Fundus imaging with a mobile phone: A review of techniques

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Fundus imaging with a fundus camera is an essential part of ophthalmic practice. A mobile phone with its in-built camera and flash can be used to obtain fundus images of reasonable quality. The mobile phone can be used as an indirect ophthalmoscope when coupled with a condensing lens. It can be used as a direct ophthalmoscope after minimal modification, wherein the fundus can be viewed without an intervening lens in young patients with dilated pupils. Employing the ubiquitous mobile phone to obtain fundus images has the potential for mass screening, enables ophthalmologists without a fundus camera to document and share findings, is a tool for telemedicine and is rather inexpensive.

Key words: Fundus imaging, mobile phone, ophthalmoscopy, smart phone

Fundus imaging is an essential part of ophthalmic practice; most often obtained using the fundus camera. Wide-field fundus imaging is possible with the Optos® camera (Optos plc, Scotland, UK) and the video indirect ophthalmoscope allows imaging the fundus periphery. Fundus cameras have become less expensive and portable thereby improving their utility.

Mobile phones with their high-resolution automatic focus cameras and light emitting diode (LED) light source has the potential to be used for fundus imaging. Mobile phones have been used in lieu of a digital camera to capture the images of ultraportable retinal cameras.[1]

In recent times, smart phones have been used for fundus imaging by us and others.[2,3] We herein review the techniques of using a mobile phone to perform indirect and direct ophthalmoscopy and imaging.

Methods

Indirect ophthalmoscopy

The mobile phone camera can be used to perform indirect ophthalmoscopy when used in conjunction with a + 20D condensing lens. The LED flash of the camera can be used to illuminate the fundus. The flash should be turned on to illuminate and view the fundus. However, the flash in most phones is not continuously on in the still photography mode, flash firing only during the exposure. In the video mode, the flash can be programmed to be always on when in the recording mode and this would allow illuminating the fundus and obtaining a video of the same. Hence the mobile phone in video mode can be used as a video indirect ophthalmoscope and we used this technique for fundus imaging. Haddock *et al*. have described the technique of using an iphone™ (Apple Inc, Cupertino, USA) in conjunction with software that allows manipulation of the camera parameters to obtain good quality images.[3]

Technique

Mobile phone indirect ophthalmoscopy can be performed through dilated pupils. The phone is set to video mode with the flash always "on" (as described above). The condensing lens is held in the other hand as one would perform indirect ophthalmoscopy and starting the recording will turn the flash on and allow visualization of the fundus once the camera, light and the condensing lens are in line with the patient's pupil. Although, the condensing lens is held at the usual distance from the eye as one would during indirect ophthalmoscopy, the mobile phone need not be held at arm's length, but much closer to the lens [Fig 1]. As in routine indirect ophthalmoscopy, tilting the condensing lens will avoid reflexes from the lens surface and moving both to different quadrants allows examination of the fundus periphery.

Direct ophthalmoscopy

The direct ophthalmoscope directs a focused beam of light into the eye, the reflected light being captured by the observer's eye. By placing a LED light source (powered by an external battery source) close to the camera, the mobile phone can effectively be transformed into a direct ophthalmoscope [Fig 2].

Technique

The LED light is turned on and taking the phone close to the eye of a patient with pharmacologically dilated pupil will allow imaging the fundus. Still photography and video recording is possible with this technique as it does not depend on the in-built flash for illuminating the fundus.

Results

Video recording of fundus findings could be obtained by employing a mobile phone as a video indirect ophthalmoscope [Fig 3]. Direct ophthalmoscopy was possible after pupillary dilation, particularly in patients with a clear lens [Fig 4]. The field of view is limited when using the mobile phone as a direct ophthalmoscope.

Discussion

Mobile phones are ubiquitous with high-resolution cameras being de rigueur. Using a mobile phone to image, the fundus offers immense possibilities. It offers the facility to image and document the fundus even if a fundus camera is not available as in a primarily anterior segment clinic or in rural camp screening. All one would need is a condensing lens if performing indirect ophthalmoscopy or an easily affixed light source to perform direct ophthalmoscopy. Mobile phones allow magnification and storing of the images, the data connectivity allowing sharing of the images for cross consultation. Using a mobile phone as a direct ophthalmoscope avoids the discomfiting proximity of the examiner to the patient.

There are limitations to using a mobile phone as a fundus camera, the primary one being the learning curve to perform indirect ophthalmoscopy. The inability to turn the flashlight on prior to capture in still photography forces us to use the video

Figure 1: Technique of indirect ophthalmoscopy with mobile phone camera. The phone is held much closer to the condensing lens in contrast to routine indirect ophthalmoscopy

Figure 2: Modification of the mobile phone camera by affixing a light emitting diode light with external power supply, allows it to be converted in to a direct ophthalmoscope

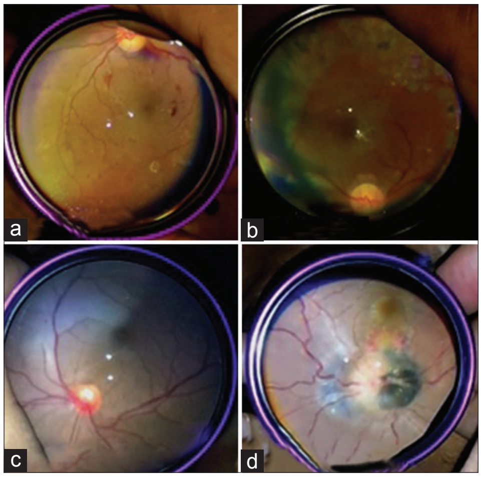

Figure 3: Mobile phone indirect ophthalmoscopic fundus images: (a) Nonproliferative diabetic retinopathy; (b) post pan retinal photocoagulation, (c) branch retinal artery occlusion with retinal whitening, (d) melanocytoma of the optic disc with peripapillary choroidal neovascular membrane

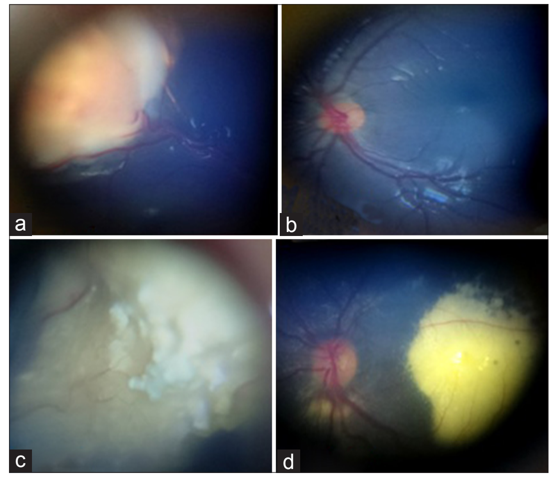

Figure 4: Mobile phone direct ophthalmoscopic images obtained in infants under general anesthesia: (a) Active retinoblastoma; (b) normal posterior pole, (c) partly regressed retinoblastoma post chemoreduction, (d) coats disease with subretinal exudates temporal to fovea

mode to perform ophthalmoscopy. This can be circumvented if an "app" can purpose created for ophthalmoscopy as described by Haddock *et al*.[3] Scleral depression is also not possible as neither hand is free to perform depression. The quality of images obtained is compromised to some extent as the flash of the mobile phone camera is not a focused beam as in an ophthalmoscope.

Direct ophthalmoscopy needs close proximity of the light source to the camera which can be achieved by affixing an additional light as described by us. We did try to move the light from the in-built flash close to the camera by re-routing it with fiber optic cable, but this provided either sub-optimal illumination or the protruding fiber prevented direct ophthalmoscopy that requires the ophthalmoscope to be rather close to the eye. Optimized positioning of the light in relation to the camera should allow the mobile phone to be used as a direct ophthalmoscope.

We have been using a mobile phone camera as a video indirect ophthalmoscope and a direct ophthalmoscope particularly to document the fundus findings of infants undergoing examination under anesthesia and also as a tool for fundus screening in camps.[4] Similar devices such as the PEEK (Peekvision.org, UK) and Cellscope (Cellscope, Inc. San Francisco, USA) with hardware adapters and custom built software are being used by other investigators across the world for screening purposes in underdeveloped countries. Being custom built devices they offer the ability of a wider field of view, ancillary testing such as vision and cataract testing, which are not possible with our techniques described above. The mobile phone camera has recently been used to perform fluorescein angiography, despite which it is unlikely that it will completely replace the fundus camera.[5] However, the capability to image the fundus practically anywhere with a device that is always with us offers a freedom that is beyond the reach of a fundus camera.

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