Unconventional techniques of fundus imaging: A review

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The methods of fundus examination include direct and indirect ophthalmoscopy and imaging with a fundus camera are an essential part of ophthalmic practice. The usage of unconventional equipment such as a hand-held video camera, smartphone, and a nasal endoscope allows one to image the fundus with advantages and some disadvantages. The advantages of these instruments are the cost-effectiveness, ultra portability and ability to obtain images in a remote setting and share the same electronically. These instruments, however, are unlikely to replace the fundus camera but then would always be an additional arsenal in an ophthalmologist’s armamentarium.

Key words: Direct ophthalmoscopy, fundus imaging, indirect ophthalmoscopy

Fundus imaging using a fundus camera is an essential part of ophthalmic practice and cameras range from the most basic to the advanced scanning laser ophthalmoscope based ones offering wide-field fundus imaging (Optos plc, Scotland, UK). While the fundus camera, direct and indirect ophthalmoscopes remain the essential and most often used instruments to view and image the fundus, unconventional instruments such as the smartphone can be used to view and image the fundus. The unconventional techniques, particularly the smartphone allows one the flexibility of fundus imaging in difficult situations such as in outreach camps and in imaging the fundus of an infant under general anesthesia. We review some such unconventional instruments and techniques for fundus imaging in this paper.

Slit-lamp Based Retinal Imaging

Fogla and Rao described the technique of mounting a digital camera to the slit-lamp oculars to enable capturing posterior pole fundus images when used in conjunction with the +78D or +90D lens thereby performing slit-lamp based indirect ophthalmoscopy.[1] This technique provides high magnification images of the posterior pole, the disadvantage being inability to image further into the periphery, given the limitations of the slit-lamp mobility and the limited field of view offered by the +78D or +90D lenses. A simpler modification of this technique would be to mount a smartphone camera instead of the originally described digital camera. The smartphone being a compact instrument is easier to mount and manipulate with the added ability to share images through electronic means with ease. While custom mounts for affixing the smartphone to the slit-lamp are available, one can fashion them using simple do-it-yourself techniques, as well.

Indirect Ophthalmoscopy with a Hand-held Video Camera

The author had described the technique of performing monocular video indirect ophthalmoscopy using a hand-held video camera modified by affixing an illumination source to it.[2]

The inbuilt flash of the hand-held video camera is not proximal enough to the camera aperture and hence a focused beam flashlight mounted on the flash mount of the camera serves as the illumination source for performing indirect ophthalmoscopy. When used in conjunction with a condensing lens, one can perform monocular indirect ophthalmoscopy with the images displayed on the screen of the hand-held video camera. Altering the white balance of the camera and zoom function allows one to get good images. This instrument can be used as an indirect video ophthalmoscope to capture fundus images of infants and children under general anesthesia [Fig. 1]. There is a learning curve involved in this technique, and scleral depression would also not be possible as both hands of the examiner are occupied.

Smartphone as an Ophthalmoscope

Mobile phones with their high-resolution cameras and light-emitting diode (LED) light source can be used instead of...
a digital camera, and it has been used to capture the images of ultraportable retinal cameras.\textsuperscript{[5]}

Smartphones have recently been used for fundus imaging by others and us to obtain fundus images by performing indirect and direct ophthalmoscopy.

**Indirect ophthalmoscopy**

The mobile phone camera can be used to perform indirect ophthalmoscopy when used in conjunction with a condensing lens. The LED flash of the camera is used to illuminate the fundus, and the camera is used to obtain the fundus image through the condensing lens. Myung \textit{et al.}, have described fabricating an attachment to affix the lens to the phone, thereby making it simpler to perform indirect ophthalmoscopy with one hand.\textsuperscript{[4]}

As the LED flash in most phones cannot be turned on prior to obtaining a photo in the still photography mode, it is easier to obtain a video in the video mode as the flash can be programmed to be always on in this mode. Software modifications do allow the LED flash to be turned on continuously even in still photo mode, wherein one can obtain still photos, also allow manipulation of the exposure settings and postcapture processing of the images to obtain good images. Other limitations being the inability to do scleral depression, and 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\textsuperscript{[5,6]} [Fig. 2].

Adapters to hold a macro lens to the phone for anterior segment photography and as an extension for fixing the condensing lens allowing indirect ophthalmoscopy have been described by Myung \textit{et al.} Fixing the condensing lens at an appropriate distance from the phone camera makes it easy for a paramedical person untrained in indirect ophthalmoscopy to obtain fundus images.\textsuperscript{[7]}

**Direct ophthalmoscopy**

The direct ophthalmoscope directs a focused beam of light into the eye, the reflected light being captured by the observer’s eye. Others and we have described that by placing an LED light source (powered by an external battery source) close to the camera, the mobile phone can effectively be transformed into a direct ophthalmoscope\textsuperscript{[6]} [Fig. 3].

Still photography and video recording is possible with this technique, as it does not depend on the inbuilt flash for illuminating the fundus. Direct ophthalmoscopy through a dilated pupil is possible with this technique. As the external light affixed to the phone does not provide a thin pencil of light, direct ophthalmoscopy with this modified smartphone is difficult in undilated pupils.

Mobile phones are ubiquitous with high-resolution cameras being de rigueur. Using the mobile phone to image the fundus 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 the mobile phone as a direct ophthalmoscope avoids the discomfiting proximity of the examiner to the patient. The smartphone ophthalmoscope allows one to document the fundus findings of infants undergoing examination under anesthesia and also as a tool for fundus screening in camps.

**Smartphone fluorescein angiography**

The mobile phone camera has recently been used to perform fluorescein angiography and the authors built the instrument by attaching an LED light source powered by an external battery and exciter and barrier filters sourced from an unused fundus camera. While the LED flash of the camera could also be used as the illuminating source, the authors preferred to use an external LED with a filter dial thereby allowing them to control the intensity of the light. The authors have performed fluorescein angiography by using the device as an
indirect ophthalmoscope with a condensing lens, as described above. The advantages of converting a smartphone to perform fluorescein angiography are that: (1) It allows angiography in recumbent patients and those being examined under general anesthesia, (2) capability to perform fluorescein angiography in nonhospital settings with an ultra-mobile device and thereby facilitating telemedicine applications. The disadvantage is that the system is not fine enough to detect subtle fundus pathology but only gross changes. While the smartphone-based imaging and angiography offers many advantages, it is unlikely that it will completely replace the fundus camera.

### Other Techniques

Yun et al., have described a technique of using a Volk 3D lens along with an operating microscope with an objective lens of F = 300 mm lens as an indirect ophthalmoscope. The lens is held between the microscope and the eye to obtain images of the fundus. This allows one to obtain videos and fundus images of surgical procedures and also fundi of infants being examined under general anesthesia.

#### Unconventional tools for visualizing the fundus

An indirect ophthalmoscope essentially aligns the examiner’s pupils, the condensing lens and the patient’s fundus in line with the path of the light beam used to illuminate the fundus. Hence, a focused light source placed between the eyes of the examiner will illuminate the fundus and allow it to be viewed through the condensing lens, but with some limitations. We found that equipment with such architecture, the head mounted light, and illuminated reading glass does allow one to visualize the fundus.

The headband mounted “miners light” when used with a condensing lens allows visualization of the fundus, the advantages of this instrument being the bright and focused beam of light it offers. These are preferably worn with the examiner’s spectacles in place to provide for a clear view [Fig. 4]. Similarly, an illuminated reading glass designed for night reading also allows one to see the fundus with the added advantage of a built-in “+” lens that obviates the need to accommodate when viewing the fundus image formed at the condensing lens [Fig. 5]. In addition, the examiner’s prescription lenses can be mounted on these glasses, as well. We used these instruments with the light at the least illumination after titrating it with a light meter for a safe dose, but concerns about the ocular safety of this light may remain. The absence of prisms to converge the examiner’s eyes disallows examination through a small pupil when using these instruments. These instruments are unlikely to be ever used as a fundus-viewing tool, but they serve to hi-light the simplicity of the indirect ophthalmoscopic principle thereby prompting out of the box thinking and simpler mainstream instruments.

#### Nasal Endoscope

The nasal endoscope with its closely approximated light and image capture optics can function as a contact fundus camera. We found that the nasal endoscope, when applied to the cornea with a viscoelastic coupling provides wide-angle fundus images of good clarity. This is particularly useful to image the fundi of children and infants under general anesthesia. The small diameter of the endoscope also allows visualizing the anterior chamber angle [Fig. 6]. While we used it at the least possible illumination after metering it with a light meter concerns regarding illumination that is not tailored for retinal imaging exists with this instrument, as well. We used a new instrument that was not used for nasal endoscopy but if one were to use an instrument that is used routinely for nasal endoscopy, it should be sterilized before considering its use on the cornea.

While we can use these unconventional systems for fundus imaging, there are limitations as they are not custom built for this purpose. Hence, the optics and illumination may be suboptimal; there is no software currently available for documentation of patient data or for storage of images. Conventional imaging systems offer appropriate software and hardware for archiving images and for storage of large amounts of data, respectively, thereby, allowing easy retrieval of data. The unconventional systems do not offer these, paving way for inelegant storage of data that makes retrieval of images difficult.
difficult. Storage of images in devices such as the smartphone with its networking capabilities makes it vulnerable to hacking and can pose a threat to maintaining patient confidentiality. Some proprietary patient management software used in electronic medical records may also not allow uploading images from the unconventional imaging devices, making it difficult to archive a particular patient data in one place. This may be overcome overtime with increasing popularity of these devices prompting the proprietary patient management system developers to allow easy incorporation of these images into the patient database. The orientation of images and eye imaged are also not apparent in the captured images. Despite these limitations, unconventional techniques, particularly the smartphone offer the freedom to screen patients anywhere with minimal equipment, utmost portability, is extremely cost-effective and allow rapid sharing of images of decent quality. The smartphone can be a cost-effective alternate for tele-screening of retinal diseases and groups across the world have started using these for this very purpose, particularly among the underserved sections of the society. While networking capability of the smartphone makes it vulnerable to maintaining patient confidentiality, the same capability however, offers the benefit of being able to transmit and share images with ease through multiple applications thereby paving way for remote screening studies wherein the images can be easily transmitted to the base hospital. This also allows one to obtain rapid specialist opinions when confronted with a confounding case.

Conclusions

Unconventional instruments can be used to visualize the fundus and also obtain images and videos of the same. The low cost and the ability to rapidly share the obtained digital images indicate the potential of these devices, particularly the smartphone for tele-screening of fundus disorders. These devices may not replace the mainstream devices, but are likely to find a worthy place in developing economies such as ours.

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Conflicts of interest
There are no conflicts of interest.

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