Novel approach towards colour imaging using a scanning laser ophthalmoscope

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Abstract

Aims—Conventional fundus imaging using a fundus camera produces colour fundus pictures. The scanning laser ophthalmoscope (SLO) has the advantages of lower levels of light exposure, improved contrast, and direct digital imaging but until now has produced monochromatic images as a laser of single wavelength is used. True representation of the fundus is possible by combining images taken using blue, green, and red lasers.

Methods—A custom built SLO was used to capture blue, green, and red fundus images from suitable volunteers and patients with fundus disease. Images were corrected for eye movement and combined to form a colour image. Colour fundus photographs were taken using a fundus camera for comparison with the SLO image.

Results—The background fundus and retinal vasculature had similar appearances with the two imaging modalities. Internal limiting membrane reflections were prominent with the SLO. Identification of new vessels in the diabetic fundus was easier with the SLO than the colour fundus photographs.

Conclusion—A colour SLO offers all the advantages of the present monochromatic imaging system with the added advantage of true colour representation of the fundus.

Figure 1 The normal fundus photograph of a healthy 30 year old male volunteer.
Suitable patients and volunteers for colour SLO imaging were selected from the eye outpatient department, Aberdeen Royal Infirmary. All subjects gave informed consent and the study was approved by the local hospital ethics committee. For comparison with the SLO colour images, colour fundus photographs were taken on the same day using a Topcon TRC V50 fundus camera. Pupillary dilatation with tropicamide 0.5% and phenylephrine 2.5% was used for both photographic and SLO imaging.

Results
Photographic and colour SLO images from three patients and one normal volunteer are presented for comparison. The normal fundus of a healthy 30 year old male volunteer is presented in Figure 1. Individual registered, intensity corrected blue, green, and red monochrome SLO images of the same volunteer are shown in Figure 2. In general the background fundus and retinal vasculature have similar appearances with the two imaging modalities. Noted differences include the appearance of reflections around the macula from the internal limiting membrane present in the SLO which are not clearly apparent in the colour slide images. In addition, the optic disc in the colour SLO image has a dark appearance with a bright central optic cup. This is at variance with the uniformly bright appearance of the optic disc on the colour slide image. This feature is seen consistently in other subjects.

Figure 3 shows the colour SLO and fundus photographic images of a patient with angioid streaks. In general the resolution of fundus structure in the colour SLO image is similar to that in the fundus photograph. The colour SLO image shows that the angioid streaks have a similar brightness and hue as the retinal vessels. This is also seen in the fundus photograph. Again the neuroretinal rim of the optic disc appears darker on the colour SLO image.

Figure 4 shows a tuft of new vessels temporal to the macula in a diabetic patient imaged with both systems. In this patient, the identification of the new vessel complex is easier in the

Figure 2  Monochromatic SLO images of the same volunteer taken at (A) 488 nm (blue), (B) 547 nm (green), and (C) 670 nm (red). The blue, green, and red images are combined to show the true colour image (D). Blue wavelengths are good for imaging the internal limiting membrane which is highly reflective at these wavelengths. Green wavelengths show the vessels at their highest contrast as blood is highly absorbed at these wavelengths. Red wavelengths can differentiate the arteries and the veins.

Figure 3  (A) Fundus photograph and (B) colour SLO image of a patient with angioid streaks.
colour SLO image as the vessels appear with greater contrast relative to the background fundus.

Figure 5 demonstrates the appearance of optic disc drusen after colour SLO imaging and fundus photography. In both images the disc drusen appear as high intensity objects lying within the substance of the optic nerve head. However, because of the lower intensity of the neuroretinal rim in colour SLO images the contrast between disc drusen and neuroretinal rim is enhanced, making their identification easier. In both images the appearances of retinal vessels and background fundus is similar. The fine striations of the nerve fibre layer are just discernible inferior to the optic disc in both images.

Discussion

We have described a method for creation of true colour SLO images which yields high quality images that have good spatial resolution and high contrast when compared with fundus photographs. These images are of sufficient quality to act as an accurate permanent record of fundus pathology in the patients shown.

There are a number of important differences between the images produced by the colour SLO and conventional photography. The appearance of the optic disc consistently shows a darker region corresponding to the neuroretinal rim with a brighter central cup. In fundus photographs the optic disc is more uniform and of consistently higher intensity. An examination of the monochrome SLO images shows that the feature of an optic disc with a dark outer rim is present at all three wavelengths. Indeed, it is widely accepted that the optic disc appears darker on SLO imaging and this feature is enhanced by the use of confocal optics. It is suggested that the conventional fundus camera view of the optic disc relies on reflection of light from a large slice of the fundus which includes the highly reflective lamina cribrosa. The confocal optics of the SLO collects light from a relatively smaller depth of the optic disc and so the disc appears to have low intensity. The darker appearance of the optic disc may confer some clinical advantage as is seen in the patient with optic disc drusen (Fig 5).

Contrast of new vessels in the fundus of the diabetic patient shown in Figure 4 was notably improved in the colour SLO image. This enhanced contrast is not seen for retinal vessels in other subjects and may be due to a less than optimum exposure during fundus photography. It remains to be seen whether retinal vascular abnormalities are generally more evident in colour SLO imaging.

As the SLO method stands it is cumbersome requiring collection of three images sequentially and image processing to enable registration and intensity correction. It is envisaged that true real time colour SLO imaging is feasible with continuous illumination of the fundus by all three lasers in pulse mode to avoid overexposure. This also allows collection of pulsed
which is selected to correspond with a known reflectance peak or trough of a fundus structure under investigation.

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