Ophthalmology Lecture 1: Ophthalmology Fundamentals

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OPHTHALMOLOGY FUNDAMENTALS (including Refractive Error and Presbyopia)

ELWA Family Medicine Residency Program
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OUTLINE

• Introduction
• Review the clinically relevant anatomy of the eye
• Epidemiology of Blindness and visual impairment
• Refractive errors and presbyopia
The Eye Care Team

- Ophthalmologist: a physician specializing in medical and surgical care of the eye.
- Optometrist are healthcare professionals who provide primary vision care ranging from sight testing and correction to the diagnosis, treatment, and management of vision changes. An optometrist is not a medical doctor. They prescribe glasses and other optical devices.
- Optician: are technicians who are trained to design, verify, and fit eyeglass lenses and frames, contact lenses, and other devices to correct eyesight.
- They use prescriptions supplied by ophthalmologists or optometrists, but they do not test vision or write prescriptions for visual correction. Opticians are not permitted to diagnose or treat eye diseases.
- Ophthalmic nurses
- Other Non clinical staff
Ophthalmologists

- The ophthalmologist is qualified as a physician to diagnose all eye diseases and to prescribe or perform medical and surgical treatment of the eye.
- An ophthalmologist may practice as a comprehensive, or general ophthalmologist, a doctor who treats a wide range of eye problems and conditions.
- Subspecialist ophthalmologists specialize in certain areas of eye care, such as children’s eye problems.
Subspecialties in ophthalmology

- Cornea and external disease
- Cataract and refractive surgery
- Glaucoma
- Neuro-ophthalmology
- Oculoplastic
- Uveitis and Immunology
- Pediatric ophthalmology
- Medical retina
- Vitreoretinal
ROLE OF FAMILY PHYSICIAN IN EYE CARE

- Eye-related complaints make up 2-3% of primary care office visits.
- Knowledge of how to respond when these patients present is fundamental for the family physician, as is recognizing when to refer to an ophthalmologist for further care.
- Family physicians should be able to recognize eye conditions that can lead to visual loss, therefore requiring urgent referral to the ophthalmologist.
- Conditions like blinding and visually impairing conditions like cataract, refractive error, and strabismus can be diagnosed by the Family physician and referred to an eye clinic.
Basic equipment such as a Snellen chart, a tonometer, a penlight, an ophthalmoscope, dilating drops and fluorescein stain are available to the primary care physician to aid in achieving the correct diagnosis.

A thorough history and physical is core in making a diagnosis and determining the urgency of the eye condition.

Comprehension of basic eye anatomy is pivotal for the primary care physician in order to perform a detailed and complete physical exam.

The primary care physician should inspect the eyelid and sclera for inflammation, abrasions, hemorrhage, erythema or lesions.

The upper eyelid should be evaluated and everted if corneal abrasion or retained foreign body is suspected.
The visual system

- A coordinated pair of eyes
- The appropriate protective mechanisms
- The necessary neural apparatus to interpret visual information

- To produce a clear image of the external world and transmit this to visual cortex of brain
• Constant dimension of eye:
  • from its mechanical properties and the intraocular pressure
• Clear optical pathway
  • Transparent ocular media with ability to focus (refract) light on retina
• Intact retina (photochemistry)
• Visual pathway
• Coordinated movements of two eyes
• Integration of visual information from both eyes to produce binocular single vision
Eyelids

- Mechanical protection to anterior globe, excessive light
- Spread tear film
- Puncta through which tears drain into lacrimal drainage system
Conjunctiva

- Thin mucous membrane
- Palpebral, fornix, bulbar

**Function:**
- Tears production by the goblet cells
- Protection
- Smooth surface for the lids to blink
Lacrimal apparatus

- **Secretory:**
  - Lacrimal gland
  - Accessory lacrimal glands

- **Excretory:**
  - Punctum
  - Canaliculus
  - Lacrimal sac
  - Nasolacrimal duct
Tear film

- **3 layers:**
  - Lipid layer
    - Reduces evaporation
  - Aqueous layer
    - Contains nutrients and uptakes oxygen for cornea
  - Mucous layer
    - Allows tear film to spread evenly on a hydrophobic surface

**Functions:**
- Smooth optical surface
- Lubricate & wet cornea, conjunctiva
- Provide nutrients, O₂ to cornea
- Remove debris/foreign particles
- Antibacterial (lysozyme, beta-lysin IgA)
Eyeball

- **Fibrous coat**
  - Cornea, sclera

- **Vascular coat (uveal tissue)**
  - Iris, ciliary body, choroid

- **Nervous coat**
  - Retina
Cornea - anatomy

- 500-700 μm thick
- Transparent, avascular
- Forms approximately the anterior 1/6 of the outer coat of the eye and is continuous posteriorly with the sclera
- 5 layers:
  - Epithelium
  - Bowman’s membrane
  - Stroma
  - Descemet’s membrane
  - Endothelium
Cornea

- Transparency
  - Relative dehydration of the stroma (75-80%) is maintained by the impermeable epithelial barrier and active pumping mechanisms of the corneal endothelium
  - The regular spacing of individual stromal collagen fibrils

- Refraction
  - The cornea is the major refractive component of the eye - 43 dioptres

- Barrier to infection and trauma
Sclera

- Collagen
- Variable thickness
  - 1mm around optic nerve head, limbus
  - 0.3mm posterior to muscle insertions, at equator
- Tough, opaque, mainly avascular
- Outer wall of the eyeball -protects intraocular contents, preserve shape
- Attachments for the extraocular muscles
Iris and pupil

- Attached to ciliary body
- Forms pupil at center

- Stroma layer:
  - Smooth muscle

- Epithelial layer:
  - Anterior
  - Posterior (pigmented)
Pupil movements

- **Mydriasis** (Dilation):
  - Dilator pupillae muscles
  - Low-intensity light, excitement, fear
  - Sympathetic

- **Miosis** (Constriction):
  - Sphincter pupillae muscle
  - Bright light, accommodation
  - Parasympathetic
Pupillary light reflex

- Superior colliculus
- Pretectal nucleus
- Lateral geniculate body
- Edinger–Westphal nucleus

Consensual

Direct
Ciliary body

- Connects the iris and the choroid
- 2 parts:
  - Pars plicata (ciliary processes)
  - Pars plana
- Ciliary body has 3 layers:
  - Ciliary epithelium
  - Ciliary stroma
  - Ciliary muscle
- Functions:
  - Aqueous humor production
  - Suspension of lens, accommodation
1. Aqueous Humour production

- Active secretion by the epithelium of the ciliary processes of the ciliary body
- \(\beta\)-adrenergic receptors
- **Function:**
  - Carries \(O_2\), nutrients to lens, cornea and waste products away
  - Maintain shape of eye by intraocular pressure
  - Flushes away blood, macrophages, inflammatory cells
Aqueous Humour drainage

- **a. Conventional** outflow:
  - Trabecular meshwork → Schlemm’s canal → episcleral vessels (90%)
- **b. Uveoscleral** outflow:
  - Anterior face of ciliary body → choroidal vessels

Aqueous production & drainage are balanced to maintain an appropriate intraocular pressure
- Normal IOP range from 8 to 21 mmHg, average 15 mmHg
- Diurnal variation
2. Accommodation

- Ciliary body anchors lens via the zonules
- The zonular fibers are under tension during distant viewing
- When the ciliary muscle contracts, it reduces the tension on the zonules
- The lens (elastic) becomes more convex
- Refractive power increase
Crystalline lens

- Transparent, biconvex structure
- Contributes 15D (total 58D entire eye)
- Radially arranged zonule fibers that insert into the lens around its equator connect the lens to the ciliary body
- Can change diopteric power but amplitude of accommodation reduces with age (presbyopia)
Choroid

- Highly vascularised structure between the sclera and the retina
- Vessel layer, capillary layer, Bruch’s membrane
  - provides $O_2$ + nutrition to the outer retinal layer,
  - Temperature homeostasis
  - Conduct blood vessels
  - Absorb excess light
Vitreous body

- Clear gel-like structure that fills the posterior eye
- 98% water + 2% collagen (type 2), hyaluronic acid, soluble proteins
- Transmission of light onto the retina, cushion to the eyeball during trauma, nutritive and supportive role in retinal metabolism
- Adherent to the retina:
  - the optic disc
  - ora serrata, pars plana (vitreous base)
  - Posterior lens
  - Around retinal vessels
Retina

- Converts light into nerve impulses
- From the optic disc to the ora serrata
- Multilayered, 10
- 2 functional layers:
  - Neurosensory retina
  - Retinal pigment epithelium (RPE)
2. Neurosensory retina

- 3 main groups of neuronal cells: photoreceptors, bipolar cells, ganglion cells
- Photoreceptor cells (rods + cones) undergo photochemical changes (phototransduction)
- Bipolar cells relay nerve impulse to ganglion cells
- Ganglion cell exit at optic disc to become optic nerve
  - Amacrine cells - likely to play modulatory roles, allowing adjustment of sensitivity for photopic and scotopic vision
  - Horizontal cells - integrate and regulate the input from multiple photoreceptors
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<thead>
<tr>
<th>Function</th>
<th>Cones</th>
<th>Rods</th>
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<tbody>
<tr>
<td>Total number</td>
<td>6-7 million</td>
<td>120 million</td>
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<tr>
<td>Highest density</td>
<td>Macula</td>
<td>Peripheral retina</td>
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<tr>
<td>Daytime vision,</td>
<td></td>
<td>Night vision, detection of movement</td>
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<td>Color vision</td>
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"Good News, Herbert, we think we've discovered the cause of your headaches."
Fundus of the eye
Macula lutea

- Oval, yellowish area at center of posterior part of retina measuring 5mm (temporal to optic disc)
- Darker color compared to surrounding fundus
- Specialized area of the retina with fovea at its centre responsible for **photopic** (day vision) and **color vision**
Fovea centralis

- The point at which visual perception is sharpest
  - Bipolar cells, ganglion cells, blood vessels displaced laterally
  - Only photoreceptors in the center
  - Maximize the amount of light to fall onto the exposed photoreceptor
  - Only cones in the floor of the fovea (highest concentration)
Optic disc

- The location where ganglion cell axons exit the eye to form the optic nerve
- Yellowish orange color (we say pink)
- 1.5mm diameter (may vary), vertically oval
- Central retinal vessels enter and leave the eye here
- No photoreceptors: physiological **blind spot**
- Centre of the optic disc, there is pale central cavity – optic cup, no nerve fibers exit here
Scleral ring

Neuroretinal rim

Cup/Disc ratio = C/D

Cup edge
Retinal blood supply

- Retinal arteries supply O2 + nutrients to the inner layers of the retina
- Outer layers (RPE-outer nuclear) supplied by choroidal capillaries
- **Superior** and **inferior** branches, which split into **nasal, temporal** branches.
- Capillaries with nonfenestrated endothelium, prevent large molecules and toxins to permeate; this forms the **inner blood retinal barrier**
Optic nerve

- Contains over 1 million fibres
  - Nerve fibres are myelinated only after leaving the eye
  - **Nasal fibres** decussate at the **optic chiasm**

- Surrounded by cerebrospinal fluid in the anterior extension of the subarachnoid space
- Protected by the same meningeal layers of the brain
Visual pathway

- Optic nerve
- Optic chiasm
- Optic tract
- Lateral geniculate body
- Optic radiations (fourth neuron)
- Visual cortex (area 17)

- Optic Nerve
- Optic Chiasm
- Optic Tract
- LGN
- Optic Radiations
Extraocular muscles

- 7 extraocular muscles
- The movements of the eyeballs are produced by the following extraocular muscles:
  - 4 rectus (superior, medial, lateral, inferior)
  - 2 oblique (superior, inferior)
    - Levator palpebrae superioris
Global impact of blindness and visual impairment

- World Health Organization (WHO) definition:
  - Distance vision impairment:
    - Mild – presenting visual acuity worse than 6/12
    - Moderate – presenting visual acuity worse than 6/18
    - Severe – presenting visual acuity worse than 6/60
  - Near vision impairment: Presenting near visual acuity worse than N6
  - Blindness – presenting visual acuity worse than 3/60 or corresponding visual field loss to less than 10 degrees in the better eye
- Globally, at least 2.2 billion people have a vision impairment or blindness, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed.
- Globally, the leading causes of vision impairment are uncorrected refractive errors and cataracts.
- The majority of people with vision impairment are over the age of 50 years.
Main causes of blindness

Developing countries
- Cataract
- Glaucoma
- Trachoma
- Vitamin A deficiency
- Onchocerciasis

Developed countries
- Age-related macular degeneration
- Glaucoma
- Cataract
- Diabetic retinopathy
- Refractive error
Emmetropia and Ametropia

- **Emmetropia** (optically normal eye) can be defined as a state of refraction, where in the parallel rays of light coming from infinity are focused at the sensitive layer of retina with the accommodation being at rest.

- **Ametropia** (a condition of refractive error), is defined as a state of refraction, when the parallel rays of light coming from infinity (with accommodation at rest), are focused either in front or behind the sensitive layer of retina, in one or both the meridians.

- The ametropia includes:
  - Myopia,
  - Hypermetropia
  - Astigmatism.
REFRACTIVE ERRORS AND VISION LOSS

- The World Health Organization estimates that 333 million people are blind or visually impaired.
- Nearly half of these, 154 million are suffering from uncorrected refractive error.
- Individuals so affected are handicapped in a variety of ways from being deprived of educational opportunities to being limited in the workplace and even being burdens to their families.
- The economic impact both personally and in terms of society at large is huge.
PRINCIPLES OF OPTICAL CORRECTION OF AMETROPIA

• Refractive error is expressed in terms of the characteristics of the lens required to correct the optics of the eye such that the image of an object at optical infinity will be in focus on the retina with the accommodation of the eye in a relaxed state.

• EMMETROPIA: The state in which the convex surfaces of the optical elements of the eye (cornea and crystalline lens) focus the image of an object at optical infinity on the retina. No optical correction is needed.
OPTICAL CORRECTION

- MYOPIA: Images of distant objects (objects at optical infinity) are focused in front of the retina by the convex surfaces of the optical system of the eye.
- A correcting lens with minus power is required to diverge incoming light and “push” the image the focus back to the retina.
- HYPERMETROPIA: Distant objects form a focus behind the retina, and a correcting lens with plus power is required to converge incoming light and “pull” the focus up to the retina.
- ASTIGMATISM: The amount of correction required varies with different meridians, and requires a lens with different powers in different meridians.
HISTORY AND SYMPTOMS OF AMETROPIA

• MYOPIA:

(1) The age of onset of simple benign myopia is usually during the peak growth years, ages 7 to 20 years. However, onset may be at any age.

(2) Subjective complaints almost include problems seeing distant objects. Complaints are often associated with specific tasks such as difficulty seeing the chalkboard at school, the screen in a movie theater, or a TV screen at home, or seeing the ball whilst playing lawn tennis.

(3) The onset of myopia is usually slow, which may leave the patient unaware of that his or her vision is worse than that of other people.

(4) A sign of myopia often observed by teachers, parents, or friends of the patient is “squinting” of the eyelids when attempting to view distant objects. These observations often lead to referral for an eye examination whether or not patient has observed reduction in distant vision.
HISTORY AND SYMPTOMS OF AMETROPIA (MYOPIA)

• (5) Occasionally, the repeated effort of trying to narrow the palpebral aperture (squint) will lead to headache.

• (6) The onset of myopia at an early age (birth through age 6) or the continuation of increase in myopia after age 25 may indicate the presence of a degenerative or pathological myopia.
HISTORY AND SYMPTOMS OF AMETROPIA (HYPERMETROPIA)

(1) Hypermetropia of less than +2.00D is commonly found in young children and tends to decrease in amount during the growth years.

(2) Hypermetropia above +5.00D will probably not decrease through the growth years and may show some increase with age.

(3) Simple hypermetropia can be overcome using accommodation so a large percentage of hypermetropic patients will not complain of blurred vision.

(4) Hypermetropic patients experience headache associated with near work. The headache may be driven by excessive use of accommodation.
HISTORY AND SYMPTOMS OF AMETROPIA (HYPERMETROPIA)

(5) Subtle symptoms may include lack of interest in reading or near work. In young patients, this may lead to poor performance in school and weak study habits.

(6) Without symptoms of blurred vision, the acceptance of a correction for hypermetropia is often poor.

(7) Since hypermetropic patients often use accommodation to correct the refractive error, symptoms increase in frequency and severity as presbyopia approaches.

(8) Children hypermetropia may present with strabismus (esotropia).
HISTORY AND SYMPTOMS OF AMETROPIA (ASTIGMATISM)

- Since astigmatism is associated with either myopia or hypermetropia, the symptom associated with this refractive error often add to the symptoms associated with the other refractive error.
- Blurred vision and headache are associated with astigmatism. Headaches in astigmatism may be due to efforts on the part of the accommodative system to achieve an accurate focus.
- Since uncorrected astigmatism tends to blur an image in only one meridian, patients can often perform quite well with significant amounts of uncorrected astigmatism.
HISTORY AND SYMPTOMS OF PRESBYOPIA

- Loss of accommodation leads to presbyopia. The loss of accommodation results in a variety of symptoms depending on whether there is any other uncorrected refractive error present at the same time.
- The onset of symptoms occurs around the age 40.
- Inability to see near objects clearly is the most common symptom of presbyopia. Patients complain they must hold reading material too far away to see clearly.
- Less obvious symptoms include the need for high levels of illumination in order to be able to read.
MANAGEMENT OF AMETROPIA

• (1) SPECTACLES
• (2) CONTACT LENSES
• (3) REFRACTIVE SURGERY
HISTORY AND SYMPTOMS OF PRESBYOPIA

- If there is any uncorrected hypermetropia, will bring on symptoms of presbyopia several years earlier.
- A patient who has uncorrected myopia in one eye only may never complain of symptoms of presbyopia, since one eye is used to see clearly at distance whilst the myopic eye is used to clearly at near.
- CORRECTED WITH READING GLASSES, BIFOCAL/TRIFOCAL/PROGRESSIVE LENSES, CONTACT LENSES OR REFRACTIVE SURGERY
REFERENCES AND ACKNOWLEDGEMENT

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• Vision and Refraction, April 2010, Orbis International
• COMPREHENSIVE OPHTHALMOLOGY
• BORROWED SLIDES FROM Dr Teh Yeong Han, Introduction to eye
THANK YOU