Video funduscopy and fluoroscopy

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SUMMARY A system of television ophthalmoscopy has been developed using commercially available colour television cameras and a specially designed high-sensitivity monochrome television camera. Funduscopy and fluoroscopy can be performed at low light levels and recorded on standard video tape for clinical evaluation and also as a teaching aid. A computerised television stereo ophthalmoscope image processor is being developed for real-time volumetric recording the volume of the optic disc cup in glaucoma.

The application of a television system to produce an electronic image of the human fundus oculi was described by Ridley¹ some 30 years ago, working in conjunction with the Marconi Wireless Telegraph Company. At that time, however, there was no satisfactory fundus camera which was free from optical artefacts. Ridley therefore designed a flying spot monochrome television (TV) ophthalmoscope, and Potts and Brown² went on to develop a colour television ophthalmoscope in 1959. The main disadvantage of their systems was an unacceptably high level of fundus illumination. This entire field of research was surveyed by Dallow.³

Improvements in TV technology over the past few years have produced a new generation of cameras such as the Cicon low-light-level single-tube colour camera, reference MV9295, and the inexpensive Hitachi Denshi Model GP5. The Badger 25 SIT is an ultra low-light-level monochrome TV camera. These cameras, coupled with a newly designed high-efficiency ophthalmoscope from Carl Zeiss, Jena, constitute the first commercially available TV funduscopy and fundus fluoroscopy systems.

Fundus fluoroscopy dates back to 1961, when Novotny and Alvis⁴ described the application of fluorescence emission photography as a practical method of displaying the fine detail of the human retinal and choroidal circulation. High-speed recording of the passage of fluorescein dye entry was obtained by a cine fluorographic technique.⁵ Although this was used in the investigation of retinal and choroidal circulatory disorders, the time delay in dark-room processing of cine film, and the subsequent need for projection screening, proved unacceptable.

The reason for designing a high-resolution TV funduscopy system was dictated by the need to make fluorographic results immediately available to the referring clinician, particularly when these were urgently required. In 1973 Van Heuven and Schaffer,⁶ using the Littman fundus camera, designed a low-light-level TV system using an image intensifier. Subsequent technological developments in TV tube design for ultra low-light-level requirements in military surveillance have resulted in the manufacture of an integral silicone intensified target tube of light weight and small dimension.

The Stereo-ophthalmoscope 110 from VEB Carl Zeiss, Jena, GDR, was chosen as having the best optical system for TV ophthalmoscopy. The fundus oculi can be observed through 3 viewing angles, 40°, 29°, and 14.5°, corresponding to 15 ×, 20 ×, and 40 × magnifications. The binocular indirect stereo-ophthalmoscope gives excellent 3-dimensional visualisation of the fundus oculi with detailed inspection of the vitreoretinal boundary layers. Stereo fluoroscopy with the blue filter enables stereoscopic observation of fluorescence angiography and spatial localisation of extravascular fluorescence.

The Stereo-ophthalmoscope 110 can be fitted with 1 or 2 supplementary observer eyepieces for instruction, discussion, and teaching, but the introduction of a television viewing system greatly improves these facilities.

Television ophthalmoscopy and fluoroscopy systems

The stereo-ophthalmoscope can be readily converted into a television ophthalmoscope by replacing the binocular tube and beam splitter with a specially

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Fig. 1 Camera set up showing Badger SIT camera mounted on television ophthalmoscope with Sony U-Matic video cassette recorder, set at stop-frame, in the background.

designed adapter for the attachment of colour and monochrome television cameras (Fig. 1). The conversion can be effected simply and quickly, with dovetail mountings and preadjusted magnetic holders.

The TV adapter has a variable aperture stop which can be closed completely and also houses the fluoroscopic barrier interference filter. There is a choice of either 50 mm or 100 mm focal length objective lens (Table 1).

The efficient light gathering power of the optical system in the Stereo-ophthalmoscope 110 and special TV adapter, in conjunction with highly sensitive monochrome and colour television cameras, results in very good quality television imaging.

Colour television ophthalmoscopy. The quality of image equates well with the appearance of the fundus oculi obtained by conventional ophthalmoscopy. The greater contrast and therefore resolution obtained from the monochrome television camera is used to advantage in television fluoroscopy.

In practice the entire fundus oculi can be covered

by manipulating the television ophthalmoscope in relation to the television monitored image, giving good control of fine focusing and reflex free fields of view. The compact lightweight television cameras are counterbalanced by the tilting and rotating stereo

Table 1 *Technical details of the television ophthalmoscope*

	50 mm lens	100 mm lens
Viewing angle	42°, 42°, 22°	40°, 30°, 15°
Magnification	7.2 ×, 10 ×, 20 × *	14.5 ×, 20 ×, 40 × †
Resolution‡ (lines/screen) in horizontal direction	Better than 250	Better than 250
Minimal structures resolvable in mm (calculated from the above)	0.22, 0.16, 0.08	0.11, 0.08, 0.04
Illumination	6V 20W halogen lamp, variable intensity	
The recommended lens is the 100 mm lens		
Increased sensitivity with some reduction in resolution is obtainable with the 50 mm lens		

*Maximum angle without vignetting.

†Provided 16 × magnification by the television system (1 inch (2.5 cm) camera tube window—20 inch (50 cm) monitor screen).

‡Theoretical limit, calculated from the image diameter on the camera tube and manufacturer's specification.

ophthalmoscope mounting, allowing the operator to pan around both central and peripheral fundus fields. Alternatively, the patient is instructed to move the eye in the required directions as in conventional ophthalmoscopy.

Because the television cameras are easily detachable they can be used as a multipurpose television camera module on different instruments such as surgical operating microscopes and biomicroscopes, thus spreading the functional cost of a single television camera over several fields of application. Television ophthalmoscopic and fluoroscopic data can be stored by means of a standard video cassette recorder either for direct visual analysis on replay or for feeding into an image analysing system for quantitative studies.

Video fluorescence angiography. The outstanding advantage of television fluoroscopy is the dynamic visualisation of choroidal and retinal vessel flow in health and disease. Although the maximum resolution is limited to about 40 μm when working with the 100 mm lens, i.e., only about a quarter of the resolution obtained from black-and-white high-speed film which is conventionally used in fluorography, this has been found adequate in practice for most clinical investigations of ocular circulatory disorders.

Basically the same instrument is used as described previously, but instead of the colour television camera an intensified target black-and-white camera, Badger SIT from RT Laboratories, UK, is used. This camera gives a clear television image at incident light levels of 10^{-2} lux, and it has a resolution which is comparable with the Circon colour television camera.

This image intensified tube has an exceptionally high-quality response and was specifically designed at RT Laboratories to have maximum sensitivity at 520–530 nm to record fluorescence for a blood

fluorescein mixture. The excitation and barrier filters used are as previously described.⁷

This system provides a method of observing the dye transit through the ocular circulations in both the anterior and posterior segments at the time of dye injection. Simultaneous video recording with a standard video cassette recorder gives a compact clinical record of archival quality. The stored data can be quickly retrieved through a computerised data retrieval autosearch control unit for routine clinical evaluation and serial comparison. The dynamic sequence can be halted at any chosen stage for still-frame analysis (Figs. 2, 3, and 4; Table 2).

FUTURE APPLICATIONS

A further development has been the design of a television stereo ophthalmoscope to be used in conjunction with a computerised image analyser and data storage bank. The video display system will perform real-time stereo data analysis and through an analogue to digital converter will give a digital display or paper print-out of optic disc cup volume. The computer stored data would be used to detect volu-

Table 2 *Manufacturers and suppliers of equipment used*

<i>Television cameras</i>	
Low-light-level, single-tube, colour television camera, with C-mount, reference MV 9295	Circon Corporation, 749 Ward Drive, Santa Barbara, Ca 93111, USA (UK representative) Video South Ltd, 5 Kingsmead Square, Bath, Avon
Hitachi Denshi Model GP5 colour television camera	Hitachi Denshi (UK) Ltd, Lodge House, Lodge Road, Hendon, London NW44DO
Badger 25 SIT low light monochrome television camera	Alrad Instruments Ltd, 19a The Precinct, Egham, Surrey TW20 9HN
<i>Video tape recorder</i>	
Colour video cassette recorder, Sony U-Matic with still frame facilities and autosearch control unit	Sony Company of Japan Ltd

Fig. 2 Still from video recording of normal fluorescence angiogram.

Fig. 3 Still frame of iris angiogram showing dye entry and leakage from abnormal iris vessels associated with central retinal vein occlusion.

metric change in low-tension glaucoma, and as an additional parameter to monitor long-term control in chronic simple glaucoma.

Discussion

Colour television funduscopy provides a method of individual and group viewing of the fundus, for the purposes of consultation, teaching, or comparison with previous video recordings.

Television fluoroscopy has the unique advantage of dynamic visual display of fluorescent dye entry, initial transit, and recirculation within the ocular circulation, and the evolution of any abnormal extravascular fluorescence. The system is simple to operate for the ophthalmologist without skilled technical assistance,

and it is particularly useful in smaller departments or the consulting room without photographic dark-room facilities.

Video cassette recording of data offers to the clinician the availability of instant replay for detailed analysis of any particular sequence. There is also the facility of remote viewing in the consulting room, either at the time of fluoroscopy or by retrieval from video records.

Considerable saving is made in running costs, including technicians' time carrying out dark-room processing, and in the cost of film materials as compared with video recording of an equivalent number of patients. Perhaps the most important consideration is the high level of patient acceptability of a silent, low-light-level recording procedure which can be

Fig. 4 Still frame of appearance of optic nerve head during early venous filling phase of dye transit in a case of central vasculitis, showing dye leakage and mural staining of veins.

performed with the minimum of stress and the maximum of convenience to both patient and doctor.

Electronic imaging can be further developed through computer technology to quantitative analysis of optic disc cup volume and measurement of retinal haemodynamics.

References

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