The essentials of fundoscopy

The direct ophthalmoscope is an invaluable diagnostic tool for doctors in both community and hospital settings, but clinicians often lack confidence in using the ophthalmoscope (Roberts et al, 1999; Gupta and Lam, 2006). It is deemed to be a difficult examination by both students and postgraduate doctors, despite being a key aspect of a complete neurological examination. The small field of view means that clinicians can easily get lost, and positioning and patient cooperation can be problematic. However, in conjunction with good history-taking skills, fundoscopy is useful in diagnosing several life-threatening conditions. This article outlines the steps in examining the fundus and highlights key signs pathognomonic of life- and sight-threatening conditions to aid the general medical doctor in clinical practice and for postgraduate examinations.

Direct ophthalmoscopy

The direct ophthalmoscope illuminates the patient's retina with a bright light source and allows the clinician to obtain an erect view of the retina magnified 16 times with clarity. *Figure 1* is a labelled image of the most commonly found ophthalmoscope in hospitals. A model of the direct ophthalmoscope in *Figure 2* illustrates how the light rays of the illuminated focussed area of the retina project through the refractive media of the patient's eye and emerge as parallel rays. These then travel through the lens of the ophthalmoscope and focus the image on the clinician's own retina. It is therefore possible to correct for refractive errors of either the patient or clinician with the ophthalmoscope by rotating through a series of 20 lenses mounted within the instrument.

For ophthalmologists, the direct ophthalmoscope confers benefits of ease of access and portability which are useful when slit-lamp examination is not possible, e.g. on the intensive therapy unit. Fundoscopy even through an undilated pupil helps view and magnify various structures in the human retina or posterior segment, including the optic disc, retinal vessels and the macula. This view may be masked by medial opacities in the aqueous, lens or vitreous so a better examination can be conducted through a dilated pupil and in a darkened room.

The main steps

Preparation and familiarization with the direct ophthalmoscope is helpful before starting the examination.

The optical features of the direct ophthalmoscope include high magnification (x15) and despite the small field of view the retinal view is not inverted. This is therefore an easier examination technique to master than the slit-lamp which requires the use of additional lenses to provide magnification and a wider field of view, and which also inverts the retinal view. *Table 1* provides a systematic approach to covering the five key steps of fundoscopy:

1. Instructions to the patient
2. Familiarity with use of ophthalmoscope

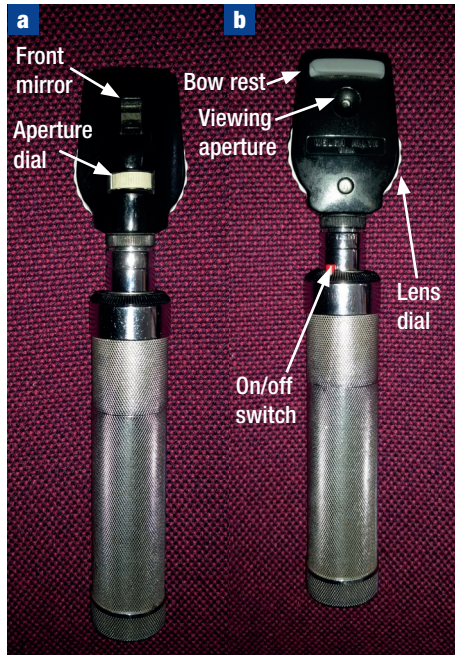

Figure 1. A co-axial direct ophthalmoscope. a. The patient's side, (b) the doctor's side. This is the most common model found on hospital wards.

Figure 2. Model of direct ophthalmoscope showing the area of retina visible to the clinician in a patient's dilated eye. Light from the device passes through a lens and reflects off a mirror to illuminate a section of the retina. This is then reflected through the adjustable lens to focus into the clinician's eye.

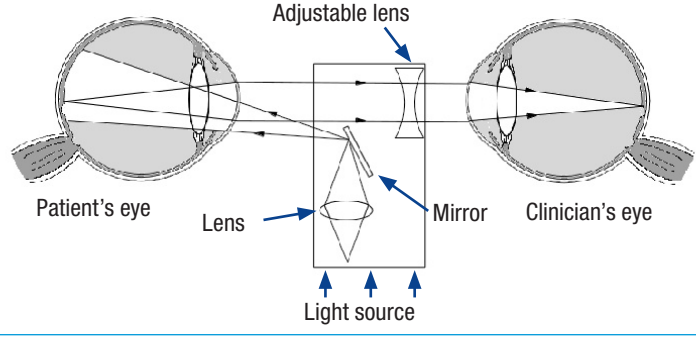

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Table 1. Initial steps in fundoscopy

Instructions to the patient	Outline the purpose and steps of the examination, then obtain consent from the patient
	Dilating the patient's pupils is optional but recommended, usually with tropicamide 1% drops or cyclopentolate 1% drops in adults. Dilating drops take around 20 minutes to have an effect but last for approximately 3–4 hours; patients must not drive during this period. Be aware of inducing a closed angle glaucoma attack (very rare but possible in elderly, hypermetropic, long-sighted individuals). Always check for a relative afferent pupillary defect before dilating the pupils and document this and the time of dilating drops in the notes
	Invite the patient to sit down. Ask the patient to continue looking over your right shoulder and fixate on a point in the distance while you examine the right eye, then your left shoulder when examining the left eye
	It is helpful to warn the patient that you will be approaching his/her face quite closely and may rest your hand on his/her forehead. Advise the patient to continue breathing normally and alert you if he/she feels uncomfortable
Familiarity with use of ophthalmoscope	Adjust the lens to 0 if there are no corrections for the clinician's vision to be made. Turn the dial clockwise to red (minus) numbers to correct the clinician's myopia and anti-clockwise to the green (plus) numbers to correct the clinician's hypermetropia
	Ensure the light is an appropriate brightness, diameter and filter. Adjust the ophthalmoscope to a bright, white light. Initially, use approximately half the maximum light intensity; once the fundus is in view this can be adjusted. Maximum intensity lights, especially when using halogen bulbs, can be uncomfortable for patients, particularly when focusing on the macula
	Adjust the light beam size to reflect the size of the patient's pupils. A light beam size that is much larger than the pupil causes glare and dazzle from the reflected rays which can hinder the examination. *Table 2* lists the various apertures and their uses
	Reduce the ambient room light if possible
	When examining a patient's right eye, use the right eye. Place the other hand on the patient's forehead for stability with the index finger or thumb ideally resting on the patient's right brow, and vice versa for the left eye
Correct use of illumination	Hold the ophthalmoscope at the same horizontal level as the patient's head, approximately 40 cm away from the eye and slightly temporal (approximately 15° lateral to the patient's line of vision). Here you will be able to elicit the orange glow of the patient's red reflex
	Advance the direct ophthalmoscope towards the patient's eye along the 15° lateral axis with the ophthalmoscope to obtain a fundal view, keeping the red reflex in view at all times
Appropriate use of lenses	To visualize the optic disc and retinal vessels (*Figure 1*), the focus may need to be altered until the view is clear
	To visualize the cornea use a +20 dioptre lens, and a +15 dioptre lens for the iris
Description of findings	Be systematic; evaluate the disc, vessels and retina including the macula
	Accurately document all key features of the examination, if possible with diagrams of the right and left disc and their associated vascular arcades to help map out your findings

Appreciating the limitations of fundoscopy will help the clinician refer the patient appropriately. Only a monocular view is obtained thus no stereopsis is possible. As the majority of the peripheral fundus is not visualized any suspicion of retinal tear or detachment, or risk of other serious ophthalmic pathology from the history should prompt urgent referral to ophthalmology

3. Correct use of illumination
4. Appropriate use of lenses
5. Description of findings

The red reflex

The orange-red glow of the red reflex can be elicited as light is reflected off the choroidal blood vessels through the transparent retinal layers. An absent or altered red reflex can be the result of opacities in the refractive media including cataract, vitreous haemorrhage and paediatric ocular tumours, or may be caused by a detached retina.

The normal fundus

The normal healthy colour of the fundus varies with ethnicity as it reflects the melanin content of the retinal pigment epithelium, the melanin content of choroidal stromal melanocytes and haemoglobin in the retinal and choroidal vessels.

Key pathological appearances

The optic disc

The normal optic disc lies medially as a circular structure that is vertically oriented.

Table 2. Light apertures and their uses with the ophthalmoscope

Small aperture	Can view the fundus through an undilated pupil and usually the most frequently used aperture in an acute setting
Large aperture	Provides an excellent view of the fundus in undilated pupils
Micro-spot aperture	Good for use in very small undilated pupils
Slit aperture	Useful in examining lesions such as tumours and elevated discs
Cobalt blue filter	Used with fluorescein dye to check for corneal abrasions, ulcers or foreign bodies
Red-free filter	Useful for examining retinal vessels

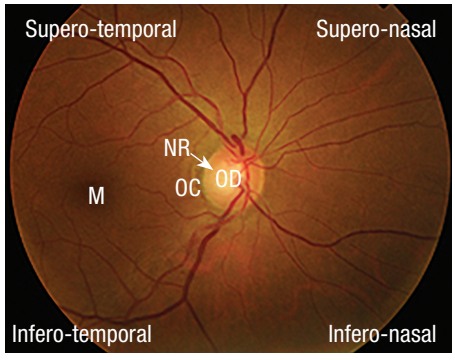


Figure 3. Normal fundus photo of left eye. M = macula; NR = neuroretinal rim; OC = optic cup; OD = optic disc. Note the normal cup:disc ratio, as well as normal healthy retinal vessels. The fovea is a normal darker colour. Note the four quadrants.

Figure 4. Optic atrophy. A pale optic disc secondary to foam sclerotherapy to treat vein on forehead, accidentally spreading to left eye. Note the cherry spot appearance in the macula. This is central retinal artery occlusion.

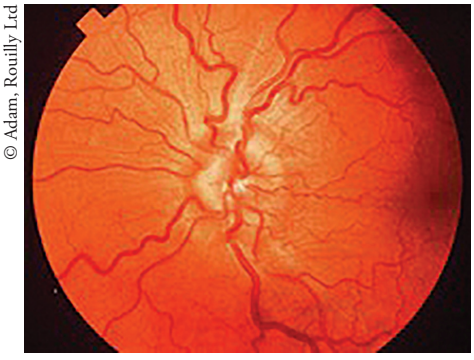


Figure 5. Papilloedema – the retinal vessels appear tortuous, and the optic disc margins are blurred.

Healthy optic discs appear orange-pink. The optic disc margin is sharply demarcated with a total disc diameter of 1.5 mm, allowing the disc to be used as a unit of measurement for other retinal structures. There is a pale depression at the centre of the disc called the physiological cup, which can vary in size.

As shown in *Figure* 3, there are three distinct features to the optic disc: the disc margins, optic cup and neuroretinal rim. A pale optic disc may point towards atrophic changes; this is illustrated in *Figure 4*. It is advisable to examine each eye for comparison. Differentials for optic atrophy are highlighted in *Table 3*.

Blurring of the disc margins may be indicative of optic disc swelling (*Figure 5*). Pathophysiology of optic disc swelling is not fully understood, but there are several contributing pathologies (*Table 4*). During a period of raised intracranial pressure, it is believed that increased CSF pressure in the optic nerve sheath causes axoplasmic flow stasis, causing axonal swelling (Hayreh, 1977). Other distinct features include elevation of the optic nerve head, haemorrhages and absence of venous pulsations. This should be recognized as an emergency and, once again, both eyes must be examined, while also keeping in mind the history elicited from the patient.

Binder et al (1986) reported that raised intracranial pressure was the main cause of a swollen optic disc. The study found that a third of 100 cases had raised intracranial pressure, which emphasizes how vital it is that this is identified on examination. Cup:disc ratio is also an important factor when examining the optic disc. The normal cup:disc ratio is 0.3, meaning that the cup occupies 3/10 of the disc. Optic disc cupping can be seen in patients with open-angle glaucoma. This is when the optic cup increases in size, as shown in *Figure 6*. Spaeth and Reddy (2014) concluded that fundoscopy remained the most useful imaging modality for glaucoma, as it is universally available and displays much information if good technique is used.

Table 3. Optic atrophy

Inherited	Retinitis pigmentosa
Compression	Extrinsic tumour, e.g. pituitary, meningioma
	Intrinsic tumour, e.g. optic nerve glioma, optic nerve sheath meningioma
Vascular	Central retinal vein occlusion
	Anterior ischaemic optic neuropathy
Inflammatory	Acute demyelinating optic neuritis
	Vasculitis
Infection	Bacterial: tuberculosis, syphilis
	Viral: measles, mumps, rubella
	Fungal: aspergillus
Nutritional	Deficiencies in vitamins B_1 (thiamine), B_2 (riboflavin), B_6, B_{12} and folate
Toxic	E.g. amiodarone, ethambutol, methanol, carbon monoxide, cyanide and lead
Other	Trauma
	Papilloedema (chronic)

From Denniston and Murray (2014)

The retinal vessels

The central retinal artery emerges as a bright red structure from the optic cup and curves over the disc surface to divide into superior and inferior branches or arcades dividing the retinal into four quadrants: in relation to the macula there are the supero-temporal, infero-temporal, supero-nasal and infero-

Table 4. Causes of optic disc swelling

Optic nerve disease	Inflammatory	Optic neuritis
	Infectious	Bacterial, e.g. tuberculosis, syphilis
		Viral, e.g. HIV, hepatitis A/B, cytomegalovirus
		Fungal, e.g. aspergillus, cryptococcus
	Ischaemic	Giant cell arteritis
	Compressive	Tumour, aneurysm, abscess
	Infiltrative	Leukaemia, lymphoma
Eye disease	Vascular	Central retinal vein occlusion, vasculitis
	Inflammatory	Posterior uveitis
Raised intracranial pressure	Intracranial	Space-occupying lesion
		Thrombosis

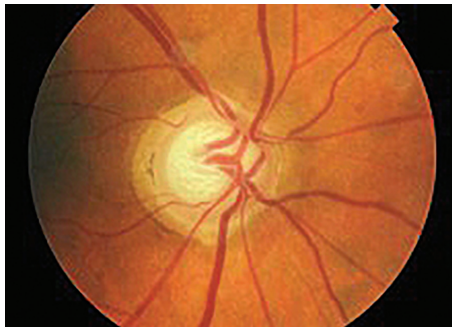


Figure 6. Optic disc cupping. Note the large cup:disc ratio as well as central blood vessels displaced nasally.

Table 5. Grading of hypertensive retinopathy

Grade 0	Normal
Grade I	Silver wiring – arteriolar attenuation and increased reflectance
Grade II	Arterio-venous nipping – narrowing of venules as arterioles cross (*Figure 7*)
Grade III	Haemorrhages, cotton wool spots and hard exudates
Grade IV	All of the above with papilloedema

From Keith et al (1939)

Figure 7. Grade II hypertensive retinopathy – the arrow details arterio-venous nipping, generalized narrowing of arterioles can also be seen.

nasal quadrants. Arterioles are narrow and bright red in appearance whereas venules are wider, dark red and more tortuous. Chatziralli et al (2012) stipulate that early retinal changes in systemic diseases can be identified using fundoscopy before clinical manifestations occur. Examining the retina is facilitated by following the vessels from the optic disc into the peripheries. This ensures all four quadrants of the retina are also examined.

Table 6. Summary of retinal vessel changes

Feature	Physiology
Cotton wool spots	Sign of retinal ischaemia, as axonal proteins accumulate the nerve fibre layer
Hard exudates	Yellow lipid deposits from leaking blood vessels, typically from a microaneurysm
Microaneurysms	Weakened region of a retinal capillary (Stitt et al, 1995)
Blot haemorrhages	Intraretinal accumulation of blood (typically from a burst microaneurysm in diabetics)
Flame haemorrhages	Blood in the nerve fibre layer. These can extend from a swollen optic disc

Hypertensive retinopathy

Hypertensive changes in the retina are graded using the Keith et al (1939) classification outlined in *Table 5*. *Table 6* details the specific changes mentioned and matching differential diagnoses.

Diabetic retinopathy

Poorly controlled diabetes can result in gradual retinal changes identified during fundoscopy. The grading system used in diabetic retinopathy are outlined in *Table 7* and expected clinical findings illustrated in *Figure 8*. The latter shows how extensive disease can progress if left untreated.

Retinal detachment

There are several causes of retinal detachment, and it is vital for a clinician to know when to suspect this and correctly spot this during fundoscopy, as urgent surgical intervention may be required. Patients describe a dark curtain obstructing their peripheral vision usually preceded by multiple floaters disturbing the vision and photopsia (a persistent flashing light). If combined with the view in *Figure 9*, one can understand why this is the case.

Table 7. Grading for diabetic retinopathy

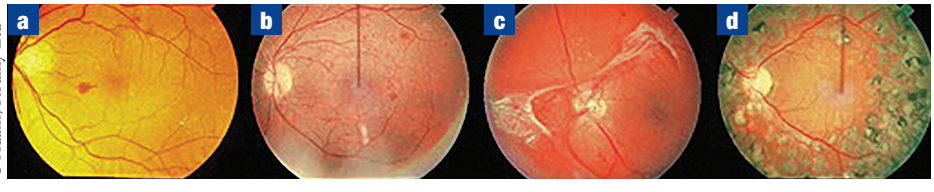
R0	No retinal vessel changes
R1	Background: microaneurysms, retinal haemorrhages or cotton wool spots
R2	Pre-proliferative: venous beading or multiple blot haemorrhages
R3s	Proliferative (stable): stable fibrous proliferation + laser, or stable R2 features + laser, or stable R1 features + laser
R3a	Proliferative (active): new vessels on disc, pre-retinal or vitreous haemorrhage, or retinal detachment
M0	No maculopathy
M1	Exudates within the macula. Microaneurysms, haemorrhages or exudates within 1 disc diameter of the fovea
P0	No photocoagulation
P1	Focal or grid evidence of photocoagulation to the macula or peripherally

M = maculopathy; P = photocoagulation; R = retinal vessels. From NHS Diabetic Eye Screening Programme (2012)

The macula

The macula lies lateral to the optic disc bounded by the temporal, superior and inferior archades. Centrally the macula contains the fovea centralis, a concentrated area of photoreceptors, with no visible blood vessels. The fovea centralis may be easier to locate in those with darker skin tones, but a small white-yellow light reflex will be

Figure 8. a. R1M1P0 – blot haemorrhages seen in the supero-temporal region and hard exudates in the infero-temporal quadrant. Microaneurysms are present around the macula. b. R2M1P0 – dot and blot haemorrhages are present throughout. Cotton wool spots in the inferior macular are a sign of retinal ischaemia. c. R3aM1P0 – large areas of retinal scarring as well as exudates and haemorrhages can be seen. Note the neovascularization on the optic disc. d. R3sM1P1 – scars can be seen in the peripheral retina, sparing the macula, from many photocoagulation laser shots.



KEY POINTS

- Familiarization is key, both with the instrument and the normal fundoscopic appearances.
- Taking a thorough history will help focus a detailed fundoscopy examination and aid formulation of a differential diagnosis.
- Ensure fundoscopy is performed as part of every neurological examination.
- Appreciating the limitations of fundoscopy can facilitate appropriate referrals and more detailed evaluation using the slit-lamp or indirect ophthalmoscope.

Figure 9. Retinal detachment – elevation of the retina by fluid can be seen in this fundus photograph.

visible as a result of the fovea's concavity which reduces with increasing age. *Figure 10* outlines the macular degeneration which can occur with increasing age.

In the context of a recent acute loss of vision, a milky appearance of the fundus together with a cherry red spot at the central macula, is highly suggestive of a central retinal artery occlusion (*Figure 4*). This is often caused by embolic occlusion of the central retinal artery, but can be associated with temporal arteritis. The visual prognosis is poor and an urgent ophthalmic referral would be indicated.

Central retinal vein occlusion arises as a result of obstruction in the venous outflow. This results in multiple haemorrhages and areas of retinal ischaemia as illustrated in *Figure 11*. Development of central retinal vein occlusion tends to be related to hyperviscosity, i.e. vascular and inflammatory, or raised intraocular pressure. *Table 6* summarizes retinal vessel changes and the pathophysiology behind these processes.

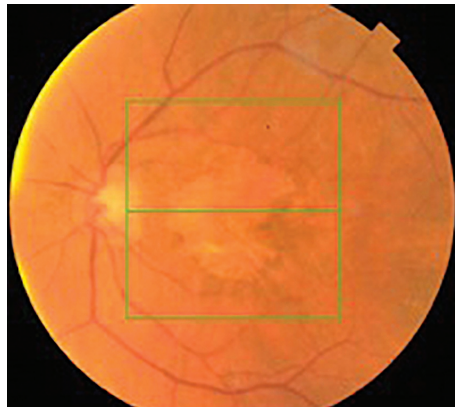


Figure 10. Dry age-related macular degeneration – generalized loss of retinal pigment can be seen, and an area of geographical atrophy can be noted. This a common feature in dry age-related macular degeneration. In other cases, drusen can sometimes be seen in the macular region. Drusen are small round hyaline bodies that form on Bruch's membrane of the choroid and are visualized as yellow multifocal changes anywhere in the fundus. They are associated with ageing and also age-related macular degeneration where they appear larger and more confluent. Multiple haemorrhages caused by choroidal neovascularization can be noted in the more serious exudative or wet form of age-related macular degeneration.

Conclusions

The direct ophthalmoscope is readily available in many acute medical and emergency units, but as Noble et al (2009) highlighted, exposure to ophthalmology in medical school is low. As important as it is to be able to practise fundoscopy on a normal subject, recognizing abnormal pathology is important for clinicians to feel confident in their ability to use the instrument.

This article has alluded to the key steps, and various clinical manifestations on examination, but it is important to provide clear instructions and be considerate to patients. A great deal of clinical information can be derived when examining a fundus, in combination with good history taking skills. Sight- and life-threatening conditions can be evident during fundoscopy, thus justifying its critical part of the neurological examination. It remains an important diagnostic tool for many conditions encountered in daily practice by medical doctors and GPs, and all clinicians must be encouraged to take opportunities to examine patients' eyes. **BJHM**

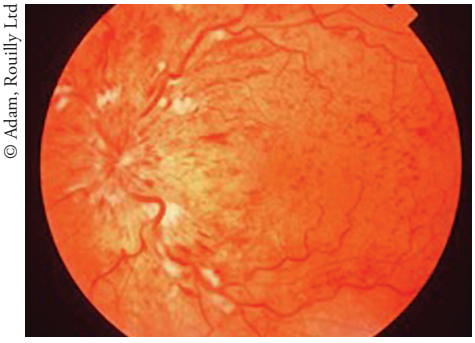


Figure 11. Central retinal vein occlusion – note the 'stormy sunset' appearance of the retina, with many flame and blot haemorrhages. Cotton wool spots are also present.

Conflict of interest: none.
The authors would like to thank Mr Hame Sehmi for designing Figure 2. *Figures 5, 7, 8, 9 and 11 are copyright of Adam, Rouilly Ltd taken from the AR303 Eye Retinopathy Trainer, also copyright of Adam, Rouilly Ltd.*

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