ENDOSCOPY AND TELEVISION*

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Awareness of the need to be able to observe the interior of the hollow tubes and organs of the human body is some hundred years old. The first attempt was made using as illumination a candle, the light of which was projected directly through an open tube. One of the first exponents of this method was Philipp Bozzini (quoted by Garrison, 1914) in the eighteenth century. In 1865 the French physicians Segelas (quoted by de Montreynaud *et al.*, 1960) and Desormeaux introduced the term "endoscopy" into the medical literature. Kussmaul, in 1873 (quoted by Kalk *et al.*, 1951), was courageous enough to pass an open tube into the stomach, and with great wisdom chose as his first patient a professional sword-swallower. Nitze (quoted by Brunner *et al.*, 1950) demonstrated the first cytoscope in 1877.

The invention of the electric-light globe by Edison opened up a new epoch in the development of the endoscope, and the early open tube with its reflected light source gave way to a much more efficient instrument with distal illumination and an optical system.

The need to record the pathological findings in some permanent form was quite obvious. The realization that a picture creates a more vivid impression than does a written description encouraged the rapid development of techniques for the photographic recording of the image using both the still and the cine method.

Endoscopy at this stage did, however, still have considerable shortcomings, chief of which was the restriction imposed by the use of a small monocular eyepiece.

The discovery of television was therefore of great interest to those concerned in the improvement of endoscopic techniques, for it offers the following potential advantages over the standard viewing methods: (*a*) the image can be viewed immediately; (*b*) it can be seen by many people and if need be in different places, so facilitating teaching and consultation; (*c*) the image can be enlarged many times; (*d*) the viewing of the image is binocular; (*e*) the image can be corrected by appropriate adjustment for brightness and contrast; and (*f*) the image can be recorded from the television screen, using either a still or synchronized cine-camera, and these records can be made quite selective.

Despite these great advantages, progress in the medical application of television techniques has for a variety of reasons been slow. The first difficulty encountered was the indifferent illumination offered by the standard endoscope. It is true that some progress has been made in this direction over the years. Brubaker and Holinger (1941) improved matters by a system which made use of an open tube and a bright and continuous proximal light source. An alternative method which made use of a lamp filament that was overburned for a fraction of a second gave sufficient illumination for taking a single photographic exposure.

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A remarkable step forward was the development made by Fourestier, Gladu, and Vulmière, which was recorded by de Montreynaud *et al.* (1956). The light, which is generated by a very powerful air-cooled projector bulb, is mounted at the proximal end of the instrument; it is focused on the end of a quartz rod which conducts the light to the distal end of the tube. Using this form of illumination, it became possible to achieve a level of light intensity at the distal end of the instrument of approximately 20 times the value reached with the standard equipment.

It was the introduction of equipment of this type which first made the use of television in endoscopy worth considering. The first televised bronchoscopy was reported by Soulas in 1956. This work was extended by Soulas *et al.* (1957). Later, McCarthy and Ritter (1957) and A. Frei (personal communication) viewed the inside of the bladder and K. Spohn (personal communication) reported further experience of television used in combination with bronchoscopy.

In our work we have used the French equipment which was described by de Montreynaud *et al.* (1956).

However, before television could win a place as a valuable aid in endoscopic technique it was necessary to give a satisfactory answer to three fundamental questions: (1) Can television technique be adapted to our standard methods of endoscopy? (2) Is the television image comparable in quality with the normal visual image? (3) Although it is admitted that the advantages of television may be considerable, are they real enough to offset the loss of colour and the other limitations of a black-and-white image?

Let us consider each of these three questions in turn.

Can Television Technique be Adapted to our Standard Methods of Endoscopy?

In the earliest television endoscopes standard studio cameras ("orthicon") were used. However, these weigh some 80 kg. and their bulk made easy manipulation impossible. Even the industrial ("vidicon") cameras were still too heavy (1.5–4 kg.) and unwieldy, and in order to facilitate accurate handling it was necessary to incorporate a counterbalancing system. One of the fundamentals of any endoscopic technique is that the operator should have complete control over the passage and manipulation of the instrument. He is largely dependent on sensations of resistance conveyed to his hands during such manipulations for the avoidance of dangerous pressure, with the risk of damage to mucous surfaces or even of perforation of a viscus. There was therefore a strong argument in favour of the development of a camera which could be coupled direct to the endoscope and which was small enough to be moved without the need for any balancing or supporting system.

With this in mind, we set about developing a television camera which would have the following specifications: (*a*) Weight and size should be as small as possible. (*b*) It should be simple enough in design and rugged enough in construction to be operated by persons untrained in television techniques. (*c*) Its use should not be time-consuming and must be without risk to the patient. (*d*) It should be as cheap as possible, both in its capital and its running cost, bearing in mind that it would eventually have to be operated within the restriction of a hospital budget. (*e*) It should work on the same lines as the local television network (in

Australia this is 625 lines) so that it could be used in conjunction with the standard commercial receivers.

With these specifications in mind we have since developed a camera and have now gained some experience in its use.

Weight and size were reduced considerably by the use of a ½-in. (12.5-mm.) vidicon television pick-up tube. We chose a 6-mm. display image as likely to afford us the optimum amount of illumination. For this reason it did not seem necessary to seek the better image quality of the 1-in. (25-mm.) vidicon tube at the cost of adding to the bulk of our camera. The camera is connected with the camera control unit of a normal television camera chain. As the voltages in this unit were established to serve the standard 1-in. (25-mm.) vidicon via a camera cable of up to 300 metres, we had to modify the equipment somewhat to transform the voltages to values suitable for our ½-in. (12.5-mm.) vidicon. This was accomplished by the incorporation of a special matching unit, which was, however, moved away to a distance 3 metres from the camera so as not to impede either the patient or the operator. The matching unit is housed in a box measuring 19 by 14 by 5 cm. and from it a cable runs to the camera control unit, which may be mounted outside the operating-theatre.

The camera is 120 mm. long, has a diameter of 45 mm., and weighs 350 g. (Fig. 1). It can be coupled and uncoupled quickly and easily to the endoscope (Fig. 2). The operator can move the camera and endoscope together so that he is able, at the same time, to have complete control of the manipulation and to make a proper measure of the resistance of the body to its movement. Initially we used a semitransparent viewing system which enabled us to view and televise simultaneously, but the loss of light in this system was considerable. A new mirror reflex system is, however, now under construction. The entire operation is quite simple and the operator controls the camera by three buttons only. To date we have had experience only with bronchoscopy, oesophagoscopy, and laryngoscopy (indirect). The television image is recorded using a 16-mm. synchronized movie camera.

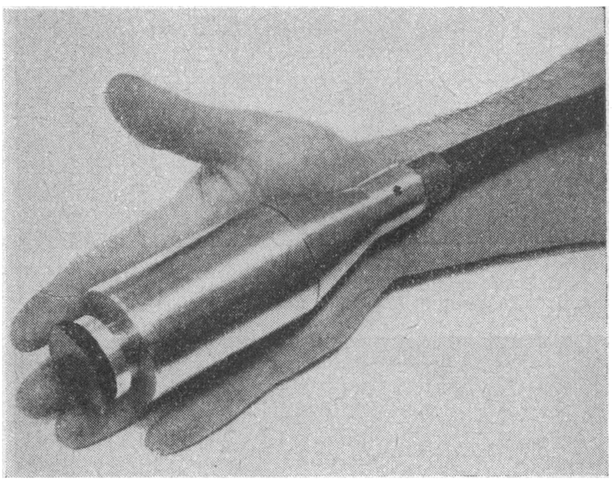

FIG. 1.—Miniature television camera.

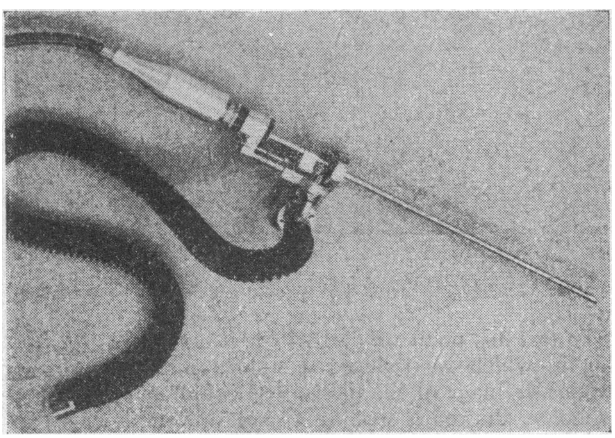

FIG. 2.—Miniature television camera connected to the French bronchoscope.

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Is the Television Image Comparable in Quality with Normal Visual Image?

As a measure of the performance of our camera we have endeavoured to compare the image obtained using the orthodox bronchoscope with that obtained with the French equipment and television used together.

Normal Bronchoscopy Using a Negus Bronchoscope.—This is an open-tube system which has no lens but distal illumination. It is 400 mm. long and has an outside diameter of 9.5 mm. The disadvantages of this type of instrument are: (1) The visual distance (object–eye) is determined by the length of the instrument and cannot be adjusted to the eye of the operator. (2) The image is very small. The operator sees the picture, which has a diameter of 8 mm., from a distance of approximately 400 mm., with an obvious loss of detail, compared with a normal viewing distance. (3) The visual field does not change significantly during alteration of the object–eye distance in the course of the examination. (4) The illumination has certain imperfections determined, in part, by its low intensity, and in part by uneven lighting due to the eccentric positioning of the globe and the resulting disturbing reflections.

French Bronchoscope.—Length 488 mm., diameter 10 mm., 180 degrees optic, objective diameter of 2.5 mm., quartz rod, proximal illumination. In contrast to the open-tube instrument: (1) this bronchoscope, which like a cystoscope carries a separate optic, transmits a wider viewing-field: the diameter of the field increases almost in proportion to the object–objective distance; and (2) the image is enlarged, making recognition of details easier.

French Bronchoscope and Television Camera.—By coupling our miniature camera to this bronchoscope we have gained the following additional advantages: (1) the picture is enlarged still further to the size of any television screen; (2) the image on the television screen can be seen by the examiner at his optimal viewing distance; (3) the brightness of the image is adjustable; and (4) binocular viewing of the image is possible.

Test Method

Optical resolution is determined as the smallest distance between two object points that allows them to be distinguished as two separate images. The human eye is able to separate two objects from each other if they form a one-minute (1′) arc. With the object at 250 mm. from the eye and with optimal contrast and illumination, the human eye can separate two object points when they are 0.1 mm. apart. In practice, however, for reliable and convenient viewing arcs of 3′ or 4′ are necessary, so that an enlarged picture has certain advantages.

To measure the performance of our equipment we have used a standard test picture which consists of bars of different thicknesses. This was photographed on a 35-mm. black-and-white film strip as a transparency, which was then illuminated from behind by a standard light source (Fig. 3).

The test picture has four different line groups with the same space between the lines in the same group. The thickness and spacing of the lines in different groups is 750 μ, 200 μ, 63 μ, and 37.5 μ. This test pattern was viewed in conjunction with the normal bronchoscope (Negus) and with the French bronchoscope coupled to the miniature camera. Our results are as follows.

Test A.—Negus bronchoscope, object–bronchoscope distance 10 mm. On the proximal end of the bronchoscope a still camera was placed to substitute the human eye. The highest resolution obtained was with the lines 200 μ thick (Fig. 4).

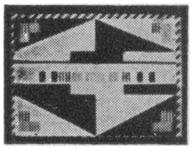

FIG. 3. — Test pattern (actual size).

FIG. 4.—Test pattern as seen through the Negus bronchoscope. Object–eye (camera) distance is 410 mm.

Test B.—French bronchoscope coupled to miniature television camera (apochromatic "kinoptik" lens, 1:2, f 40 mm.). Television receiver EV 25 with a 10-in. (250-mm.) screen (BmV 25). The picture was taken from the enlarged image on the 10-in. (250-mm.) television screen, using a still camera.

B1: Test pattern, objective distance 25 mm. The group of 200-μ lines is still clearly recognizable (Fig. 5).

B2: Test pattern, objective distance 15 mm. The group of 63-μ lines can now be appreciated (Fig. 6).

B3: Test pattern, objective distance 10 mm. The group of 63-μ lines is still clearly recognizable and the 37.5-μ group line structure can also be observed as they are enlarged on the 10-in. (250-mm.) screen (Fig. 7).

In our experiments the normal (Negus) bronchoscope gave an image diameter of 8 mm. with an object–eye distance of 410 mm. In contrast, using the televised method, the image appeared on the 10-in. (250-mm.) screen with a diameter of 150 mm. In addition we were viewing a wider field than with the open-tube system.

Are the Advantages of Television Real Enough?

In the examination of certain pathological states, of which inflammation is the most familiar, visualization of the natural colour would seem to be of primary importance. In most endoscopic examinations, however, the dominant colour is red and the contrast range in natural colours is not great. In fact, the difference in appearance of most structures as seen on endoscopy is determined in the main by small variations within the red spectrum. This would be true, for example, in the examination of a blood-vessel running on the wall of the bladder. The range of contrast of the television screen is greater than that of the colour photograph. Therefore in black-and-white examinations the contrast is in fact much greater and so more detail may be evident.

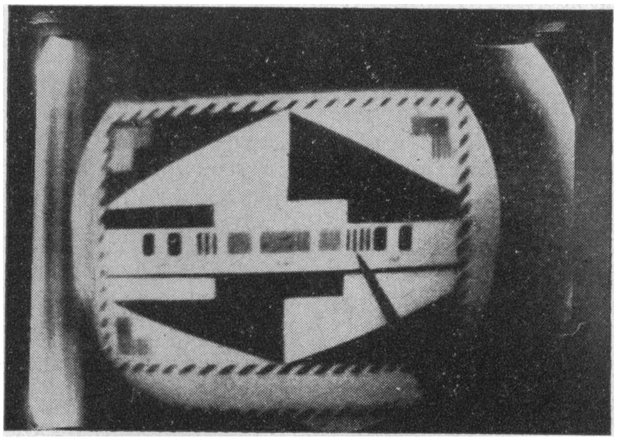

FIG. 5.—Test pattern as seen through the French bronchoscope coupled to the miniature TV camera. Object–objective distance 25 mm. The oblique linear shadow in the right lower corner is due to a pin placed on the surface of the test pattern.

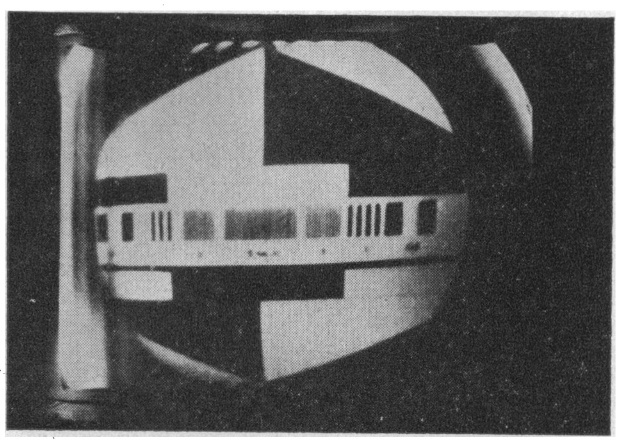

FIG. 6.—Test pattern as seen through the French bronchoscope coupled to the miniature TV camera. Object–objective distance 15 mm. The group of 63-μ thick lines is still clearly recognizable.

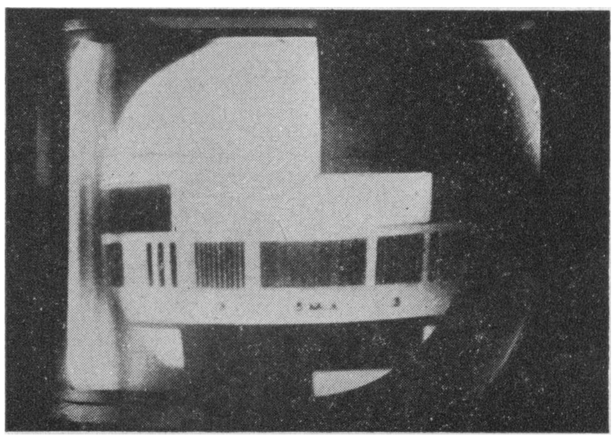

FIG. 7.—Test pattern as seen through the French bronchoscope coupled to the miniature TV camera. Object–objective distance 10 mm. The 37.5-μ group line structure can also be observed.

To test this point we carried out a bronchoscopy in a dog in which we induced a sudden occlusion of the venous drainage of the lung. The colour picture of the bronchus showed a striking degree of venous engorgement, but the same point was not less evident from the examination of a photograph of the television image.

It must be admitted that, in general, colour documentation should be the method of choice in medicine, but in this special field the quality of the black-and-white image appears to be good enough to make it of value in diagnosis, and the increased contrast obtainable from the television circuit offsets the loss of colour differentiation.

It is felt, therefore, that the use of television offers considerable advantages and we have been encouraged to adapt this technique to other endoscopic methods.

In the routine use of our equipment we have run into some difficulties. Not all of them have been peculiar to the use of television and most of them have now been overcome. For instance, we have modified the French bronchoscope to enable us to pass biopsy forceps under vision and to allow the administration of oxygen at the distal end of the instrument throughout the examination (Figs. 8 and 9).

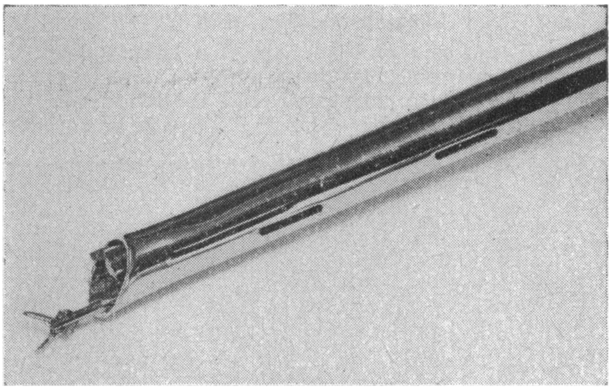

FIG. 8.—Biopsy forceps.

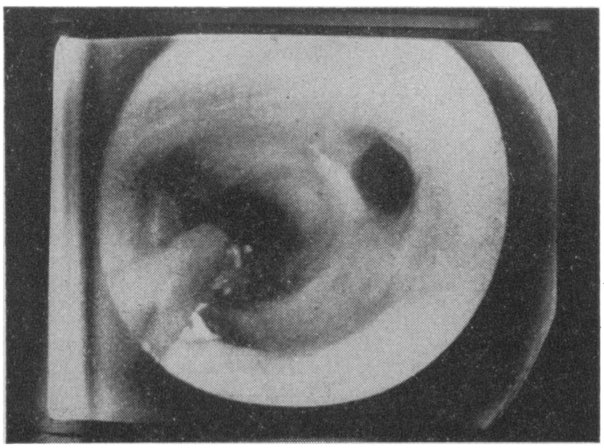

FIG. 9.—Biopsy under "televisual" control.

To facilitate accurate and easy documentation with the French laryngoscope (Vallancier) we have devised a "manipulator," which we will describe elsewhere.

The field for television in endoscopy is still largely unexplored. At the moment we are improving the miniature camera so that it can be connected to a central control unit, thus enabling several miniature cameras as well as a normal industrial camera to be operated together and used in turn at the press of a button. We hope in this way to be able to make simultaneous use of an image intensifier coupled with an industrial television camera. It will be possible to see the x-ray image of the endoscope in position on the television screen and to correlate, for example, in oesophagoscopy, the endoscopic picture and the position of the instrument in relation to the diaphragm and the vertebrae.

Moreover, with the help of our x-ray television image storage unit, on which we will be reporting in due course, it should be possible to combine several examinations in one session, as, for example, bronchoscopy and selective bronchography.

Conclusions

The use of television techniques in certain fields of endoscopy is described. A miniature camera has been developed for this purpose.

It is believed that in pathological conditions, where the black-and-white image with higher contrast is valuable as documentation, television can be employed.

With further increase of the illumination the existing image quality can be improved. The resolution is demonstrated with a test pattern in comparison with the open-tube system.

The further progress in the development of television pick-up tubes should result in the increase of the overall image quality.

Summary

A miniature television camera has been developed as an adjunct to endoscopy. Attention is drawn to some of the advantages of this equipment and to its potential.

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A British medical team has arrived in Northern Rhodesia on its way to Luapula Province, where it will work to combat the high degree of blindness among African children. The team is being financed largely by the Royal Commonwealth Society for the Blind, but the Northern Rhodesia Government, the Federal Ministry of Health, and the Northern Rhodesia Council for the Blind are also contributing. The team is led by Dr. Benjamin Cobb (St. Thomas's Hospital, London). (*Newsletter*, Federation of Rhodesia and Nyasaland, April 6.)