 456 points while in OCT only 600–768 points are used.

RETINAL THICKNESS ANALYSER

Retinal thickness analyser (RTA) from Talia Technology (Fig. 4.42A) is an ophthalmic imaging device for the mapping and quantitative measurement of optimal thickness and disc

A



B

Fig. 4.42: *(A) Retinal thickness analyser (RTA); and (B) Talia, RTA report printout (Courtesy: Talia Technology).*

topography (Fig. 4.42B). It uses a computerized laser slit-lamp to measure retinal thickness at the central 208 of the macula, and overlaps a map of measurements on the patient's retinal image.

A vertical narrow green He–Ne (543.3 nm) laser slit-beam is projected at an angle on the retina while a CCD camera records the back-scattered light. Due to the oblique projection of the beam and the transparency of the retina, the backscattered light returns two peaks corresponding to the vitreoretinal and the chorio-retinal interfaces. A 3 × 3 × 3 mm scan consisting of 16 optical cross-sections is acquired within

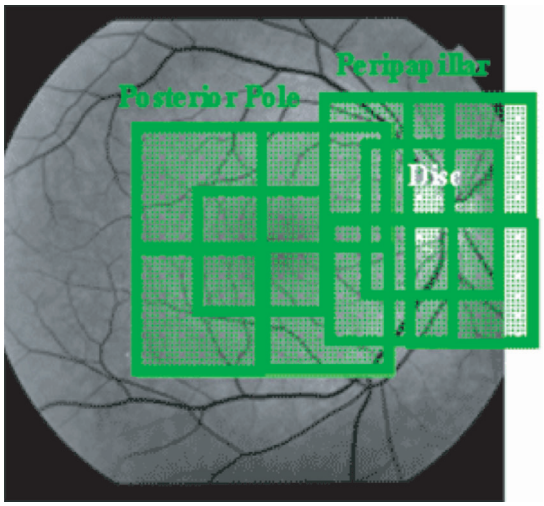


Fig. 4.43: *Thirteen RTA-scanned areas.*

0.3 seconds. Five such scans are obtained at the macula, three scans at the disc and additional five scans cover the peripapillary area (Fig. 4.43).

Clinical applications

Retinal thickness analysis

As the CCD camera records the reflected image of the retinal cross-sections, a thickness algorithm identifies the location of the anterior and posterior retinal borders (Fig. 4.44).

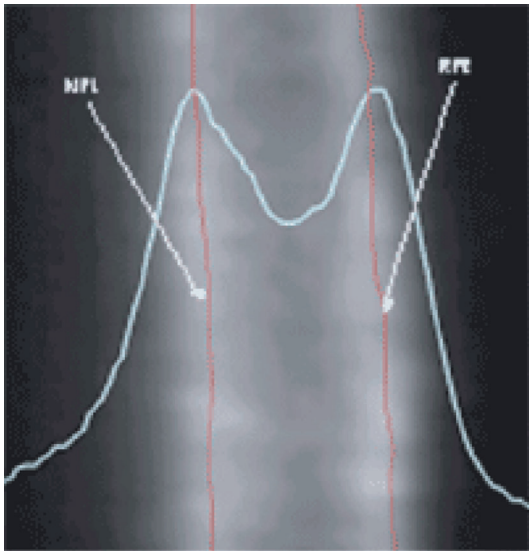


Fig. 4.44 *Light intensity profile as detected by the RTA's thickness algorithm.*

The calculated distance between the two light peaks determines the retinal thickness at a given point. The algorithm measures 16 data points on each slit, 187.5 m apart, totalling 2560 thickness measurement points.

Indications of retinal thickness analysis include:

- Diabetic macular edema
- ARMD
- Cystoid macular edema
- Macular holes
- Epiretinal membrane, etc.

ONH topography analysis

The RTA acquires three scans over the disc covering a 3 × 3 × 3 mm area. Each of the 16 slit images represents the disc topography along a vertical line. Using edge detection analysis, the topography algorithm identifies the left border of the light, corresponding to the vitreoretinal surface, and calculates the disc topography (Fig. 4.45).

In order to obtain quantitative stereometric measurements, the operator is required to draw a contour line along the disc edge. The same contour line is used in follow-up visits to ensure accurate monitoring of subtle changes. The disc topography report displays a rim/cup area map (Fig. 4.46A) and a pseudo 3-D representation of the disc topography (Fig. 4.46B).

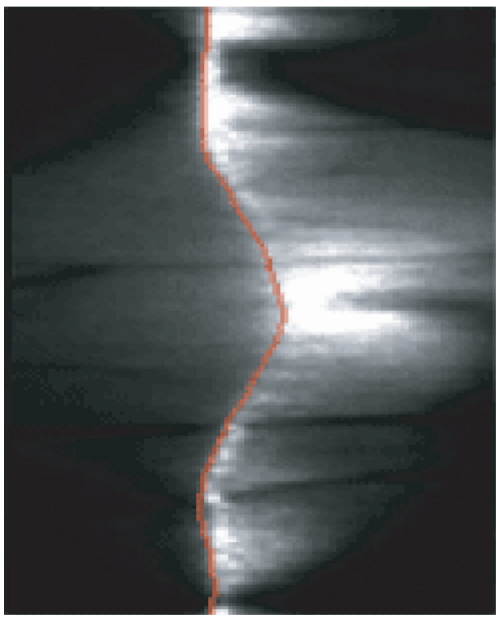


Fig. 4.45: *The vitreoretinal surface as detected by the RTA's topography algorithm.*

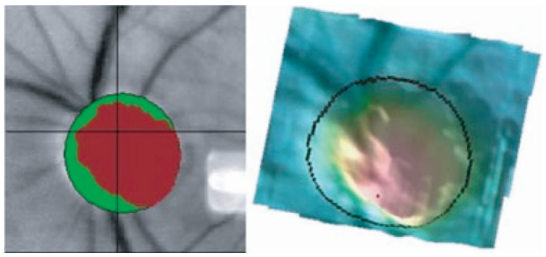


Fig. 4.46: *RTA—disc topography map: (A) Rim/cup area map; and (B) pseudo 3-D representation.*

Thus, the RTA may be used to assess the optic nerve in terms of the cup to disc (C:D) ratio as well as other ONH parameters. It is also able to monitor progression of nerve fiber layer thinning in glaucoma. Findings are presented in numerical values and may be shown in 2- or 3-D representation.

RTA: Clinical applicability in glaucoma. Early detection of glaucomatous damage is critical for successful treatment. Glaucoma is associated with ganglion cell and nerve fiber layer loss. Today we know that up to 50% of the total number of ganglion cells are located in the macula. The loss of these two layers is directly reflected in retinal thickness.

None of the other automated imaging tools has emerged as a new gold standard for early glaucoma diagnosis and monitoring. The RTA, however, in addition to imaging the optic disc cupping, identifies and quantifies the anatomical damage in the macula and the peripapillary region even before the symptoms appear.

The RTA is the only tool that provides objective assessment of all three key components of glaucoma-associated changes in the fundus of the eye: macula, peripapillary region and disc area.

Anatomy imager 3-D rendering

Recently, the RTA has incorporated an anatomy imager into the device. The anatomy imager allows 3-D rendering of retinal thickness measurements over the fundus photo captured

by the device. Alternatively, the programme allows easy importation of an external image (such as a fluorescein angiography study). The 3-D block may be rotated and cleaved as necessary to appreciate the relationship between abnormalities in retinal thickness and pathologies seen on fluorescein angiography.

SCANNING LASER POLARIMETRY (SLP)

SLP provides on objective quantitative assessment of the peripapillary RNFL, and thus is also called *RNFL analyser* GDx; the commercially available RNFL analyser has two models: the GDx FCC (old model) and GDx VCC (new model). RNFL analyser with variable corneal compensation (available as GDx VCC) is the most appropriate structural test for early detection of glaucomatous damage as it quantifies the morphology of RNFL.

PRINCIPLE AND OPTICS

The RNFL analyser works on the principle of SLP. The operating principle of SLP by which it determines the RNFL thickness is the measurement of the *retardation* of a polarized laser light passing through tissues possessing the physical property of *form birefringence* (explained below).

Form birefringence refers to splitting of a light wave by a polar material into two components. These components travel at different velocities, which creates a relative *phase shift*, also termed retardation. The amount of phase shift or retardation is proportional to the thickness of polar tissue. The polar tissues are composed of parallel structures, each of which is of smaller diameter than the wavelength of the light used to image it. The RNFL behaves as a polar tissue because of the microtubules (with diameters smaller than the wavelength of light) present in the highly ordered parallel axon bundles. The greater the number of microtubules, the greater the retardation of the polarized laser light, indicating the presence of more tissue; thus giving an assessment of RNFL.

Optics. Figure 4.47 depicts the optics of SLP. The near-infrared laser light (780 nm) enters the eye at specific orientation. As the laser double passes the RNFL, it is split into two parallel rays by the birefringent microtubules (present in the axons forming RNFL). The two rays travel at different speeds, and this difference (called retardation) is measured.

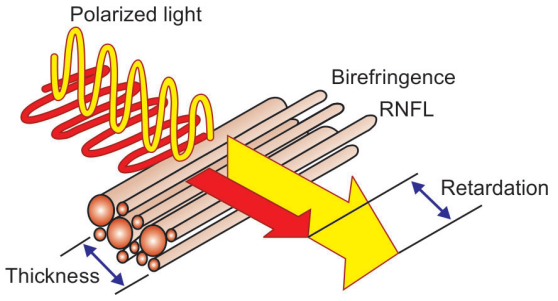


Fig. 4.47: *Optical principle of scanning laser polarimeter (SLP) (nerve fiber layer analyser).*

Total birefringence, anterior segment birefringence and RNFL birefringence

Total birefringence—associated retardation is the sum of anterior segment birefringence (from cornea and lens) and RNFL birefringence.

RNFL birefringence can be isolated from the total birefringence by compensating for the anterior segment birefringence.

Fixed versus variable corneal compensation

- *Fixed corneal compensation (FCC)* was employed in the earlier models of nerve fiber layer analysers (e.g. GDx FCC), ensuring that all individuals had a slow axis of corneal birefringence (corneal polarization axis) 15° nasally downward with a magnitude of 60 nm (corneal polarization magnitude). However, recently it has been shown that there exists a wide variation in the axis and magnitude of corneal polarization in healthy and glaucomatous eyes.
- *Variable corneal compensation (VCC)* is required to exactly measure the RNFL birefringence. The modified version of nerve fiber layer analyser (GDx VCC) measures and individually compensates for anterior segment birefringence for each eye and thus allows the exact measurement of RNFL birefringence.

GDX VCC NERVE FIBER LAYER ANALYSER

The new modified version of nerve fiber analyser, i.e. GDx VCC (Fig. 4.48) is an SLP, which basically consists of a confocal scanning laser ophthalmoscope with an integrated ellipsometer to measure retardation.

Procedure of measurement

The measurement is performed with an undilated pupil of at least 2 mm diameter. A 780 nm infrared laser is used to scan the parapapillary area to give the RNFL measurements. Time taken is about 0.7 seconds. Total chair time is less than 3 minutes for both eyes. First the eye is imaged without compensation. The uncompensated image presents total retardation from the eye. The macular region of this image is then analysed to determine the axis and magnitude of the anterior segment birefringence. The macular region birefringence is uniform and symmetric due to radial distribution of Henle's fiber layer.

Interpretation of the GDx VCC printout

The measurements are compared with a *normative database* (from healthy volunteers of different races) to determine any significant deviations from normal limits which are flagged as abnormal with a *p* value. Most of the parameters on GDx VCC printout are calculated from the calculation circle. This is the area of 8 pixels between two concentric circles centered around the optic disc. The GDx VCC printout is interpreted as below (Fig. 4.49):

Fig. 4.48: *Commercially available nerve fiber layer analyser (GDx VCC) (Courtesy: Carl Zeiss Meditec AS).*

1. ***Colour fundus image*** is seen at the top of the printout. It is depicted as 20° × 20° image of the disc and parapapillary area (Fig. 4.49A). It is produced by more than 16,000 data points from the scanned area.

2. ***Thickness (polarization) map*** shows the RNFL thickness in a colour-coded format in the 20° × 20° parapapillary area as below (Fig. 4.49B):

- *Thick RNFL areas* are indicated by bright colours: yellow, orange and red.
- *Thin RNFL areas* are indicated by dark colour (dark blue, blue and green).
- *Typical normal pattern* is characterized by bright yellow and red colours (thicker areas) in the superior and inferior sectors and dark blue and green (i.e. thinner areas) in the nasal and temporal sectors.

Abnormal patterns of thickness map include:

- *Diffuse loss of RNFL* leads to its decreased thickness, seen as yellow instead of red.
- *Focal defects* are seen as concentrated dark areas.
- *Asymmetry* between superior and inferior quadrants of RNFL.
- *Asymmetry* between the RNFL of two eyes.
- *Increased thickness* of RNFL in nasal and temporal quadrants of RNFL (seen as red and yellow instead of blue).

3. ***Deviation map.*** It shows the location and magnitude of RNFL defects over the entire thickness map. It tells how the patient's RNFL thickness compares with values derived from the normative database in a 128 × 128 pixel (20° × 20°) region centered on the optic disc. Small colour-coded squares indicate the amount of deviation from normal at each given location and are presented over a black and white fundus image to provide a visual form of reference (Fig. 4.49C). Dark blue squares represent areas where the RNFL thickness is

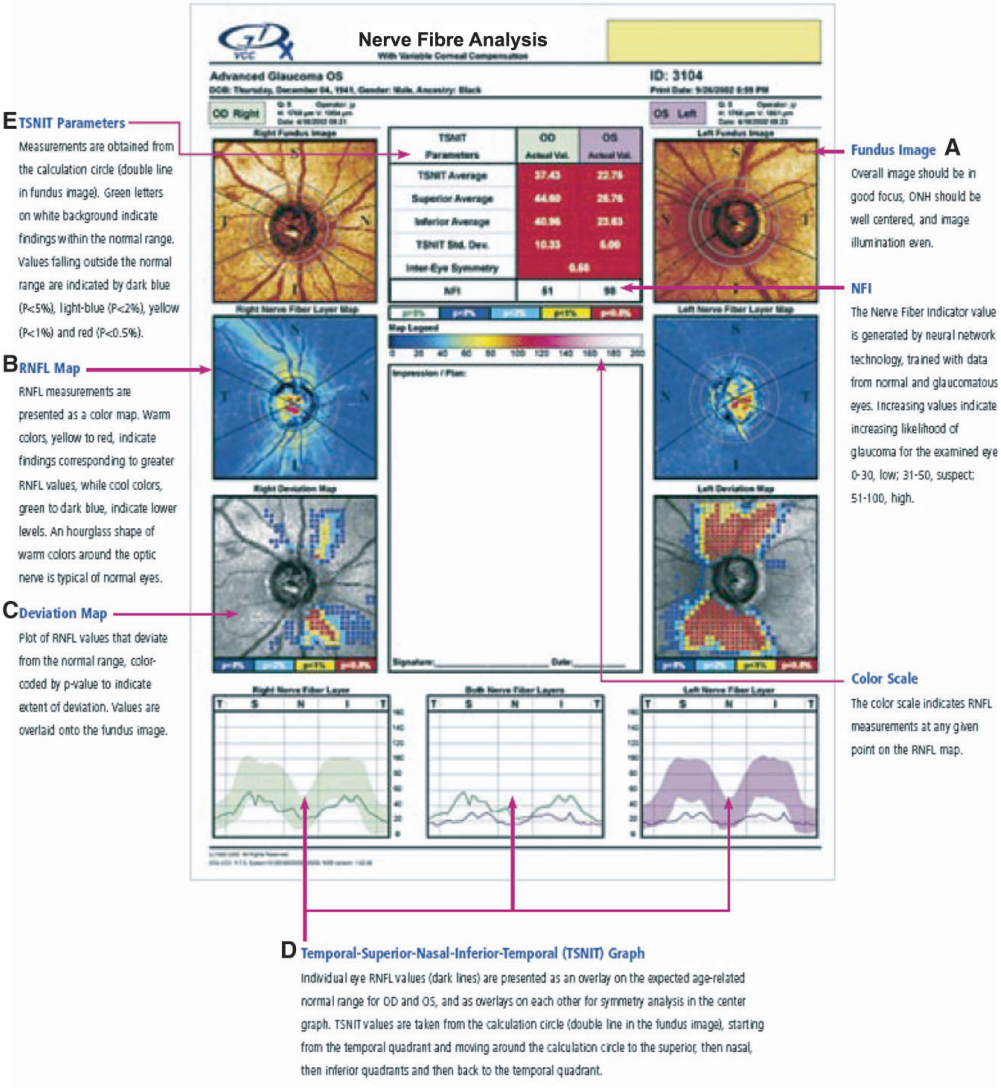


Fig. 4.49: *A representation printout of GDx VCC retinal nerve fiber layer analyser.*

below the 5th percentile of the normative database; i.e. there is only 5% probability that the RNFL thickness in this area is within the normal range. Light blue squares represent deviation below the 2% level, yellow represents deviation below 1% and red represents deviation below 0.5%. Thus, a quick look at the deviation map gives an idea of the wedge defects of RNFL and the pattern of defects.

4. ***The TSNIT graphs*** (Fig. 4.49D)**.** The TSNIT, i.e. 'temporal-superior, nasal-inferior-temporal' graph displays the range and the patient's values of RNFL thickness along the calculation ellipse in TSNIT order separately for right (OD) and left (OS) eyes.

- In a normal eye, the typical TSNIT graph shows a typical 'double-hump' pattern.
- A flat TSNIT graph indicates loss of RNFL.
- *TSNIT symmetry graph* is obtained by displaying the graphs of two eyes together. Normally, the curves from two eyes overlap. However, in glaucoma, one eye often has more advanced RNFL loss and, therefore, the two curves will have less overlap. A dip in the

curve of one eye relative to another is indicative of RNFL loss.

TSNIT serial analysis graph and deviation from reference map for a given eye, for analysis of serial changes between visits can also be obtained from GDx VCC. This is very useful to demonstrate progression over a period of time.

5. ***TSNIT parameters.*** These are displayed in a table on the center of printout (Fig. 4.49E). The TSNIT parameters are summary measures based on RNFL thickness values within the calculation ellipse and include TSNIT average, superior average, inferior average, TSNIT standard deviation, intereye symmetry and the nerve fiber indicator (NFI).

- *TSNIT average* refers to average RNFL thickness around the entire calculation ellipse.
- *Superior average* is the average RNFL thickness in the superior 128 region of calculation ellipse.
- *Inferior average* is the average RNFL thickness in the inferior 1208 region of calculation ellipse.
- *TSNIT standard deviation* indicates the modulation (peak to trough difference) of the double-hump pattern. A normal eye has high and a glaucoma eye has low modulation in the double-hump pattern.
- *Intereye symmetry* measures the degree of symmetry between the right and left eyes. Normal eyes have good symmetry with values around 0.9.
- *NFI.* It is the most important parameter, since it is an indicator of the likelihood that an eye has glaucoma. NFI is generated from the patient's scanned data obtained from within and outside the calculation circle.

  The output of NFI is a single value that ranges from 1 to 100 and indicates the overall integrity of the RNFL. The higher the NFI the more likely that the patient has glaucoma. The values of NFI are generally interpreted as:
  - Normal: 1–30 (less likelihood of glaucoma)
  - Glaucoma suspect: 30–50
  - Abnormal: >50 (high likelihood of glaucoma).

Normal versus abnormal values of TSNIT parameters

Normal values of TSNIT parameters reported from Indian population are:

- TSNIT average: 54.8 ± 4.1 (45.6 – 66.8) μ
- Superior average: 66.8 ± 6.70 (55.1 – 85) μ
- Inferior average: 62.1 ± 6.6 (38.9 – 74.3) μ
- NFI: 17.2 ± 6.9 (4–35) μ

Abnormal values. Although there is no consensus on definition of abnormal scan, the following guidelines have been recommended for TSNIT average, superior average, inferior average, TSNIT standard deviation, intereye symmetry and NFI:

- Abnormal at *p*, <1% level
- Borderline at *p*, <5% level

Additional diagnostic parameters

Additional diagnostic parameters available in the machine for an extended analysis include the following:

- ***Symmetry.*** It is the ratio of the average of the 1500 thickest pixels each in the superior and inferior quadrants. The values closer to 1 indicate more symmetry and thus more chances of normal scan.
- ***Superior ratio.*** It is the ratio of superior quadrant thickness (average of 1500 thickest pixels) and temporal quadrant thickness (average of 1500 median pixels).
- ***Inferior ratio.*** It is the ratio of inferior quadrant thickness (average of 1500 thickest pixels) and temporal quadrant thickness (average of 1500 median pixels).
- ***Superior nasal.*** It is the ratio of superior quadrant thickness (average of 1500 thickest pixels) and nasal quadrant thickness (average of 1500 median pixels).
- ***Maximum modulation.*** It is ratio of thickest quadrant versus thinnest quadrant. Normally the maximum modulation is more than 1, since superior and inferior quadrants are thicker than nasal and temporal quadrants. Value of 1 or less indicates RNFL loss.
- ***Superior maximum.*** It is the average of the 1500 thickest pixels in the superior quadrant.

- ***Inferior maximum.*** It is the average of the 1500 thickest pixels in the inferior quadrant.
- ***Ellipse modulation.*** It is the ratio of the thickest quadrant and the thinnest quadrant within the ellipse area.
- ***Ellipse average.*** It is the average thickness (in microns) of RNFL in the ellipse surrounding the ONH.

Advantages and limitations of GDx VCC

Advantages of GDx VCC

- Easy to operate
- Does not require pupillary dilation
- Good reproducibility
- Does not require a reference plane
- Can detect glaucoma on the first examination
- Early detection before standard visual field
- Comparison with age-matched normative database.

Limitations of GDx VCC

- Does not measure actual RNFL thickness (inferred value).
- Low sensitivity and specificity for detection of pre-perimetric glaucoma in clinical studies.
- Does not differentiate true biological change from variability.
- Limited use in moderate and advanced glaucoma.
- No database from Indian population.
- Affected by anterior and posterior segment lesions such as:
  - Ocular surface disorders
  - Macular pathology
  - Cataract and refractive surgery
  - Refractive errors
  - Peripapillary atrophy (scleral birefringence interferes with RNFL measurement).

BIBLIOGRAPHY

1. Matthew T. Witmer, MD, Szila'rd Kiss, MD. Wide-eld Imaging of the Retina. Surv Ophthalmol 2013;58;2:143–54.
2. Rosenthal ML, Fradin S. The technique of binocular indirect ophthalmoscopy. Highlights Ophthalmol 1966;9:179–257.
3. Rubin ML. Magnification; practical instruments: the indirect ophthalmoscope. In: Optics for clinicians. 2nd edn.
4. Saine P, Tyler M. Ophthalmic Photography. A Textbook of Retinal Photography. Angiography and Electronic Imaging. Boston, MA, Twin Chimney Publishing; 1997.

CHAPTER

5

Evaluation and Assessment of Traumatized Eye

Chapter Outline

INTRODUCTION

A proper evaluation of the traumatized eye is absolutely essential for appropriate and effective management of the injury. Classification of the injury and calculation of the ocular trauma score are essential aspects which should be brought into practice. It should be remembered that in case of ocular trauma, the ophthalmologist is treating the patient and not only the eye, pay attention to any systemic features, social bearing of the ocular injury and ultimately to the visual rehabilitation of the patient. Scheme of approach to a patient with ocular trauma described below is summarized in Fig. 5.1.

Initial approach. Patients usually present to the ocular emergency in a state of panic or frenzy. The sudden threat to vision can be emotionally damning. This places upon the treating ophthalmologist an added responsibility of counselling not only the patient but also their family members. It is always advisable to maintain a confident and humane approach.

Systemic evaluation. Prior to taking history and performing a thorough examination of the eye, it is important for the attending ophthalmologist to evaluate the systemic condition of the patient. Ocular trauma can be compounded by life-threatening injuries as in cases of polytrauma commonly observed in road traffic accidents. If a systemic injury is found, its treatment will obviously take precedence over the ocular management. In these cases, the emergency team stabilizes the patient before calling in for

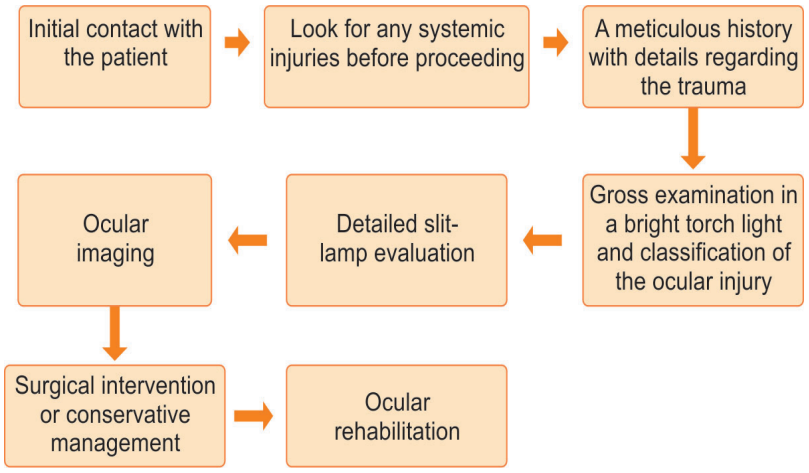


Fig. 5.1: *Scheme of approach to a patient with ocular trauma.*

an expert ophthalmic opinion. Even in cases presenting directly to the ophthalmologist, it is always better to be suspicious of occult injury to other organ systems.

Initial triage should consist of systemic evaluation of vitals, gross mental status and obvious fractures or soft tissue injuries. The patient should be referred to a trauma facility, if at any point of the examination, the following are found:

- Unstable vital parameters
- Altered mental status or an unresponsive patient
- Serious bony or soft tissue injury.

Once it is established that the systemic status is stable, the surgeon can turn attention to the ocular evaluation.

CLINICAL WORK-UP

HISTORY

The importance of a well-taken history, at the time of initial presentation, cannot be over-emphasized. Not only does this give the ophthalmologist a chance to build a rapport and earn the trust of the patient but a well-documented history is also necessary for legal proceedings. The history will guide the ophthalmologist towards the examination.

It is best to allow the patient to tell his or her version of the incident without much of an interruption. Leading questions can be asked in between to bring the patients back on track, if they ever get diverted off course. The history should highlight the following important points:

Events leading up to the injury. It is of utmost importance to elucidate the minutest detail of activity which the patient was performing at the time of sustaining the injury, e.g. whether the activity was related to sports, bow and arrow and bursting of crackers during Diwali/Dusshera festivals, a labourer crushing stones while using a chisel and hammer, industrial or agricultural pursuits, involved in roadside accidents and finally an assault with the use of some kind of armament.

***Detailed description of the mechanism of trauma to note whether*:**

- A high-velocity or a low-velocity trauma
- Injury with a blunt or a sharp object.

Time of the injury and time elapsed between the insult and initial presentation should be documented:

- As it decides management. A fresh open corneal wound would be dealt with urgently and more aggressively than a self-sealed corneal laceration in a quiet eye which is a week old.
- Important for medicolegal purposes.

Rural or an urban setting should be noted. The incidence of infection in cases of trauma in rural settings is higher and so is the risk of endophthalmitis.

Chemical nature of the insulting object should be noted:

- If an intraocular foreign body is suspected its nature and chemical composition must be known (iron, copper or steel)
- Any chemical agent, such as an alkali or acid, may further complicate the mechanical injury.

Prior ocular history should specifically include:

- Any history of previous ocular surgery or trauma
- Use of any ocular medications
- Prior vision of the injured eye and the uninjured eye.

Generalized medical history of any chronic systemic illness or use of any drugs or medications should be documented. It is important to note any drug allergies and status of tetanus immunization. If an open globe injury is suspected, general anaesthesia would be required and the patient should be asked about the time he last consumed solids and liquids.

OCULAR EXAMINATION

External inspection in diffuse illumination

Prior to examining the patient on the slit-lamp, a gross evaluation of the ocular condition can be made out with the help of a diffuse illumination of a pen torch.

- *Forehead and the periorbital tissues* should be inspected under bright illumination. Evaluate for the presence of any laceration, abrasion, periorbital edema and ecchymosis.
- *Look for exophthalmos*, enophthalmos or any foreign body, such as a stone present in the margins of the laceration.
- *Orbital walls* should be palpated to look for evidence of any bony discontinuity.
- *Crepitus and infraorbital hypoesthesia* may indicate an orbital fracture.

Inspection of globe

Attention should now be given to the ocular structures per se. The eyelids may be parted with the help of an eye speculum or a lid retractor in individuals wherein the periorbital oedema makes examination difficult. Inspect the globes for:

- Prolapse of intraocular contents
- Protruding foreign bodies
- Any sign of occult open globe injury (hemorrhagic chemosis, pupillary peaking).

Note. It should be kept in mind that no pressure is given on the globe lest the intraocular contents prolapse out. In cases of highly swollen lids or an uncooperative patient, the examination of the globe can be deferred till imaging is done or can be carried out under sedation.

Visual function assessment

Visual acuity. The presenting visual acuity is a crucial prognostic indicator in determining the outcome of injury. The visual acuity is measured separately for each eye. It should be preferably recorded on a standardized chart (ETDRS or Snellen). If the patients are immobilized or on a stretcher, due to systemic comorbidities, visual acuity can be assessed by asking the patient to count fingers at a specific distance. Poor vision can be recorded as either hand motions or light perception with a documentation of projection of rays. The test of light perception and projection of rays should be carried out with the brightest possible light (indirect ophthalmoscope).

Relative afferent pupillary defect. The presence or absence of RAPD is an indicator of gross visual dysfunction. The test is performed as a swinging flash-light test with a bright light source. Apparent dilation of the pupil of the eye in which light is shown points towards the presence of RAPD. It indicates an optic nerve or a severe retinal damage with a poor prognosis.

Afferent pupillary defect can also be elucidated in cases wherein the iris is injured and the pupil is not reacting. In this case rather than visualizing the direct pupillary response in each eye, only the response in the normal reacting pupil is observed. RAPD is said to be present when the pupil of the fellow eye dilates when light is moved to the injured eye.

Visual field assessment. Rapid assessment of the peripheral visual field can be carried out in the emergency setting using the confrontation test. It can give additional information about retinal or optic nerve damage.

Ocular motility assessment

- If *injury to the cranial nerves* or bony orbital margin is suspected, ocular motility must be evaluated.
- *A case of blowout fracture* with an entrapped inferior rectus muscle can be made out at this stage and treatment modified accordingly.
- However, it is not always possible to examine for motility as the patient's periorbital oedema or lack of cooperation may mask the findings.

Examination of conjunctiva

Foreign bodies or precipitates of chemicals may be lodged within the conjunctival fornices. The lids should be everted and fornices examined. Double eversion of the upper lid with a Desmarres retractor is needed to look for hidden foreign bodies in the superior fornix.

Presence of haemorrhagic chemosis should make one suspect of an underlying breach in the eyewall.

Subconjunctival haemorrhage, the posterior extent of which cannot be reached, raises the possibility of a fracture of the base of the skull.

Lacerations of the conjunctiva may be difficult to make out initially. Manipulation with a cotton swab following anaesthetic instillation can clearly delineate the edge of the laceration. A thorough search for an underlying scleral wound should be made in these cases.

Examination of cornea

Epithelial defects. Patients usually present with pain and photophobia. A drop of a topical anaesthetic helps to allay their discomfort and allows for a thorough examination at the slit-lamp. Fluorescein staining and documentation of the size of the epithelial defect is of prime importance. Look for abrasion, opacification and ulcerations.

Superficial corneal foreign body. The depth of penetration of the foreign body should be evaluated on the slit-lamp. If the entire thickness of the cornea is breached, the injury gets classified as an open globe injury. The foreign body in this case is best removed in the operation theatre. For smaller foreign bodies which are more superficial, removal on a slit-lamp with a hypodermic needle is sufficient.

Corneal wounds should be analysed whether they are full thickness or partial thickness. This can be carried out with the help of a Seidel's test. Leakage of aqueous from a full thickness breach would dilute the fluorescein dye forming a green stream (positive Seidel's test).

Examination of sclera

- A detailed examination of the sclera should be carried out to look for any breach in the eyewall. This is not always easy as the associated subconjunctival haemorrhage may prevent adequate visualization.
- If a defect in the continuity of the scleral wall is suspected and adequate visualization is not possible, a surgical exploration should be planned.

Examination of anterior chamber

Contents of anterior chamber should be analysed for the presence of any aqueous cells or flare. Traumatic iritis following the insult can lead to inflammation in the anterior chamber. RBCs may also be found in the anterior chamber with damage to the iris. Look for any retained foreign body, hyphema or hypopyon.

Depth of the anterior chamber must be noted:
Deep anterior chamber may be a sign of:
- Posterior dislocation of the lens
- Posterior scleral rupture
- Iridodialysis.

Shallow anterior chamber may be a sign of:
- Anterior dislocation of the lens
- Corneoscleral perforation
- Suprachoroidal haemorrhage
- Serous choroidal detachment.

Examination of iris

- *Iris is one of the most common sites of damage* in both open and closed globe injuries. A slit-lamp evaluation should be carried out to look for sphincter tears, iridodialysis, iridodonesis and full thickness iris defects.
- *In case of corneoscleral wounds,* the iris may be prolapsed to block the site of perforation. In

old injuries, the iris tissue may get incarcerated in the wound leading to an adherent leukoma.

Examination of crystalline lens

- A note should be made of phacodonesis, dislocation, subluxation or zonular dehiscence.
- Blunt trauma can lead to a break in the posterior capsule forming a rosette-shaped concussion cataract at the posterior subcapsular region.
- Look for the integrity of the anterior capsule. A tear in the capsule would result in anterior subcapsular opacification or in leak of cortical material into the anterior chamber and further inflammation.
- Intralenticular foreign bodies must be looked for.

Intraocular pressure measurement

- Measurement of intraocular pressure should be carried out in all cases of trauma; provided an open globe injury has been ruled out.
- Following a contusion, the intraocular pressure may rise acutely, especially if inflammation and blood is present.
- An abnormally low IOP would point towards an occult open globe injury but can also be seen with ciliary body detachment.

Examination of posterior segment

- *An in-depth analysis of the posterior segment* of the eye should be carried out after ruling out globe rupture before the media clarity is compromised.
- *90 D slit-lamp examination* should be attempted in case the media permits or else *20 D indirect ophthalmoscopy* be carried out (without indentation at this stage) in order to rule out retained intraocular foreign body, vitreous haemorrhage, retinal break (inferotemporally—direct injury) or retinal dialysis (superonasally—countrecoup injury), choroidal ruptures, macular oedema and optic nerve avulsion, etc.
- *In most cases, mydriatics* should be used to facilitate view of the retina and vitreous. It is to be borne in mind that the use of mydriatics should be properly documented so as to avoid misinterpretation of subsequent pupillary examinations. (Pupillary reflexes are also evaluated to look for evidence of neurological damage).
- *In case of open globe injuries with prolapse of uveal tissue,* it is advisable to defer the evaluation of the posterior segment to a later date after the surgical repair is completed.

ORBITAL IMAGING

It becomes necessary to bank upon imaging modalities to provide additional information whenever significant trauma is suspected to the periorbital or in cases wherein view of the posterior segment is compromised (corneal decompensation, traumatic hyphema). In cases of open globe injury, some form of an imaging investigation should be ordered to look for a retained intraocular foreign body.

PLAIN RADIOGRAPHY

- With the advent of CT scan, the dependency on plain X-ray radiography has diminished. However, if a CT scan is not available, an X-ray of the orbit can also serve as a useful tool in evaluating bony trauma (Fig. 5.2) or an intraocular foreign body (Fig. 5.3).
- In addition to the advantage of diminished exposure to radiation as compared to CT, plain X-ray orbit will save the practicing

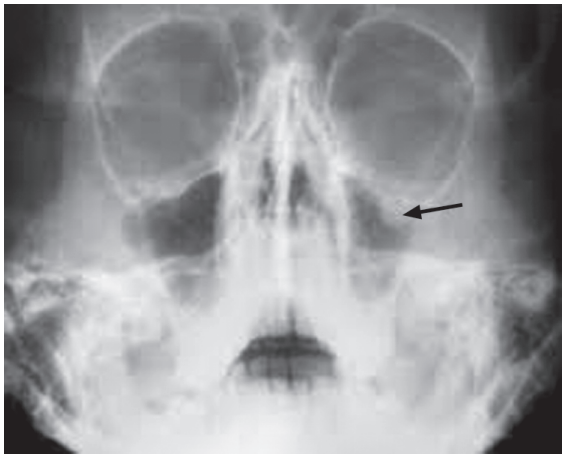


Fig. 5.2: *Plain X-ray orbit (AP view) showing herniated orbital contents (arrow) with blowout fracture.*

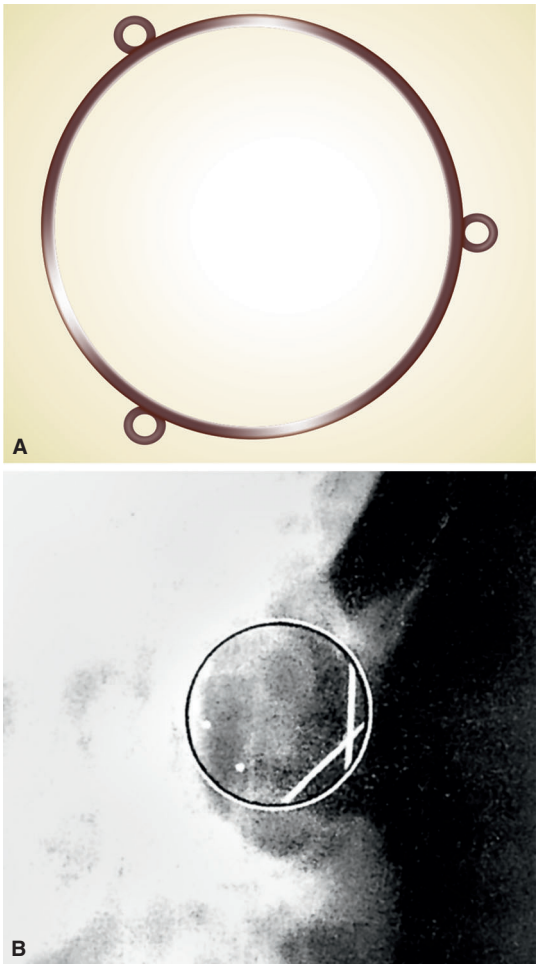


Fig. 5.3: *Limbal ring method of localizing RIOFB: (A) Limbal ring; (B) X-ray orbit lateral view with limbal ring.*

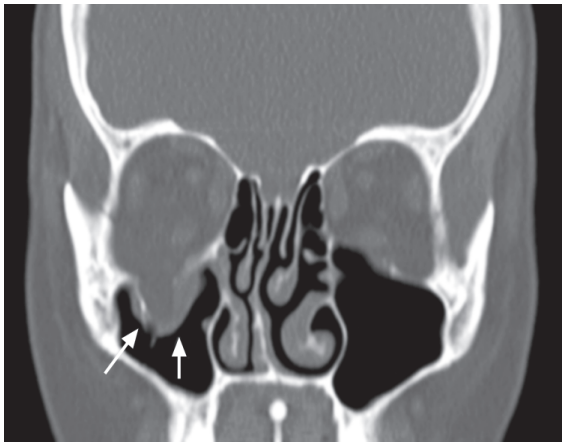


Fig. 5.4: *CT scan of orbit: Axial view depicting fracture floor of the orbit with herniation of the orbital contents*

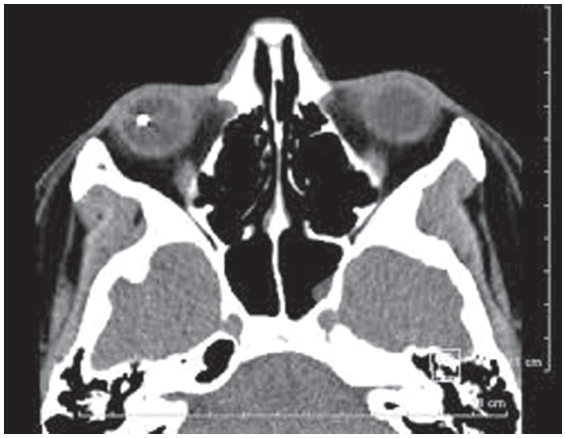


Fig. 5.5: *CT scan of the orbit depicting intraocular foreign body.*

ophthalmologist from the risk of Consumer Protection Act (CPA) and must be ordered even with the slightest suspicion of retained intraocular foreign body (RIOFB).

COMPUTED TOMOGRAPHY

- *CT scan has replaced X-ray radiography* as the most commonly used and most useful investigation in patients with severe periorbital or ocular trauma.
- *Coronal and axial scans* provide a detailed view of the bony structure of the orbit (Fig. 5.4) as well as the ocular anatomy. The size, shape and location of a foreign body can be easily demarcated with a CT scan (Fig. 5.5).
- Being readily available in the emergency setting, CT scan unlike ultrasonography *can be carried out even in patients with open globe injuries.*
- *Radiologist should be advised to use thinner cuts* (1–2 mm) so as to better delineate the ocular anatomy.
- *Common CT scan findings* that are suggestive of open globe injuries are:
  - Deformity of the globe
  - Intraocular foreign body
  - Intraocular air
  - Intraocular haemorrhage.
- *Sensitivity and specificity of CT scan* in determining open globe injury are 56–68% and 79–100%, respectively.

ULTRASONOGRAPHY

- *Utilizes high frequency sound waves* to delineate ocular structures in real time.
- *Ultrasonography requires a direct contact* with the lids and in cases of open globe injuries is contraindicated till the injury is repaired. In these cases, USG can be carried out in the operating room after repair with the patient under general anaesthesia.
- *B-scan ultrasonography helps to realize posterior segment pathology*, if the view of the fundus is compromised. It is useful in detecting (Fig. 5.6):
  - Retinal detachment (Fig. 5.6A)
  - Choroidal detachment (serous or haemorrhagic) (Fig. 5.6B)
  - Vitreous haemorrhage (Fig. 5.6C)
  - Posterior vitreous detachment
  - Intraocular foreign bodies (radiolucent and radio-opaque) (Fig. 5.6D)
  - Posterior breaks in the continuity of the eyewall (perforation *vs* penetrating injury).

MAGNETIC RESONANCE IMAGING

Role of an MRI in the setting of ocular trauma is limited by its availability and longer image acquisition times. Furthermore, it cannot be used if a metallic intraocular foreign body (iron) is suspected or in patients on pacemakers.

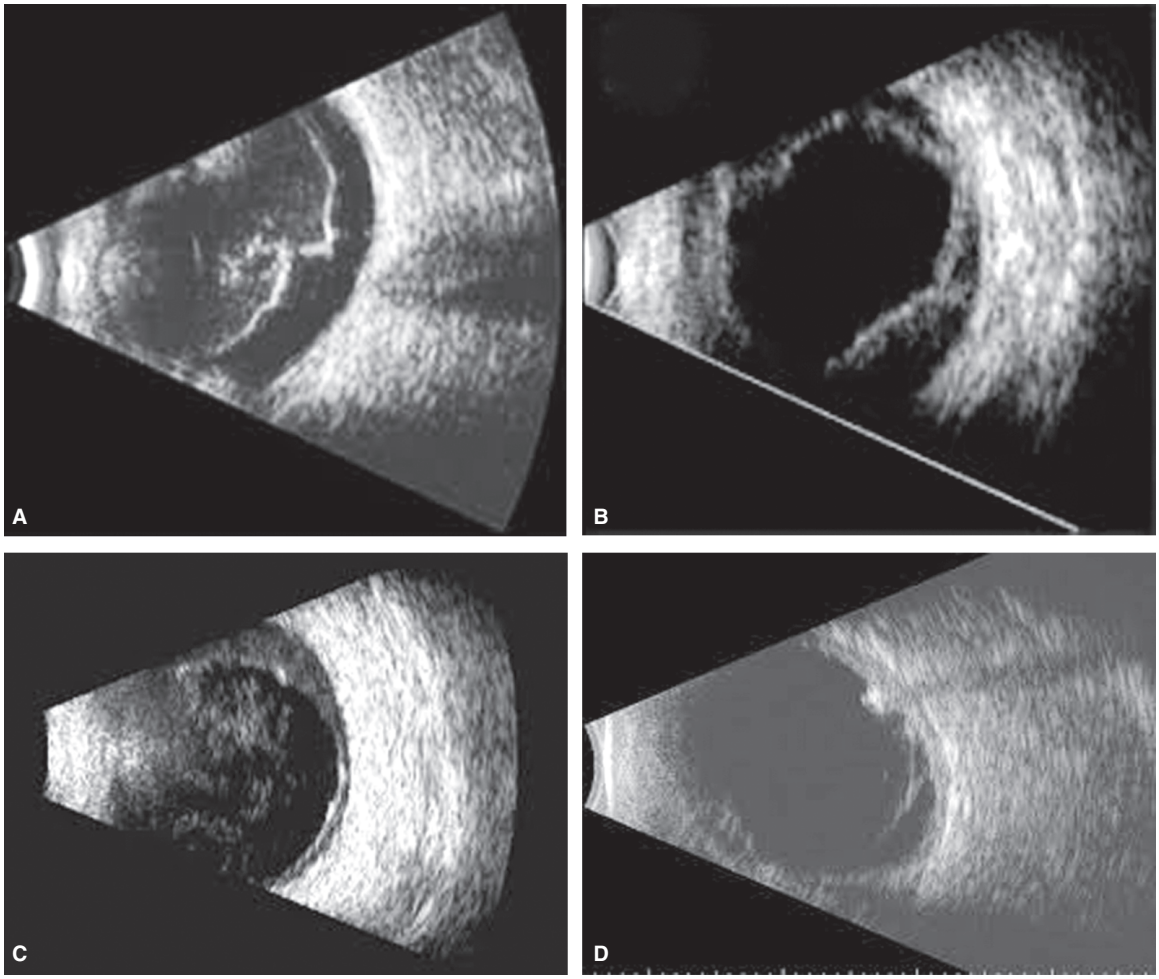


Fig. 5.6: *B scan of traumatic eyeball depicting: (A) Traumatic retinal detachment; (B) Choroidal detachment; C. Vitreous haemorrhage; (D) Intraocular foreign body.*

SURGICAL EXPLORATION AND EXAMINATION UNDER ANAESTHESIA

Indications. In cases wherein significant doubt remains about the nature of injury despite imaging modalities and examination or those cases who resist examination, a surgical exploration may be necessary for accurate diagnosis.

- *General anaesthesia* should be preferred.
- *An adequate conjunctival peritomy* should be done and the scleral shell should be evaluated under high magnification for any breach. Always remember to look at weak points on the eyewall especially at the limbus, at areas of old scars and at the insertion of extraocular muscles.
- *Cornea and anterior chamber should be examined* under high magnification. The angle can be evaluated with the help of a direct gonioscope lens.
- *Ultrasonography and indirect ophthalmoscopy* can be performed to look for posterior segment pathology.

PATIENT COUNSELLING

Last but not the least patient counselling is most important sensitive part of clinical work of eye trauma. Counselling of the patient and relatives begins at the point of initial contact in the emergency environment. This begins with initial comforting of the patient and aims to allay anxiety. The counselling must be informative, truthful, accurate and should be an ongoing process till the conclusion of treatment. This is especially important in patients who would require surgical intervention. It is true that the final visual acuity remains in doubt following ocular trauma in the initial few weeks, however, a realistic opinion about the visual prognosis can be gathered from the ocular trauma score. The patient must be encouraged not to give up hope. It is important to counsel the patient for any life adjustments that may be required.

BIBLIOGRAPHY

1. Arey ML, Mootha VV, Whittemore AR, Chason DP, Blomquist PH. Computed tomography in the diagnosis of occult open-globe injuries. Ophthalmology 2007;114:1448–52.
2. Boldt HC, Pulido JS, Blodi CF, et al. Rural endophthalmitis. Ophthalmology 1989;96:1722–6.
3. Kuhn F, Maisiak R, Mann L, Mester V, Morris R, Witherspoon CD. The Ocular Trauma Score (OTS). Ophthalmol Clin North Am 2002;15:163–5.

CHAPTER

6

Examination of a Neuro-ophthalmic Case

Chapter Outline

INTRODUCTION

Examination of a neuro-ophthalmic case basically includes a thorough ocular, neurological and systemic clinical work-up and investigations including neuro-imaging to reach up at the proper diagnosis.

COMMON NEURO-OPHTHALMIC MANIFESTATIONS

- *Visual loss,* i.e. either transient visual loss or visual impairment due to lesions of visual pathway and or cortical centers and psychosomatic condition.
- *Diplopia,* primarily because of palsies of cranial nerves supplying various extraocular muscles.

- *Visual field defects* due to various lesions of visual pathway.
- *Deranged higher visual functions* in the form of visual-hallucinations, illusions and agnosia.
- *Papilledema* is an important neuro-ophthalmic manifestation.
- *Anomalous pupillary reflexes* make up essential clues in a neuro-ophthalmic case.

In this text examination of a neuro-ophthalmic case is discussed as:

- Clinico-investigative approach to a patient with visual loss
- Clinico-investigative approach for a patient with diplopia.

CLINICO-INVESTIGATIVE APPROACH TO A PATIENT WITH VISAUL LOSS

Visual loss can be broadly classified into

- Transient visual loss
- Visual impairment.

TRANSIENT VISUAL LOSS

Transient loss or blurring of vision in one or both eyes is not an uncommon visual complaint. The approach to such a patient is complicated by challenging differential diagnosis and overlapping disease profiles. It is an important sign of cerebrovascular diseases in some patients and thus warrants a systematic approach in examining, investigating and treating such patients.

TERMINOLOGY

Transient visual obscuration (TVO), i.e. fleeting loss of vision lasting just a few seconds

Monocular transient visual loss includes:

- *Amaurosis Fugax,* i.e. partial or total (rare) monocular blindness lasting a few seconds to minutes.
- *Transient monocular blindness* refers to more prolonged (30 minutes to hours to days) episodes of partial or total loss of monocular vision.

Binocular transient visual loss includes episodes of bilateral loss of vision lasting from 5–30 minutes and occasionally longer, involving either homonymous field, inferior or superior altitudinal fields or the central fields.

CAUSES OF TRANSIENT VISUAL LOSS (TVL)

1. Non-ischemic causes of TVL

- *Ocular surface disorders* such as dry eye, blepharitis (anterior or posterior) and recurrent corneal erosions
- *Corneal endothelial disorders* such as dystrophies and decompensation
- *Intermittent angle closure*
- *Uveitis*
- *Vitreous floaters*
- *Optic disc disorders* such as papilledema, papillitis, drusen and colobomas.

2. Ischemic causes of TVL

i. ***Embolic diseases***

- Carotid embolic diseases, e.g. atheromas and obstruction
- Cardiac embolic diseases, e.g. valvular—rheumatic, prosthetic valves, fibrillation and myxomas
- Great vessels embolic diseases, e.g. aortic arch embolus.

ii. ***Vasculitis***

- Giant cell arteritis

iii. ***Hypoperfusion*** as seen in:

- Carotid obstruction
- Vertebrobasilar insufficiency
- Ocular ischemic syndrome.

iv. ***Vasospasm,*** e.g. migraine

v. ***Hyperviscosity,*** e.g. polycythemia

vi. ***Hypercoagulability.***

APPROACH TO A PATIENT WITH TRANSIENT VISUAL LOSS

1. History

A meticulous history is very important. It should include:

i. ***Age*****:** In less than 50 years of age vasospasm and migraine are the commonest causes of TVL and in more than 50 years of age carotid embolic disease is a common cause.

ii. ***Associated medical conditions*****:** To be enquired include hypertension, diabetes, coronary artery diseases and Raynaud's phenomenon.

Features of TVL:

- Monocular or Binocular TVL?
- Duration of visual loss

- Number of episodes of visual loss
- Pattern of visual loss and recovery should be noted:
  - Shade or curtain coming down and then lifting is typical of amaurosis fugax due to carotid disease.
  - Positive visual phenomenon, e.g. scintillating scotomas in migraine.
  - Transient blurring of vision with exercise and increased body temperature is typical of *Uhthoff* phenomenon seen in optic neuritis associated with multiple sclerosis.
  - Abrupt change in vision may be associated with posterior circulation ischemia.

iii. ***Associated symptoms:*** To be noted include headaches, weight loss, fever, scalp tenderness, loss of consciousness, diplopia, dizziness, dysarthria and focal weakness.

2. Examination and investigations in a patient with transient visual loss

In a patient with monocular visual loss

Examination tests include:

- Visual acuity
- Ocular motility in cardinal positions of gaze
- Orbital examination for proptosis. Gaze evoked blurring of vision is reported in intraconal mass lesions
- Pupillary evaluation for RAPD, and anisocoria
- Slit-lamp biomicroscopy for lids, lashes, cornea, anterior chamber (cells, flare), cataract and anterior chamber angle depth
- Applanation tonometry
- Gonioscopy to note open, closed or occludable angles
- *Fundus examination* for evalution of optic disc, retinal vessel calibre, emboli, and signs of ischemia (hemorrhages, cotton wool spots)
- *Auscultation* of carotids for bruit and cardiac murmurs
- Palpation of temporal artery
- *Pulse rate* and *blood pressure* recording.

Investigations should include:

- Complete hemogram
- Erythrocyte sedimentation rate (ESR)
- C-reactive protein (CRP)
- Coagulation profile
- Lipidogram
- Serum glucose levels
- Carotid Doppler
- Magnetic resonance imaging (MRI)
- Magnetic resonance angiography (MRA)
- Carotid angiography—Gold standard for the assessment of carotid stenosis
- Echocardiography
- ECG, Holter monitoring.

CLINICAL ENTITIES ASSOCIATED WITH TVL

Non-ischemic transient visual loss

- ***Ocular surface diseases and corneal abnormalities*** are one of the commonest causes of non-ischemic TVL. Patients usually complain of transient visual obscurations of vision at specific times of the day, many times a week and more so in certain seasons. Slit-lamp exam reveals abnormal tear break up time, anterior or posterior blepharitis. Patients usually respond well to warm compresses, anti-inflammatory and antibiotic therapy of short duration supplemented with tear substitutes.
- Patients with ***corneal endothelial diseases and dystrophies*** report episodes of blurring of vision lasting many hours usually more pronounced in the mornings. Slit-lamp exam, pachymetry and specular count are diagnostic. Hyperosmotic drops, ointments and IOP lowering drugs help in symptomatic relief. Lamellar or full thickness corneal transplants can completely cure symptoms.
- ***Intermittent angle closure*** is an important cause of episodes of TVL. Patients usually complain of episodes of transient blurring of vision accompanied by ocular discomfort, seeing coloured haloes and mild headaches. Slit-lamp exam to grade AC depth along with gonioscopy show occludable angles and help clinch the diagnosis. Symptoms are completely relieved by YAG peripheral iridotomy.
- ***Papilledema and optic disc drusen*** can be associated with episodes of transient visual obscurations or episodes of gray, black or white vision. The episodes are usually associated with changes in posture. The likely etiology for TVL in these cases is axonal compression/stasis at the elevated optic nerve head.

- ***Papillitis/optic neuritis*** is associated with TVS similar to cases of papilledema. The likely etiology is demyelination and inflammation of the optic nerve.

Ischemic transient visual loss

Characteristic of transient visual loss are:

- Ischemic transient visual loss occurs due to temporary interruption of the blood supply to the retina, optic nerve or retrochiasmal visual pathways in the brain.
- Patients tend to be more specific, descriptive and discrete about the pattern of visual loss and recovery—onset, duration, number of episodes, central or peripheral field involvement.

Carotid artery stenosis or occlusion is the commonest cause of ischemic TVL. Atherosclerosis is the commonest cause but other causes like Takayasu arteritis, trauma, radiation arteritis and carotid dissection should be kept in mind. Carotid related amaurosis fugax results either from emboli originating from the diseased proximal internal carotid segment to the retinal arterial circulation or from decreased blood flow to the retina. The typical features of embolic monocular TVL are sudden onset, painless, described as a shade or a curatin coming down on the field of vision which lifts and vision clears in 1–5 minutes (sometimes up to 30 minutes).

Emboli that cause TVL can often be visualized with an ophthalmoscope or slit-lamp fundus biomicroscopy (78 D, 90 D lens) and often appear distinctive, their probable site of origin can be inferred which becomes crucial directing appropriate patient evaluation.

- *Cholesterol emboli (Hollenhorst plaques)* appear as yellow-orange refractile deposits at bifurcations of vessels and are typically a sign of carotid disease.
- *Platelet fibrin emboli* are dull grey or white in colour, concave meniscus at each end, lodge along the course of vessel and are likely a result of carotid thrombosis, thrombosis associated with recent myocardial infarction or heart valves.
- *Calcium* emboli are chalky white in colour, large round or ovoid, lodge in the first or second vessel bifurcations or may overlie the optic disc. They can arise from the heart (rheumatic heart disease, calcification of mitral valve) or great vessels (calcific aortic stenosis).

Stroke and transient visual loss

- The risk of stroke from *amaurosis fugax* per annum is approximately 2% and a 1% risk of permanent visual loss.
- In patients *with carotid stenosis*, ipsilateral eye symptoms may be accompanied by those *of ipsilateral cerebral ischemia* like contralateral hemiparesis, sensory loss, language deficits and hemianopia.

Clinical work-up

- ***General examination*** should include pulse rate (irregular in arrhythmias, fibrillation), cardiac auscultation (murmurs) and carotid auscultation (bruit). However, presence or absence of a carotid bruit is generally not helpful for diagnosing significant carotid stenosis or predicting a carotid source of emboli.
- ***Carotid ultrasound and Doppler*** are effective screening tools for identification and estimation of the degree of internal carotid artery stenosis.
- ***Magnetic resonance imaging–angiography*** (MRA) is another non-invasive test for carotid stenosis, however, it tends to overestimate the degree of stenosis.
- ***Computed tomographic angiography*** (CT angio) is another screening test and can be used to confirm MRA or ultrasound findings.
- ***Conventional angiography*** is the gold standard test for evaluation and quantification of carotid stenosis as its specificity and sensitivity exceed those of any noninvasive tests.
- In a elderly patient if the all the general work-up including carotid tests are unrevealing then an atheroma arising from the more proximal vessels like the aorta or an acephalic migraine should be considered as possible etiologies for TVL.
- In a young patient with an unrevealing work-up, vasospasm and hypercoagulable states, due to antiphospolipid antibodies, protein C, protein S and antithrombin III levels should be considered possible causes for TVL.

Treatment

If not contraindicated, antiplatelet therapy with aspirin should be immediately started in patients with amaurosis fugax to reduce the risk of stroke. Addition of clopidogrel or anticoagulants can also be considered in consultation with an interventional cardiologist. Multiple clinical trials have established the benefit of carotid surgery for symptomatic (retinal or hemispheric TIA) carotid stenosis greater than 70%. The management of asymptomatic carotid stenosis is however extremely controversial.

VISUAL IMPAIRMENT

A patient presenting with diminution of vision without any evidence of structural abnormalities in the eye is a puzzle for an ophthalmologist. It is important to have a logical and meticulous approach to evaluate such patients so as to come to a conclusion regarding the cause of visual loss. This includes detailed history, thorough clinical examination and appropriate investigations.

COMMON CAUSES

Visual impairment can be broadly classified to belong to the following pathologies:

1. Refractive errors and media opacities
2. Lesions of visual pathway
   - Optic nerve lesions
   - Chiasmal lesions
   - Retrochiasmal lesions
3. Macular lesions
4. Amblyopia
5. Psychogenic/malingering

We will further see how to rule out each of them and come to a problem oriented working diagnosis. Figure 6.1 is the flow chart for assessment of visual impairment and segregating patients with refractive errors, media opacities.

CLINICAL WORK-UP AND TESTS

TESTS FOR REFRACTIVE ERRORS, MEDIA OPACITIES AND VISUAL PATHWAY LESIONS

PINHOLE TEST AND STENOPEIC SLIT TEST

As refractive errors are one of the leading causes of decreased vision they should be the first ones to be ruled out. Use of pinhole and stenopeic slit determines whether or not vision will improve with refractive correction. Improvement by two lines on Snellen's chart or more on looking through the pinhole or stenopeic slit makes it clear that the visual impairment is due to optical problems.

As the pinhole eliminates paraxial rays of light, minimizing blurring of the image falling on the retina, all optical defects can be neutralized to some extent with this method, not only the refractive ametropias. However, many patients, especially children and old people find it difficult to peek through the pinhole and do not give reliable responses. The method is uncertain, and improvement of less than two lines should certainly be interpreted with

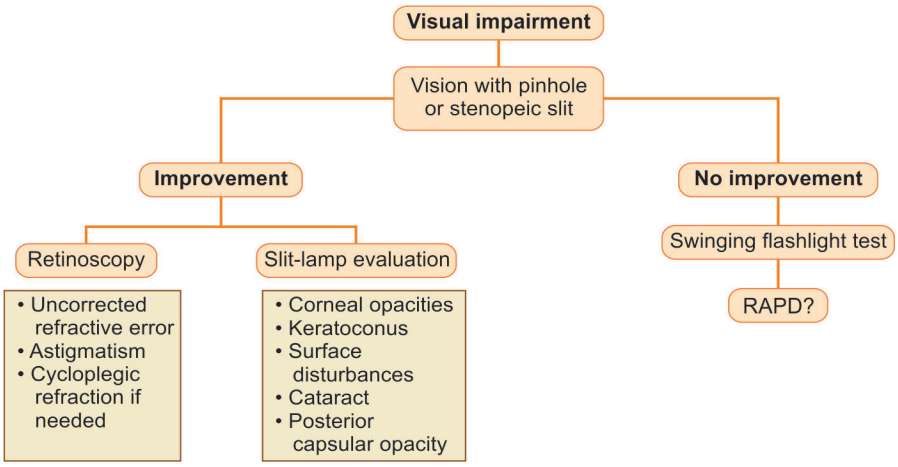


Fig. 6.1: *Flow chart for a patient with visual impairment.*

caution. Repeated subjective and cycloplegic *refraction* will usually uncover an undetected and irregular corneal astigmatism or hypermetropic error.

- Limitations of pinhole are that vision may apparently worsen in patients with central media opacities (such as posterior subcapsular cataract) and macular pathologies. Vision does not improve to 6/6 if refractive error exceeds ±4 DS.
- Detailed slit-lamp examination will reveal any obvious corneal opacities, surface irregularities, keratoconus and not to mention presence of cataract or posterior capsular opacity.
- If the vision does not improve with the pinhole, the next step will be checking the pupils for relative afferent pupillary defect.

SWINGING FLASHLIGHT TEST

This is performed to detect the presence of relative afferent pupillary defect (RAPD).

Remember: Relative = compared to the other eye, and Afferent = problem in the afferent pathway.

The main use of RAPD is in evaluating a patient who has decreased vision in one eye and normal vision in the other. If it is present, there is lesion in one of the eyes, or asymmetric optic nerve or retinal lesion. If it is not present, retina or optic nerve of both eyes are normal or symmetrically involved. But brisk pupillary reaction to light definitely rules out optic nerve pathology.

Technique of swinging flashlight test

The swinging flashlight test is performed as follows:

- *Patient is seated* in a dimly lit room and asked to fixate at a distant target. This provides maximum relaxation of the iris sphincter muscle.
- *Torchlight is shone* into one eye. The light should be directed from below so that it does not act like a near target and induce miosis associated with accommodation. It should be shone into the eye for about 2–3 seconds.
- *Pupillary reaction is observed* and the light is quickly moved across the bridge of the nose and directed into the opposite eye. If the light is moved too slowly; the pupil is seen to constrict when finally the light falls on it and thus gives a false impression of a normal reaction.
- *Pupillary reaction of the other eye is observed* and compared in amplitude and speed to the first eye.
- *The light should be moved across one eye to the other* briskly and rhythmically at least 5 times. This is important to be sure that any papillary dilatation on one side is not just the sphincter movement due to physiological pupillary unrest. The light should be bright, but not so bright that it makes the patient photophobic.
- *RAPD can be identified even in cases where the reaction of both pupils cannot be studied,* for example, single eyed individuals, patients in whom one pupil is distorted, non-dilating and fixed or constricted due to neurological disease, iris trauma or synechiae.

Observations

While performing the swinging flashlight test, we observe the pupil that is being illuminated. But the opposite pupil also reacts in an identical manner. Thus, in these cases the examiner must observe only the reactive pupil. If the abnormal eye is the eye with the fixed pupil, then the normal eye will react briskly when the light is shone into it and will dilate when the light is shone into the opposite eye. On the other hand, if the eye with the apparently normal pupil is the affected eye, then its pupil will dilate when the light is shone onto it and constrict when the light is directed on the other eye (with the fixed pupil).

Normal response (RAPD absent)

When light is shone into one eye, the pupil constricts. When it is transferred to the other eye, its pupil is either already constricted (due to consensual reflex) or constricts further. When it is shone back into the first eye, the same response takes place.

Abnormal response (RAPD present)

When light is shone into the normal eye, its pupil constricts. When light is transferred to the other abnormal eye, it will either consistently constrict more weakly compared to the normal eye; or

does not react; or actually dilates on light stimulation (phenomenon called pupillary escape); RAPD is said to be present. At this point the other eye's pupil will also be dilated.

Presence of RAPD means that cause of visual loss is unilateral or asymmetric bilateral retinopathy or neuropathy.

- Interpretation of presence of RAPD is shown in Fig. 6.2.
- On dilated fundus examination, a retinopathy severe enough to cause RAPD will be easily appreciated.
- However, optic neuropathy may be present in the absence of any fundus abnormalities.

Retinal pathologies capable of causing RAPD are:

- Central retinal artery occlusion
- Central retinal vein occlusion
- Total retinal detachment.

These will have substantial changes in the fundus and a careful dilated fundus examination can help differentiated them from neuro-ophthalmological disease.

If RAPD is absent, visual loss in these cases may be due to:

- Macular pathologies
- Amblyopia
- Psychogenic causes/malingering.

Use of neutral density filters

The neutral density filters are available ranging from 0.3 to 2 log units; in steps of 0.3 log units. Neutral density filters can be used for:

- *Quantifying the RAPD.* The neutral density filters are placed in front of the normal eye. The density of the filter that neutralizes the RAPD is the measure of the defect.
- *Unequivocal findings.* The neutral density filters are successively placed in front of either eye. If RAPD is present in an eye it becomes more obvious when the filter is placed in front of that eye. If it is absent, when the filter is placed in front of one eye the pupil will dilate on shining light onto it; and this will repeat when the filter is shifted to the other eye, i.e. there will be an 'Artificially created RAPD'.

Grading of RAPD

Grade I. A weak initial constriction and greater re-dilatation

Grade II. Initial stall and greater re-dilatation

Grade III. Immediate pupillary dilatation

Grade IV. Immediate pupillary dilatation following prolonged illumination of the good eye for 6 seconds

Grade V. Immediate pupillary dilatation with no secondary constriction.

Note: As mentioned before, the presence of a relative afferent papillary defect almost always confirms a neuro-ophthalmological cause, but the absence of it does not rule out the same. So either ways, we must go ahead with further optic nerve function tests which complement our findings and which assume special importance in case of unequivocal results or if pupil cannot be examined.

OPTIC NERVE HEAD EXAMINATION

A meticulous optic nerve head examination using slit-lamp biomicroscope and high power

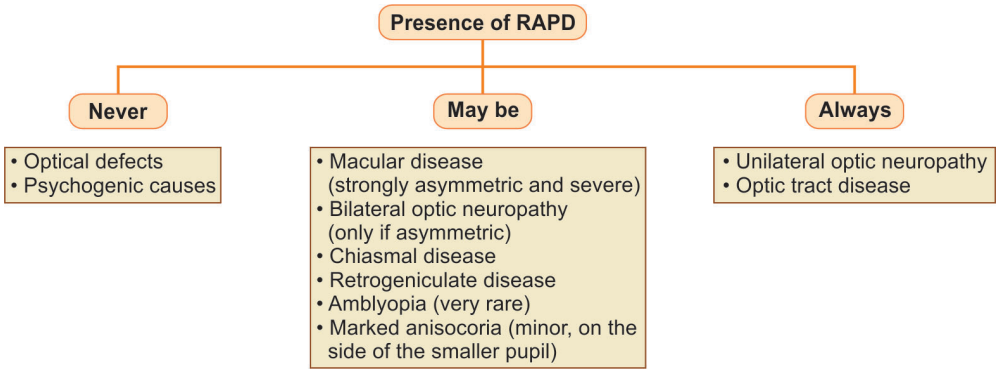


Fig. 6.2: *Interpretation of presence of RAPD.*

lenses like 78 D or 90 D gives valuable information about the acuteness of the condition and to some extent the etiology.

COLOUR VISION TESTING

Testing the colour vision helps to differentiate optic nerve pathology from other pathologies. Usually in day-to-day clinical practice, Ishihara pseudoisochromatic tests plates are used. Inability of indentifying a number at all is considered as defective colour vision. The D 15 colour vision test is based on a set of coloured plates or disks which have to be arranged in the correct order. Tests like Farnsworth-Munsell 100 hue test and Hardy-Rand-Ritter (HRR) charts are more detailed tests which include various colours which have a very subtle difference of hue which the patient has to compare and obtain the nearest match. Though these tests can identify very early or fine changes, they are very time consuming and very difficult to carry out in day-to-day busy clinics.

To determine whether the colour vision deficit is due to optic nerve involvement we need to note if:

- There is relevant history (acquired loss of colour vision)
- Colour vision worse in dim light
- Preferential inability to discriminate between red and green colours (in macular abnormalities there will be preferential loss of ability to differentiate blue and yellow colours).

Colour saturation

To patients with optic nerve disease colours appear less bright, faded (desaturated) or darker in the affected eye than the normal eye. To check for this, a red stimulus (brightly coloured stimulus preferred) is presented to each eye in succession and patient is asked if to one eye the colour appears 'brighter' or 'richer' than the other. If the patient clearly says yes it is taken as a positive response. To the eye with defective optic nerve function the red colour may appear as a faded colour such as orange, pink or faded red (indicating decreased saturation) or brown, gray (indicating decreased brightness).

BRIGHTNESS COMPARISON TEST

This test detects decreased brightness sensitivity in the affected eye if any. Bright torchlight is shone into each of the eyes and patient is asked which appears brighter. Taking the brighter one as 100% patient is asked to compare it with the other eye and determine how much is the decrease in the brightness perception in the other eye. This test is slightly more sensitive than the RAPD and may help detect an early defect.

CONTRAST SENSITIVITY TESTS

Visual acuity determines the smallest spatial detail that can be resolved for a high contrast stimulus, whereas measurement of contrast sensitivity checks the responses of visual system to different sizes and contrasts. These tests are thus useful adjuncts to reveal the deficit in patients with normal visual acuity but who may have a visual pathway lesion.

- It is usually determined by measuring the contrast thresholds for sinusoidal gratings, an alternating pattern of light and dark bars, the luminance of which varies sinusoidally in a direction perpendicular to the orientation of the grating. The size of the grating is specified according to the spatial frequency which is the number of cycles of the grating pattern (i.e. the pair of dark and light bars) per degree of visual angle. The contrast sensitivity function measures between 3 and 10 spatial frequencies from 0.5 to 30 cycles per degree.
- Other tests available to measure the contrast sensitivity are Pelli-Robson contrast sensitivity chart, Vistech contrast sensitivity chart and a low contrast version of the Bailey-Lovie visual acuity chart. These charts make use of contrast letters to measure contrast sensitivity. However, whether these tests are superior to the ones using sinusoidal gratings to measure contrast sensitivity is controversial.

Note. One must note that sensitivity losses have little specificity for differential diagnosis purposes. Similar patterns of loss can be obtained by a wide variety of conditions and at the same time many types of disorders can produce similar amounts of visual acuity loss.

VISUAL FIELD TESTING

Confrontation test

The next step is to determine any defect or decreased sensitivity in the visual fields. This

can be done in the OPD performing the confrontation test which is done as follows:

1. ***Patient should be comfortably seated.*** The clinician is seated about 1 meter in front of and at the level of the patient, who is asked to fixate on the bridge of the examiner's nose. While testing patient's right eye, his left eye should be occluded and the clinician's right eye should be closed.

2. ***Firstly ask the patient*** if he can see the examiner's full face clearly. If not, then ask him to elaborate which parts are missing or not clearly visible to him. This will tell us about any gross defects in the field of vision.

3. ***Testing of single quadrants.*** One or two stationary fingers are presented randomly in each quadrant of the right eye taking care that the stimulus remains well within 30 degrees of the visual field; and the patient is asked to count the fingers. Children can be asked to simulate the number of fingers seen and at the same time the examiner looks for the eye movements brought forth by the stimulus.

4. ***Delineating the scotoma.*** If the patient is not able to see the fingers—move the finger from the defective quadrant slowly towards the vertical meridian. Patient is asked to identify as soon as he sees the stimulus. This way we can recognize if the border of the defect is aligned to the vertical meridian. Same procedure should be repeated to if there is presence of a defect respecting the horizontal meridian.

Steps 2, 3, 4 are repeated in the left eye.

5. ***Testing double quadrants.*** This is performed if the patient correctly identifies stimuli in single quadrant testing but the clinician suspects presence of defect in a certain quadrant. One or two fingers of both the hands are simultaneously presented in two different quadrants and the patient is asked to count the total number of fingers seen.

6. ***Brightness comparison.*** If the patient responds correctly to the above tests he may be asked to compare the clarity or brightness of two fingers simultaneously presented in two different quadrants and if there is any reduction in brightness of one of them.

7. ***Red desaturation test.*** Two identical bright coloured objects (preferably red) are presented to the patient in two different quadrants and asked if there is any difference in the brightness of the colour in any of the quadrant. If yes, the object is moved slowly from the defective quadrant towards the vertical meridian and the patient is asked if the object becomes brighter or duller in the course. If there is marked difference, a hemianopic defect exists. Same manoeuvre is repeated with the horizontal meridian.

The confrontation test gives a rough idea about presence of any gross visual field defects. It has very less specificity and sensitivity as it depends largely on the patient's ability to understand how to perform the test and maintain fixation. Though it should never replace formal visual field testing, it assumes importance in certain scenarios like examination of a bedridden patient where technical investigations may not be possible.

Automated visual field examination

One of the most important investigations in neuro-ophthalmology is the automated visual fields examination. Central 30 degrees of field testing in standard automated perimetric programmes is preferred.

Visual field analysis must be considered

- If RAPD is present
- If any of the adjunctive clinical tests (colour vision, colour saturation, brightness sensitivity, contrast sensitivity) are abnormal
- Optic nerve head examination shows pallor/edema/optic atrophy/glaucomatous changes.

Visual field examination helps greatly to quantify the defect and localise the lesion along the afferent visual pathway and thereby can be called an important part of visual testing.

While trying to localise the lesion we must try to differentiate between a non-hemianopic and hemianopic defect. The loss of entire hemifield is not necessary for the diagnosis of hemianopic defect, it is enough that the border of the defect is aligned to the vertical fixation meridian. If the field defect is hemianopic, it points towards the cause of an optic neuropathy or retinopathy, whereas a hemianopic defect would point to a chiasmal lesion.

TESTS FOR MACULAR PATHOLOGIES

Tests that can be used to rule out macular pathologies are as follows.

Amsler's grid test

In the standard Amsler's grid chart the patient is presented a grid of black lines on a white background and a central black dot for fixation at a reading distance. The patient must wear his refractive correction. First the patient is asked if he can see the central dot. He is then asked to mark on the chart if any of the squares seem bent or distorted or of unequal sizes; or if he is unable to see any parts of the grid. The presence of metamorphopsia is diagnostic of macular disease, as it is caused by the separation, distortion or crowding of foveal cones by oedema, fluid or scarring.

There are other types of Amsler's grids:

- White squares on black background and central white dot
- White squares on a black background with a central white dot and diagonal white limits of his scotoma
- Red squares on a black background with a central red dot. This chart helps to diagnose optic nerve, chiasmal, or toxic amblyopia related problems.

Photostress test

Baseline visual acuity of the patient is determined. Bright light is directed into one of the eyes for ten seconds. This bleaches the photoreceptors. After ten seconds the patient's Snellen's visual acuity is recorded again. The time between bleaching and recovery to within one Snellen line of the original visual acuity is measured. If the time taken to recover is substantially greater in one eye than the other, it indicates impaired regeneration of photoreceptor pigment in the retinal pigment epithelium. However, this is a highly subjective test and can hardly be relied upon for the diagnosis.

Electroretinogram (ERG)

In the standard full field (Ganzfield) ERG the potentials are excited by short flashes of light and detected by recording electrodes contacting the anterior surface of the eye. The stimulus covers the entire retina, and the recorded responses are a summation of the electrical potentials generated by the entire retina. It thus is a mass response and will detect generalized outer retinal disease and fails to detect isolated macular or other localized pathologies. Multifocal ERG (Mf ERG) is the new specialized type of ERG which is capable of highlighting such localized pathologies.

This is useful in determining the cause of visual disabilities when there are no visible findings on ophthalmoscopy.

Fundus fluorescein angiography

This is done to identify subtle macular lesions and vascular pathologies and is capable of detecting defects in the RPE and choroid too. It occasionally spots lesions not visible even on high magnification ophthalmoscopy.

TESTS FOR AMBLYOPIA

If there is absence of retinal lesion, the visual loss can be attributed to amblyopia. Amblyopia refers to poor vision caused by abnormal visual development secondary to abnormal visual stimulation.

History of squinting or cataract in childhood or congenital ptosis which occludes the visual axis may give a clue towards the presence of amblyopia. Binocular amblyopia may be considered in the cases of children with high hypermetropia. There are no confirmatory investigations for this entity and the diagnosis of amblyopia is made when all other causes are ruled out. A few simple clinical tests may aid in the diagnosis.

Testing for 'crowding phenomenon'

An amblyopic patient when asked to read single letters, is said to have a higher visual acuity then when he is asked to read an entire line. This is called *crowding phenomenon*.

Neutral density filter test

A 2 log unit neutral density filter is used in this setting. It is placed in front of the normal eye and the visual acuity is checked. It causes a drop in the visual acuity. When the same procedure is repeated in front of the other suspected amblyopic eye, it degrades the visual acuity less.

Base out prism test

This test detects the presence of a central fixation scotoma <5 degrees and is not specific for amblyopia. A 4 PD prism is placed in front of the normal eye in the base out position. The image is thus shifted temporally in that eye. There is bilateral vergence movement away from the eye behind the prism to take up fixation and similar movement of the other eye. However, since the image falls within the small scotoma the eye does not show any refixation movement. Similarly, when the prism is placed in front of this eye, there is no movement of either eye.

NEUROIMAGING

Neuroimaging is essential in certain scenarios to come to the correct diagnosis. It should be considered in cases of:

1. *Acute loss of vision*; unilateral (suspicion of haemorrhagic, ischaemic, embolic phenomenon) or bilateral (suspecting a lesion above the level of chiasma)
2. *Haemianopic field defects* on visual field analysis indicating chiasmal lesion
3. *Trauma* to rule out haemorrhage, fractures, optic nerve injury or compression
4. *Suspicion of compressive pathology.*

The choice of imaging modality depends upon the clinical diagnosis, available facilities and the cost factor. Magnetic resonance imaging (MRI) and computed tomography (CT) are the most commonly ordered investigations by a neuro-ophthalmologist.

Magnetic resonance imaging (MRI)

MRI is the investigation of choice in neuro-ophthalmology; especially for a patient with acute vision loss. It is more useful in:

- Identifying small lesions
- Identifying vascular lesions
- Characterization of lesion
- Extent and invasion of surrounding lesion
- Surgical planning if necessary.

MRI offers better delineation of soft tissues and thus an improved differentiation between retrobulbar soft tissues (fat, muscle and optic nerve), between normal components of the brain (gray and white substances) and between differing forms of pathological change (infarction, haemorrhage, inflammation, and neoplasms).

MRI with gadolinium contrast enhances the blood vessels, extraocular muscles and active lesions and is preferred in this setting.

The most important advantage of MRI scanning lies in the fact that the signal strength in the image determined by tissue-specific parameters, the T_1 and T_2 relaxation times. This produces a high-resolution image with excellent tissue identification. Normal anatomy is best demonstrated in **T_1-weighted** images, whereas **T_2-weighted** images are better for demonstrating intracranial or other pathology.

Magnetic resonance angiography (MRA) *and* ***Magnetic resonance venography (MRV)*** are performed when the MRI does not yield any results but there is a strong suspicion of vessel pathology.

Absolute contraindications to MRI:

- Cardiac pacemakers
- Incorporated ferromagnetic foreign bodies/implants
- Shrapnel wounds
- Aneurysm clips of uncertain origin.

Computed tomography (CT)

CT is the imaging method of choice for patients with skull/brain injuries. The presence and course of fractures in the orbit can be studied, using the windows that allow the best definition of bones' anatomy (**Bone window**). The effects of direct ocular trauma, or retrobulbar haemorrhages, are best studied when using the window settings for soft tissues (**Soft tissue window**). Thus, ophthalmic vein distension may be detected because of a traumatic carotid cavernous fistula.

In soft tissue tumours where we expect calcification or hyperostosis (like meningioma) or an orbital tumour CT scan is a better choice of investigation. Also for detection of foreign bodies CT scan is preferred as such cases are a potential contraindication for MRI.

CT with contrast is done for better visualization of blood vessels.

Contraindication of contrast: It is important to remember the contraindications for the use of contrast materials:

- Allergy to iodinated compounds
- Hyperthyroidism
- Poor renal function
- Paraproteinemia.

SUMMARY

If all the above-mentioned causes of visual loss are eliminated with the aid of clinical tests, visual field examination, neuroimaging and other diagnostic investigations; and still no cause is found; the visual loss can then be attributed to psychogenic causes.

It is often tempting enough to refer such a patient with unexplained visual loss to the neuro-ophthalmologist but what is essential is a systematic and rational approach to come to a working diagnosis and thus save the patient of anxiety, dissatisfaction and expenses.

Clinico-investigative approach to a patient with visual loss is summarized in Fig. 6.3.

CLINICO-INVESTIGATIVE APPROACH FOR A PATIENT WITH DIPLOPIA

INTRODUCTION

Diplopia essentially means double vision. Causes of diplopia range from benign and common entities such as a decompensated phoria to ominous entities such as aneurysmal third nerve palsy or sixth nerve palsy due to increased intracranial pressure. Dysfunction of the extraocular muscles may be the result of an abnormality of the muscle itself or an abnormality of the motor nerve to the muscle. The major symptom associated with this dysfunction is diplopia. Diplopia is a common presenting symptom to ophthalmologists and emergency room physicians with many potential causes that can involve many different structures. Given that the etiology of diplopia spans such a broad-spectrum, it is important to have a systematic approach in evaluating patients presenting with this symptom.

CAUSES OF DIPLOPIA

MONOCULAR DIPLOPIA

Monocular diplopia is defined as double vision that is present in the affected eye while the other eye is occluded. Monocular diplopia in nearly all circumstances is the result of local ocular aberration (defects of the cornea, iris, lens or retina). Neurologic misalignment causes binocular diplopia, whereas ocular causes such as refractive error, lead to monocular diplopia. Patients with optical causes of monocular diplopia like media opacity such as subtle changes in the optical density of anterior and

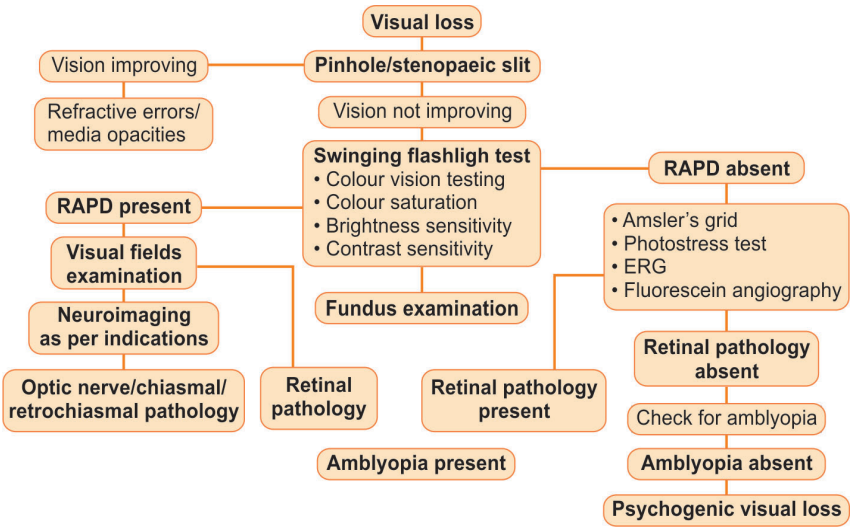


Fig. 6.3: *Summary of clinico-investigative approach to a patient with visual loss.*

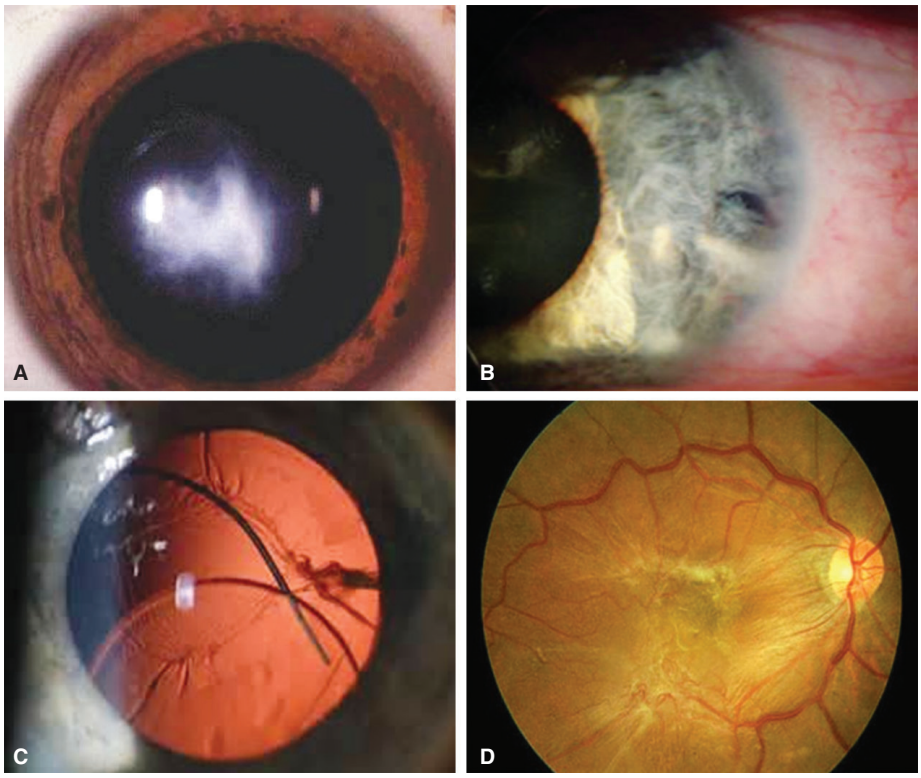


Fig. 6.4: *Common causes of monocular diplopic: (A) Corneal scar; (B) Iridotomy; (C) Subluxated IOL; (D) Macular pucker.*

posterior layers of lens in the case of incipient cataract generally describe blurring and glare and the patient may see a ghost image that is much lighter and less defined. Other causes include defects of cornea like irregular astigmatism, corneal scars (Fig. 6.4A), scars due to laser eye surgery (LASIK), iris defects (Fig. 6.4B) or in appropriately placed peripheral iridectomy, subluxated crystalline lens or IOLs (Fig. 6.4C). In all these conditions monocular diplopia resolves with pin hole. Patients with macular disorders generally describe a break, bend or distortion of the viewed edge leading to a distorted image. This type of monocular double vision generally does not improve when the object is viewed through a pinhole, in fact, vision is often worse in these cases. Common disorders of macula include choroidal neovascular membrane or an epiretinal membrane (Fig. 6.4D). The other cause of monocular diplopia which does not resolve with pinhole is central diplopia which is caused by lesion involving visual cortex and is associated with visual field defects. In this setting the patient may also complain of triple or quadruple vision.

BINOCULAR DIPLOPIA

Binocular diplopia, on the other hand, resolves with closure of either eye. From the eye to the brain, the following seven mechanisms and their associated locations should be kept in mind while gathering historical information regarding binocular diplopia:

- Orbital/ocular displacement
- Extraocular muscles restriction
- Extraocular muscles weakness
- Neuromuscular junction dysfunction
- 3rd, 4th and 6th cranial nerve dysfunction
- Cranial nerve nuclear dysfunction in brainstem
- Supranuclear dysfunctions (pathways to and between nuclei of 3rd, 4th and 6th cranial nerves).

Common causes of binocular diplopia are summarized in Table 6.1.

Table 6.1 *Common causes of binocular diplopia*

Types of lesion	*Causes*
Orbital disorders	• Trauma • Tumour/mass • Infection
Extraocular muscle restriction	• Thyroid associated ophthalmopathy • Mass/tumour • Extraocular muscle entrapment • Injury/haematoma due to ocular surgery
Extraocular muscle weakness	• Congenital myopathies • Muscular dystrophy
Neuromuscular junction dysfunction	• Myasthenia gravis • Botulism
3rd, 4th and 6th cranial nerve dysfunction	• Ischemia • Hemorrhage • Tumour/mass • Vascular malformations • Aneurysm • Trauma • Multiple sclerosis • Meningitis
Cranial nerve nuclear dysfunction in brainstem	• Stroke • Haemorrhage • Tumour/mass • Vascular malformations
Supranuclear dysfunction	• Internuclear ophthalmoplegia • Convergence spasm • Convergence and divergence insufficiency • Pseudoabducens palsy • Skew deviation • Monocular elevator palsy

SUPRANUCLEAR PATHWAY LESIONS

GAZE PALSIES

1. ***Conjugate gaze palsy.*** If both eyes are equally paretic in the same direction of gaze and causes no diplopia. These are of two types:

- *Horizontal—conjugate* gaze palsies localize to pons or frontal cortex.
- *Vertical*—conjugate gaze palsies localize to midbrain.

2. ***Disconjugate gaze palsy*** results in diplopia. It is of two types:

a. *Horizontal*, e.g. internuclear ophthalmoplegia.

b. *Vertical*—skew deviation.

INTERNUCLEAR OPHTHALMOPLEGIA

Disruption of the MLF in the pons or midbrain results in an internuclear ophthalmoplegia (INO). There is adduction deficit in the eye on the same side of lesion and simultaneous nystagmus of the abducting eye in lateral gaze. The side of the adduction deficit determines the side of the INO. It is most commonly associated with multiple sclerosis and stroke.

Clinical features

The patients with INO may complain of horizontal diplopia, particularly when there is profound adduction weakness. Those patients with subtle paresis may have no symptoms or

complain of blurred vision with eccentric gaze only. Since a skew deviation is frequently associated with lesions of the MLF, vertical diplopia may be another complaint. Oscillopsia may be the other symptom which may result from either the abduction nystagmus or an impaired vertical vestibular ocular reflex.

- The hallmark finding of INO is impaired adduction of the eye. Subtle cases may be evident only upon fast eye movements from midline to eccentric gaze which is known as medial rectus float. The demonstration of intact convergence in INO establishes the supranuclear localization of the medial rectus weakness and usually signifies a lesion of the MLF within the pons. In contrast patients with MLF lesions close to the third nerve nucleus may have impaired convergence. However, some patients with INO have poor convergence because of the vertical misalignment produced by the associated skew deviation. Therefore, the absence of convergence may not be a totally reliable sign to localize the lesion in a discrete part of the MLF pathway.
- The eye that is contralateral to the MLF lesion typically exhibits an abducting nystagmus in end gaze. Evidence suggests that this abducting nystagmus is an adaptive phenomenon to increase the innervation to the weak adducting eye.
- Since the otolith pathways project through the MLF, a skew deviation is commonly observed with an INO. Typically, the hypertropic eye is on the same side as the adduction weakness. There is downbeating nystagmus in the eye ipsilateral to the MLF lesion and torsional nystagmus in the contralateral eye.
- Bilateral lesions of the MLF usually produce additional eye findings, including impaired vertical pursuit and vertical gaze holding defects. Severe bilateral INOs may also result in a large angle exotropia in primary gaze in so-called WEBINO (wall eyed bilateral INO).

Diagnosis

The diagnosis of INO is usually straightforward, especially when there is impaired medial rectus dysfunction in lateral gaze with normal convergence. A unilateral INO in an older patient usually results from a brainstem infarction, while bilateral INO in a young patient typically signifies a demyelinating process such as multiple sclerosis. However, a variety of lesions may be associated with INOs including vascular malformations, tumours; head trauma, infections, vasculitides such as systemic lupus erythematosus, Behçet's disease and giant cell arteritis; nutritional disorders such as Wernicke's disease; metabolic disorders such as hepatic encephalopathy; Arnold-Chiari malformation; and degenerative conditions, progressive supranuclear palsy.

- The combination of an INO with an ipsiversive conjugate palsy is a pontine one-and-half syndrome due to simultaneous ipsilateral involvement of the PPRF and the MLF. Damage to the MLF in addition to the corticospinal tracts results in the Raymond. Cestan syndrome, characterized by an INO and contralateral hemiparesis.

SKEW DEVIATION

Skew deviation is an acquired vertical misalignment of the eyes that commonly occurs from acute brainstem dysfunction. It may also result from peripheral vestibular or cerebellar lesions. Patients may complain of binocular vertical diplopia, sometimes with a torsional component. The associated neurologic symptoms and signs often helps in differentiating skew deviation from other causes of vertical misalignment such as third and fourth nerve palsies.

Ocular tilt reaction. The combination of skew deviation with ocular torsion and a head tilt is known as the *ocular tilt reaction (OTR).* This syndrome typically develops because of loss of otolithic input to the INC from a central lesion, which may be in the medulla, pons, or midbrain. With an ocular tilt reaction, if the head is tilted to the left, the right eye becomes hypertropic, and both eyes rotate toward the lower ear. The opposite response of the eyes occurs if the head is tilted to the right. A fourth nerve palsy is the motility disorder that may be the most difficult to distinguish from a skew deviation since both conditions may be associated with a positive head tilt or three step test. With a fourth nerve palsy, the compensatory head tilt is opposite the

side of the higher eye (similar to ocular tilt reaction), but the hypertropic eye is extorted which is opposite of the skew deviation.

Thalamic esodeviation is an acquired horizontal deviation that occurs with lesions near the junction of the diencephalon and midbrain. This disorder may be seen in younger patients with pineal tumours or craniopharyngioma or in older patients with cerebral haemorrhage.

CONVERGENCE SPASM

This condition, characterized by convergence, accommodation, bilateral papillary miosis, and pseudomyopia, may mimic bilateral sixth nerve palsies. The distinction is important because convergence spasm is almost always indicative of a functional disorder. Patients usually complain of double vision, and they often have obvious personality disorders or other hysterical symptoms. The hallmarks are pupillary constriction on attempted abduction and a variable esotropia. Other features include normal abducting saccades, intact abduction during the oculocephalic manoeuvre or testing of monocular ductions, and resolution of the myopia following cycloplegia. The miosis may resolve upon occlusion of the fellow eye by disrupting the binocular input necessary for convergence. Convergence spasm should be distinguished from convergence retraction nystagmus or pseudoabducens palsy from pretectal lesions.

CONVERGENCE INSUFFICIENCY

Patients with convergence insufficiency describe horizontal diplopia at near, typically after a period of reading. Medial rectus function is normal when ocular ductions are tested, but patients typically have an exodeviation worse at near. A common sequela of head trauma, the condition may also be seen in association with dorsal midbrain syndrome, may be a decompensation of long standing exophoria or may be idiopathic.

DIVERGENCE INSUFFICIENCY

This ocular motility deficit is characterized by acquired horizontal diplopia at distance but not near, a comitant esophoria or esotropia at distance, motor fusion at near, and full ocular ductions without evidence of a sixth nerve palsy. Divergence insufficiency is typically benign, and affected patients are usually neurologically normal otherwise. However, since small bilateral sixth nerve palsies may mimic divergence insufficiency, elevated intracranial pressure, masses, and pontine lesions must be excluded with neuroimaging. Small vessel ischemic disease is a relatively common finding on magnetic resonance imaging studies of older patients with this condition.

- Prenuclear vertical misalignment seen in brainstem and cerebellar lesions may be comitant or incomitant with full motility but vertical misalignment decreases when patient lays supine.

CLINICAL EVALUATION OF DIPLOPIA

Diplopia may be the initial presentation of the potentially life-threatening disorder or it may be secondary to a harmless process. So, a detailed history as well as physical examination of a patient with diplopia is must to review the most common associated features that help localise the cause of diplopia.

HISTORY

The examiner should first determine whether the patient rarely sees double or has blurred vision of one eye, an overlay of the image or sees a halo surrounding the image. This information is obtained by a careful history and also we can ask the patient to draw a picture of what he sees. Once it has been confirmed that the images are truly separated, placing a cover over either eye will determine whether the diplopia is monocular or binocular.

The following questions should be kept in mind while approaching a patient with diplopia:

- Is the diplopia monocular or binocular?
- Is the onset acute or gradual?
- Is it constant or intermittent?
- Is there any variability/remission?
- Are there any associated signs and symptoms?
- History of ocular surgery/trauma?
- Any systemic diseases—Diabetes, hypertension, hyperlipidemia, hyperthyroidism, parkinsonism?

Features of diplopia

- ***Onset.*** Diplopia is almost always sudden in onset. The only exceptions are thyroid ophthalmopathy, divergence insufficiency and myasthenia gravis where gradual progression is seen.
- ***Constant or intermittent.*** We should always enquire from the patient whether the diplopia is constant or intermittent in nature. Most common causes of intermittent diplopia by far are decompensating phorias, vergence problems, accommodative spasm, headache (temporal arteritis) and myasthenia gravis. Myasthenia gravis is one condition which should be investigated in detail in a patient complaining of intermittent diplopia.
- ***Separation of images.*** Normally we do diplopia charting to look for separation of images. But we can always narrow down group of muscles which are affected by asking about the separation of images.
- ***Horizontal separation*** of two images indicates 6th nerve palsy.
- ***Vertical separation*** if pure can be due to 4th nerve palsy.
- ***Oblique separation*** of images occurs in 3rd nerve palsy.
- ***Orbital processes*** can cause horizontal, vertical or oblique diplopia.
- ***Horizontal diplopia*** worse at distance is associated with esotropia and implies lateral rectus palsy.
- If mainly at near, medial recti are implicated and is diagnosed as convergence insufficiency.
- Internuclear ophthalmoplegia and myasthenia gravis are other causes of horizontal diplopia.
- ***Thyroid associated ophthalmopathy***, skew deviation and myasthenia gravis present as vertical diplopia.

Associated symptoms

Associated signs and symptoms are vital to localize the site of injury:

- Elderly patient with severe headache and isolated 3rd nerve palsy with dilated non-reacting pupil implicates a compressive injury of 3rd nerve in subarachnoid space. Most likely cause would be intracranial aneurysm of posterior communicating artery.
- Symptoms of jaw claudication, headache, scalp tenderness and arthralgias should be enquired in older patients with diplopia to rule out temporal arteritis.
- Patient should be asked about associated neurological symptoms like facial numbness or weakness, hearing loss, dysphagia, dysarthria, vertigo, incoordination or numbness or weakness of extremities to rule out brainstem injury and supranuclear pathway injuries.
- If a patient reports with eye pain and diplopia, then common causes like cellulitis, any mass lesion, inflammatory disorders like pseudotumour should be ruled out.

Diurnal variation of diplopia

Diplopia that progressively worsens throughout the day or worsens with reading is common with neuromuscular junction disorders that affect extraocular muscles like myasthenia gravis. More than 50% patients of myasthenia gravis present with ptosis and diplopia alone.

Palinopsia refers to seeing multiple images of an object immediately after turning away from the object or after the object is removed from the sight. This is known as after image or strobe effect. This condition is seen in discrete lesions with occipitoparietal or occipitotemporal cortex and homonymous visual field defects are also associated with these cortical visual illusions.

EXAMINATION

Examination of all basic visual sensory and ocular motor functions is necessary in the evaluation of diplopia.

GENERAL EXAMINATION

- In general examination of a patient note should be made of gait, physical appearance, stature, head posture, facial symmetry, moist hands or tremors on a handshake.
- Blood pressure, random blood sugar and resting pulse rate should be recorded.
- ***Unaided and best corrected visual acuity followed by visual fields*** to confrontation,

pupillary appearance and reaction to light and pupil response to viewing a near target should be recorded. An invaluable tool for measuring visual acuity is a hand-held pinhole device (Fig. 6.5) that allows a patient to have monocular view of an eye chart through small holes. Pinhole can eliminate refractive errors, ocular aberrations and correct monocular diplopia caused by the same. On the other hand macular disorders of the retina do not improve with pinhole.

- ***An amsler grid*** can be used to identify macular diseases which can be confirmed on indirect ophthalmoscopy and fundus biomicroscopy.

GLOBE, ORBIT AND EYELID EXAMINATION

- The examiner should note periorbital swelling (Fig. 6.6), forward displacement proptosis (Fig. 6.7), backward displacement enophthalmos (Fig. 6.8) or sideways displacement (dystopia) of the globe.

Fig. 6.5: *Pinhole.*

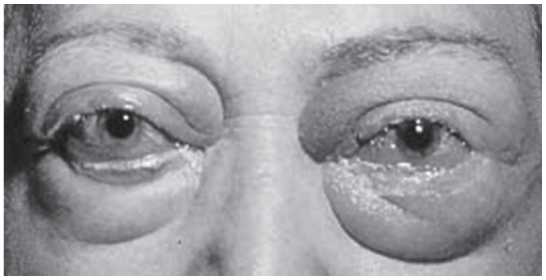


Fig. 6.6: *Periorbital swelling.*

- An exophthalmometer is used to detect and measure proptosis. Reading greater than 21 mm for either eye or a differences of more than 2 mm between each eye indicates proptosis/enophthalmos.
- ***Eyelid position and function*** should be examined. When the upper eyelid is above the upperborder of iris and sclera is showing, lid retraction is diagnosed and if the eyelid lags behind the eye on downward eye pursuits lid lag is present (Fig. 6.9). These two signs are commonly present in thyroid associated ophthalmopathy, whereas eyelid retraction

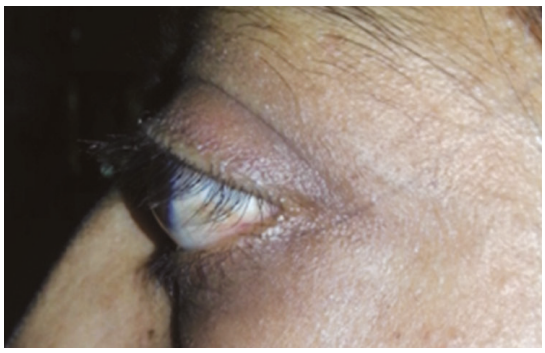


Fig. 6.7: *Proptosis.*

Fig. 6.8: *Enophthalmos.*

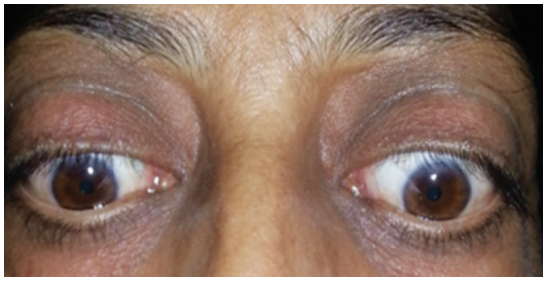


Fig. 6.9: *Lid lag.*

without lid lag is seen in dorsal midbrain disease. Ptosis is present if there is less than 4 mm between corneal light reflex and the upper eyelid with the patient fixating in primary gaze. Neurologic causes of ptosis result from dysfunction of the levator palpebrae muscle, controlled by the third cranial nerve or from dysfunction of the Müller's muscle, controlled by sympathetic innervations.

EXTRAOCULAR MUSCLE EXAMINATION

Ocular movement

The cardinal positions of gaze are examined by asking the patient to follow a target or the examiners finger held approximately 12 to 14 inches away from the patient's eyes. Ocular motility of each eye should be tested separately called ductions. Normal ductions rule out mechanical restriction of extraocular muscles but do not exclude possibility of paresis of extraocular muscles as paretic eye may move normally into the paretic field due to maximal innervation. Paresis is diagnosed by testing the versions (binocular eye movements). We should note that whether both eyes move fully and simultaneously or whether there is limitation or excessive movement of non-fixating eye. If duction/versions are limited, then one has to determine whether the limitation is caused by restrictive process, muscle weakness, neuromuscular junction dysfunction, cranial nerve palsy or supranuclear injury. Figure 6.10 shows eye movements in cardinal positions of gaze and corresponding muscles responsible for different directions of gaze.

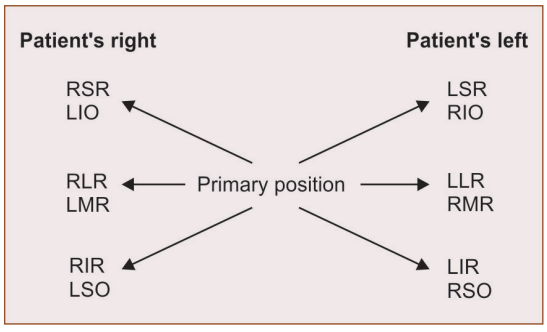


Fig. 6.10: *Eye movements in cardinal positions of gaze and corresponding muscles responsible for different directions of gaze.*

Forced duction test

Forced duction testing is done to detect mechanical restriction. When there is an actual restriction of movement, it becomes essential to determine, whether the restriction of movement is due to the primary under action of paretic muscle or is it because of presence of contractures in the antagonist muscle. Under topical anaesthesia the eye is moved with two toothed forceps, applied to the conjunctiva near the limbus in the direction opposite that in which mechanical restriction is suspected. If no resistance is encountered then the motility defect is caused by the paralysis of muscle. If resistance is encountered mechanical restrictions do exist and contracture of muscle, conjunctiva, tenon's capsule or myositis must be considered. Restrictive diplopia, due to orbital processes such as thyroid-associated ophthalmopathy, is associated with positive forced duction testing.

Active force generation test

Active force generation test determines the active force generated by a contracting muscle and is useful in assessing the function of apparently paretic muscles. The examiner stabilizes the eye with forceps while the patient tries to move the eye in the direction of paretic muscle against this obstacle. The presence of tug on the forceps indicates that residual innervation is present and there is incomplete or partial paralysis whereas absence of tug is due to complete paralysis of muscle.

The examination of a patient with ocular misalignment involves more than the evaluation of movement of eyes. The examiner should measure ocular alignment in various directions of gaze and with a right or left head tilt.

Measurement of deviation

Methods to measure diviation include:

1. Objective method
   - Prism bar cover test.
2. Subjective methods
   - Red-green glasses
   - Maddox rod test

- Maddox wing test
- Hess and diplopia charting
- Lees screen test.

The motility disturbance will be obvious after inspection and testing of vergences. However, more subtle problems will require quantification of the misalignment using prism alternative cover or Maddox rod techniques.

Maddox rod test

Maddox rod can be used to determine the presence and degree of ocular misalignment. The red line is held over either the right or left eye while the patient focuses on a distant, pinpoint light source. The ridges are placed in the horizontal direction to evaluate for horizontal misalignment and in the vertical direction to evaluate for vertical misalignment. The relationship of the line to the light that the patient sees determine the type of misalignment (Fig. 6.11). The red line seen by the patient is oriented vertically, when the ridges are placed horizontally over the right/left eye and *vice versa*. The Maddox rod test is also useful in quantitating the degree of torsional misalignment.

BRAINSTEM EXAMINATION

The brainstem examination includes examination of all the cranial nerves (Fig. 6.12).

- 2nd, 3rd, 4th and 6th cranial nerve exam—visual acuity, eye movements in cardinal positions of gaze
- Facial strength and sensation
- Corneal sensations
- Masseter strength
- Hearing
- Elevation of palate and uvula
- Sternocleidomastoid and trapezius strength
- Gag reflex
- Position and strength of tongue.

SUPRANUCLEAR PATHWAY EXAMINATION

The most important examination feature of a supranuclear motility deficit is the ability to overcome the ocular motility limitation with an oculocephalic manoeuvre (oculocephalic reflex) depicted in Fig. 6.13.

In cases of supranuclear injury, the nuclei of 3rd, 4th and 6th cranial nerves are still intact and the cranial nerve fascicles are functioning normally. Therefore, stimulation of the nuclei with head movements should result in full ocular ductions.

To perform the oculocephalic reflex the patient should be instructed to fixate at a object/target 14 to 16 inches away. Then, while the patient is fixating the patient's head is tilted slowly to the

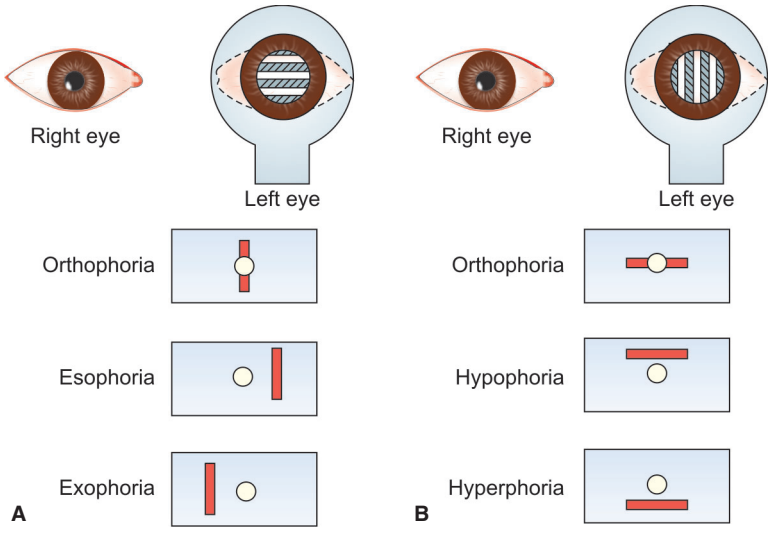


Fig. 6.11: *(A) Horizontally placed Maddox rod over left eye to detect horizontal misalignment; (B) Vertically placed Maddox rod over left eye to detect vertical misalignment.*

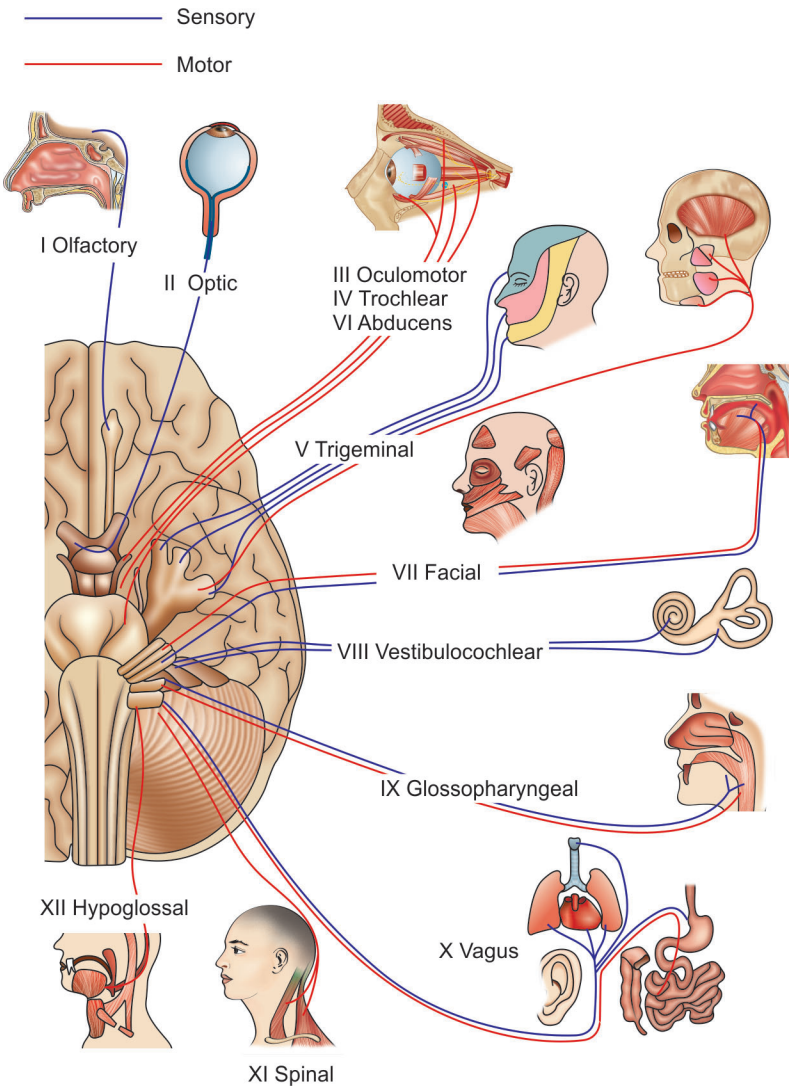


Fig. 6.12: *Cranial nerves: Origin and organs supplied.*

right/left and up/down. This head movement during fixation should overcome any limitations of ductions or versions due to supranuclear pathway dysfunction.

INVESTIGATIONS

Investigations required depend on the suspected etiology of diplopia as follows:

- **Monocular diplopia**—refraction, pinhole vision
- **Orbital disorders**—USG/CT/MRI orbit
- **Neurological causes**—CT/MRI/MRA
- **Suspected Myasthenia**—Edrophonium test

TREATMENT

The ophthalmoparesis in some of the disorders described, such as ischaemic and traumatic oculomotor palsies, will often resolve spontaneously. Other cases, such as those due to myasthenia gravis or bacterial meningitis, will improve as the underlying cause is treated.

Treatment modalities for diplopia are as under:

- *Glasses*
- *Stick-on occlusive lenses*
- *Fresnel prisms* (Fig. 6.14). Temporary Fresnel paste on prisms can be used initially followed by ground-in-prisms in chronic cases.

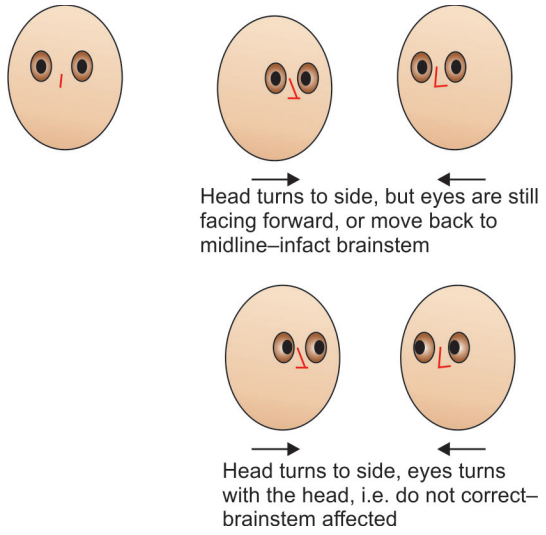


Fig 6.13: *Demonstration of oculocephalic reflex.*

Fig. 6.14: *Stick on Fresnel prisms.*

- *Patching.* Children patched for symptomatic relief should have the patch alternated daily between eyes to prevent occlusion amblyopia.
- *Chemo-denervation.* Botox therapy (Fig. 6.15)—Botulinum toxin injections into the antagonist muscle of a paretic one, even in supranuclear disorders.
- *Immunomodulation*—steroids, immunosuppressives
- *Surgical correction of strabismus*—individuals with paresis who do not improve spontaneously, and whose condition remains stable for 6 months, are candidates for corrective eye muscle surgery.
- *Speciality consultations*—neurology, endocrinology.

Fig. 6.15: *Botulinum toxin vial.*

BIBLIOGRAPHY

1. Burde RM. Amaurosisfugax. An overview. J Clin Neuro-ophthalmol 1989;9(3):185–9.
2. Friedman DI. Pearls: diplopia. Semin Neurol Feb 2010;30(1):54–65.
3. Lutwak N. Binocular Double Vision—A Review. American Journal of Clinical Medicine 2011;8(3): 166–9.
4. Newman NJ. Cerebrovascular disease. In Hoyt, William Graves; Miller, Neil; Newman, Nancy J.; Walsh, Frank. Walsh and Hoyt's Clinical Neuro-ophthalmology. 3 (5th ed.). Baltimore: Williams & Wilkins 1998;3420–6. ISBN 0-683-30232-9.
5. Pelak VS. Evaluation of diplopia: an anatomic and systematic approach. Clinical review article. Hospital Physician March 2004;6–25.
6. Ravits J, Seybold ME. Transient monocular visual loss from narrow-angle glaucoma. Arch. Neurol. 1984;41(9):991–3.
7. Rucker JC, Tomsak RL. Binocular diplopia. A practical approach. Neurologist 2005;11(2): 98–110.
8. Sadun AA, Currie JN, Lessell S. Transient visual obscurations with elevated optic discs. Ann. Neurol 1984;16(4):489–94.
9. Smit RL, Baarsma GS, Koudstaal PJ. The source of embolism in amaurosisfugax and retinal, 1994.
10. Torun N. A practical approach to a patient with diplopia. Journal of Experimental and Clinical Medicine 2012;28:S55–7.