THE USE OF IMAGE AMPLIFICATION, X-RAY CINEMATOGRAPHY AND TELEVISION IN CLINICAL RADIOLOGY

M. DENNY, *Radiologist, Lister Buildings, Johannesburg*

In March 1959, Philips (S.A.) Ltd. initiated the radiological technique of image amplification and X-ray cinematography in this country by installing a 5-inch amplifier and 16 mm. Arriflex camera at the Brenthurst unit of our practice.

The installation was loaned on an experimental basis to ascertain its value in clinical radiography, and in the first instance primarily to determine its value in the performance of renal angiography with specific reference to selective renal catheterization. Its value was soon confirmed and presented to the medical profession through the medium of a film at the 42nd South African Medical Congress at East London in September 1959.[1]

This particular unit was used extensively in many radiological examinations, usually as an adjunct to routine procedures; in angiocardiography it entirely displaced the serial static technique.

A pattern of usefulness was evolved, and when it became apparent from our experience and similar evidence in the literature that the method was here to stay, the Philips 9-inch unit, then new on the market, was purchased. This unit and a more recently installed similar unit with closed-circuit television, has been in constant clinical use in all manner of examinations.

It would appear that the time is appropriate to pass on to our colleagues some of our experiences, namely those which the agents cannot give, and which are not dealt with to any extent in the world literature, especially because so many radiologists are now considering the installation of such units, or indeed have already equipped themselves in this manner.

VARIOUS AVAILABLE UNITS

The original 5-inch unit served a good purpose in introducing the method to the profession, but was limited in its application by the size of the field, which, of course, owing to geometric magnification of the image, was less than 5 inches. As a portable unit, it retains a niche in theatre radiography, perhaps to be expanded by the possible success of a method of increased intensification where detail is not vital.

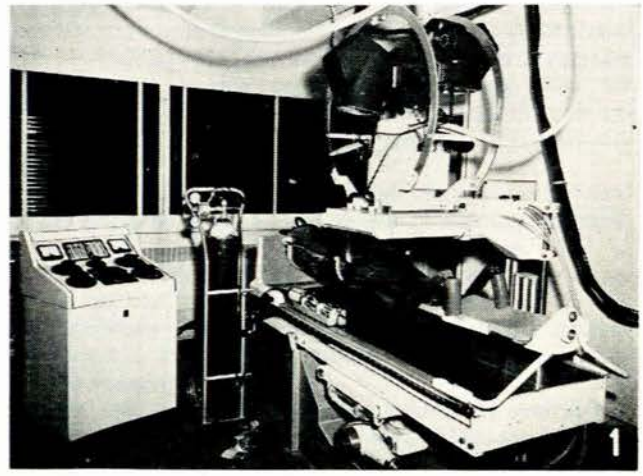
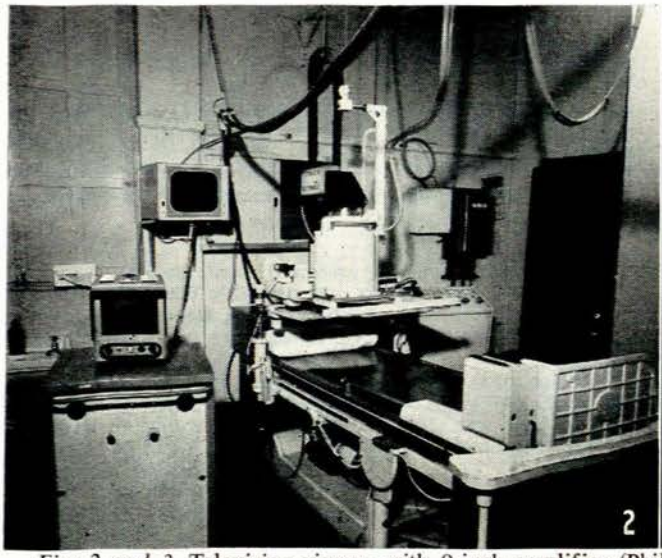
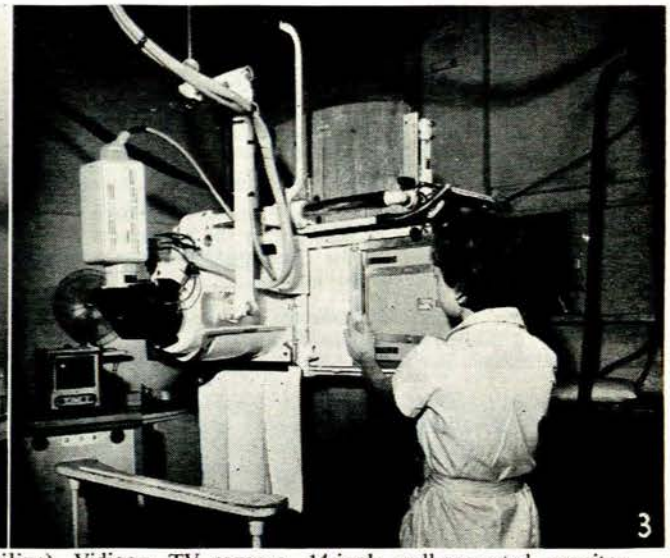


Fig. 1. Combination table, with 9-inch image amplifier (Philips), duplex mirror viewing system, Arriflex 35 mm. camera, and rotating cradle (Brenthurst unit).

The 7-inch intensifier, produced by Siemens with a slightly larger field, may prove to be a better theatre unit, but is still too small to occupy pride of place as a single unit in any practice.





Figs 2 and 3. Television viewer, with 9-inch amplifier (Philips), Vidicon TV camera, 14-inch wall-mounted monitor, and 8-inch cabinet-mounted monitor (gastro-intestinal unit).

Mirror Viewing

The 9-inch unit is large enough to encompass a wide variety of routine examinations adequately and indeed, in two of our screening units, is the only equipment used for gastro-intestinal studies. The mirror method of viewing and cinematography made possible by an image distributor (Fig. 1) has proved extremely efficacious, and our long experience of this equipment has disproved the myth of awkwardness attributed to the mirrors, with one exception — for those who palpate the stomach during barium-meal examinations, difficulty is experienced in the erect position.

The detail associated with mirror viewing is high, but not so much more that it should be regarded as a deciding factor against television viewing. In our cardiovascular section this method is used not so much for the reason that it is more appropriate than television, but because it is adequate and certainly a less expensive installation.

Television

With the Vidicon system of television we have noted that on occasion the viewing of the progress of the dye is confused by the slight image lag inherent in this system. Although this may be related to variations in this rather sensitive system, its occurrence detracts a little from its value in angiocardiography.

For the practice concerned with more routine radiology, and in particular, gastro-intestinal studies, there is little doubt that television viewing is preferable (Figs. 2 and 3).

It should immediately be stated that in neither system of viewing is conventional light accommodation essential. The saving of time to a busy radiologist by this release from a tedious time consumer need hardly be emphasized. For those used to conventional screen viewing, television at first proves disconcerting, but familiarity, rather than breeding contempt, ensures yet another convert to this remarkable advance in radiology.

Unlike the Vidicon system of television, the Orthicon method does not require the use of an image amplifier. This system has appeared in the form of a 12-inch field, and also does not have the tendency to image lag found in the Vidicon method. One such apparatus, marketed by Marconi Ltd., is based on the 1,024-line scanning system, as opposed to the 625 - line Vidicon system. The Orthicon system should, therefore, have a greater image detail than the Vidicon. The apparatus (Fig. 4) tends to be more bulky than the 9-inch amplifier, but adequate ceiling suspension and counterbalancing appreciably lessens this disadvantage. The greatest disadvantage of the Orthicon system is the cost, which is considerably more than the Vidicon method, and is probably beyond the spending range of most private radiologists.

Cinematography

The method of cinematography differs from the Vidicon system in that the television monitor is filmed, rather than the input phospher of the 9-inch amplifier. This entails a method of phasing the cine camera by using a polarized synchronous motor which is locked to the main supply. The camera, a Paillard Bolex, is also geared to the motor (Fig. 5). Phasing is necessary, since simple filming of the

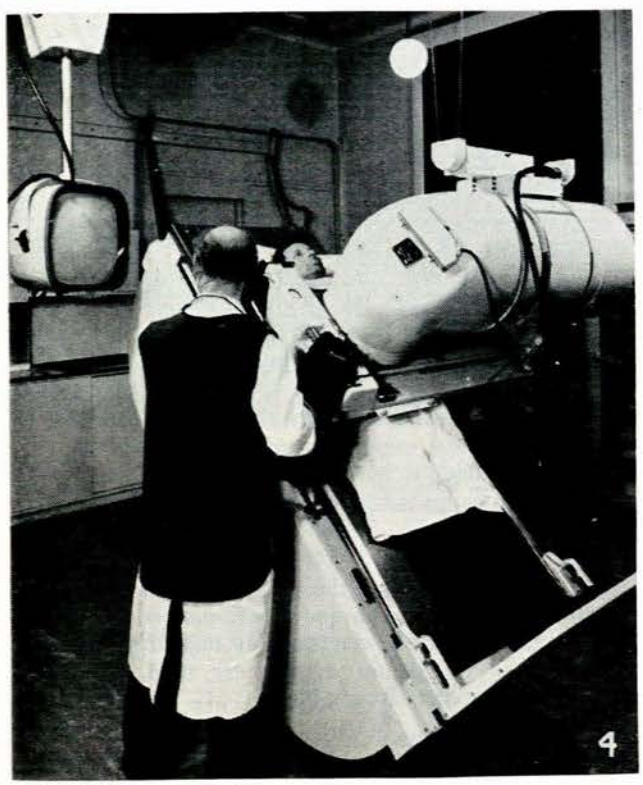


Fig. 4. Marconi Orthicon unit.

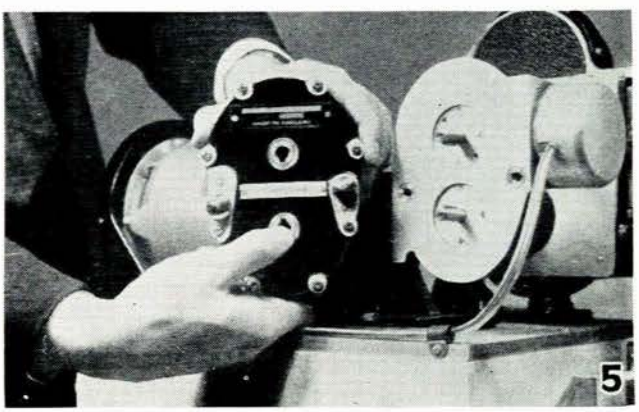


Fig. 5. Gearing for Bolex camera unit (Marconi).

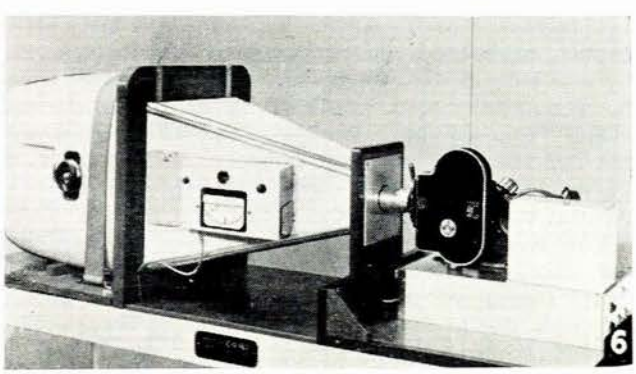


Fig. 6. Marconi method of filming monitor.

monitor is complicated by the stroboscopic effect of the television which produces a constant broad white line passing regularly across the field and therefore registered on the cine film. This line is not observed by the human eye viewing the monitor. This method of cinematography (Fig. 6) employed by Marconi, allows for the cine installation to be placed remotely, as is the case with the 100 mm. stills recording unit (Fig. 7). A further amenity provided by Marconi is the Video tape-recording system,

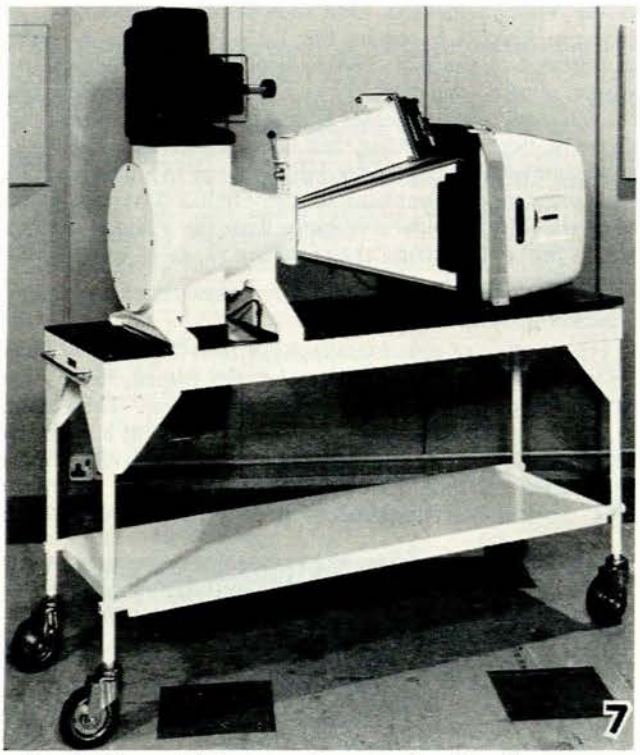


Fig. 7. Marconi 100 mm. still and polaroid unit.

which enables the examining radiologist to record the examination completely, and replay it at leisure for further study. The acquisition of such accessories increases the cost of installation appreciably, since both photographic recording systems require additional monitors. Their great value cannot, of course, be denied.

Filming of the television monitor in the Vidicon system can also be achieved by a method similar to that employed by Marconi. With an Arriflex camera which has a reflex shutter mechanism, alternative phasing of the television by a phasing device can be accomplished. This does not, however, appear to be possible with the Philips television chain. Stevenson[2] has successfully used this method with the Pye television unit, but it limits the film speeds to 25 or 12 frames per second, and only the expensive Arriflex camera can be used.

Whatever the system of phasing, it must be noted that the radiation intensity required is significantly lower than direct filming of the image intensifier screen. This is obviously due to the increased brilliance of the television monitor achieved at the low screening current, which is in the vicinity of 3 milliamps.

For those confined to a restricted budget who wish to use cineradiology in conjunction with television, a possible alternative to the more elaborate installation exists.

It is possible, once the correct lenses which will produce an infinity field have been fitted to the intensifier, to replace the television camera by a conventional cine camera with an appropriate lens. This may be accomplished by a simple locking procedure. This method has been well described by Stevenson,[2] who has designed his own lens system.

It is important to realize that the expensive Arriflex camera need not be used and can be replaced by a quality product which is far less expensive.

It is possible that a 16 mm. Paillard Bolex unit will meet the purpose. The purchaser should also be aware of the fact that since the camera is to be used for medical purposes only, it is permissible for the agent to claim, on behalf of the purchaser, a refund of the duty initially imposed at the time of importation of the camera. This ruling only applies if the camera has been imported within the last three years.

Viewing of the field to be registered is then done through the camera during the cine run. Since there is no indication of varying densities, the field should, as far as possible, be confined to areas of equal or near equal density.

A considerable degree of latitude exists where contrast medium in the nature of barium is used. The method would appear to be contraindicated, although not impossible, in cardiovascular studies. Assessment of the radiographic factors resolves itself into a problem of routine radiography, taking into consideration the patient's size, the tube rating and the capacity of the unit. The latter should certainly be capable of the higher kilovoltage range as in all cine radiology. It would also be expedient to have a special timer capable of up to 20-second exposures, inserted into an alternative timing circuit.

At the cost of some inconvenience this method will give better detail than filming of the Vidicon screen, but both methods are being presently explored and it is hoped to report more fully at a later date.

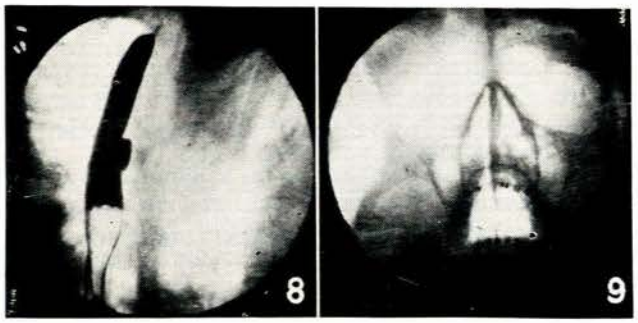
It should be noted that the Philips 9-inch intensifier is usually supplied with the correct lens system.

Screening, generally using either method of amplification, results in a decreased radiation level and with our Vidicon unit the average adult is screened at 1 milliamp, and from 90 to 100 kilovolts. It is, however, common knowledge to those using this equipment, that in the larger patients 3 milliamps may well be required, and indeed there should be no hesitation in using increased radiation where it is called for. Recent advances suggest that this will not be necessary for over-long.

Image detail on cine films using the Vidicon system is better with the technique of filming the intensifier screen rather than the monitor. In high-contrast studies where media of barium density are used, filming the monitor is, however, acceptable.

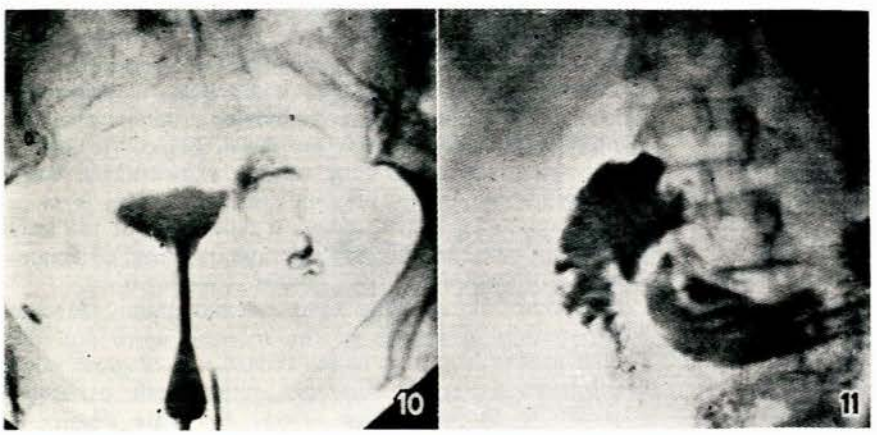
Still Recording

Still recording is achieved in both the Philips and Marconi systems (Figs. 8 - 11). If anything, bone detail



Figs. 8 and 9. Philips 70 mm. still pictures (contact prints).

appears to be slightly better on the Philips 70 mm. film than on the Marconi 100 mm. film. In contrast studies up to the field size required for gastro-intestinal work, it would appear that both 70 and 100 mm. stills will, in due course, replace conventional large-size X-ray film.



Figs. 10 and 11. Marconi 100 mm. still pictures (contact prints from reproductions).

The consequent convenience of maintaining less bulky records is obvious.

Bucky Diaphragm

It is important to emphasize the necessity of having an undercouch Bucky diaphragm in the screening unit, since films may be required once the catheter has been correctly positioned. This can be dispensed with, in a more elaborate installation, where a moving table top can transport the area of primary fluoroscopy to the position of secondary radiography. This system envisages the use of an automatic serial unit placed at the head of the table, over which the floating table top moves. One cannot, however, advise too strongly that virtually all examinations can be satisfactorily undertaken on a conventional combined screening Bucky table.

The multiplicity of special tables for cardiological, urological and other procedures is almost certainly a luxury, only to be enjoyed by Provincial or Government departments.

It does, however, appear certain that in retrograde pyelographic procedures which are conducted under television control, a special table, or a modification of the present Young table, will be necessary.

The Young table can be modified by the attachment of a floating top which will carry the patient towards the urologist during fluoroscopy and back over the Bucky diaphragm for radiography. Of necessity, the table will be firmly anchored to the floor.

Viewing of Film

Viewing of 35 mm. film is, in my opinion, best achieved on the Philips editor. This machine is extremely expensive, and it may well be that a 16 mm. camera with a Specto 16 mm. projector would be a better financial proposition for the smaller practice. The difference between 16 mm. and 35 mm. registration is, I believe, not so great that 16 mm. film cannot be used. It is indeed my intention to use a 16 mm. camera for our gastro-intestinal unit.

The development of an alternative reduced 300-line scanning system as opposed to the conventional 625-line system with increased brilliance is imminent.

CLINICAL APPLICATIONS

1. *Fluoroscopy*

This can be used for the following investigations and procedures: (*a*) cardiovascular, (*b*) hysterosalpingography, (*c*) bronchography, (*d*) gastro-intestinal studies, (*e*) myelography and encephalography, (*f*) operative and postoperative cholangiography, (*g*) percutaneous transhepatic cholangiography, (*h*) fracture manipulations, (*i*) renal cyst puncture and biopsy and pyelo- and nephrolithotomy, and (*j*) foreign-body removal.

2. *Cinematography*

This is useful in investigating the following: (*a*) the cardiovascular system, (b) the swallowing mechanism, (*c*) the oesophagus, (*d*) the gastro-intestinal tract, (*e*) temporo-mandibular joint movement, (*f*) cine dacrocystography, and (*g*) voiding cine cysto-urography and pelvi-ureteric function.

It is proposed to deal only briefly with each individual examination, since more detailed documentation of each technique becomes a paper in itself.

1. *Fluoroscopy*

Cardiovascular. Mirror or closed-circuit television viewing of the catheter has contributed greatly to the success of these examinations, and is mandatory if only for the fact that in children and infants the milliamps range from 0·2 to 0·5, representing $^{1}/_{6}$ - $^{1}/_{15}$ reduction in radiation intensity. Preliminary test injections, scorned by many, serve to ensure a completely intraluminal position of the catheter or needle.

Coronary artery calcification can be detected, even in minute form, by a careful scanning of the heart with a coned field in the antero-posterior and oblique positions. The variable contrast control on the Vidicon monitor enhances this accuracy. The prognostic significance of

coronary artery calcification has yet to be firmly established, but it has been suggested[3] that its presence may well be statistically significant. The hearts of all patients referred to this unit for cardiac investigation are examined for calcification. Preliminary observation suggests that it is less common than in Samuel's unit,[4] and also less marked in degree. Its relationship to the incidence of coronary thrombosis in White South Africans has not yet been radiologically established. It would also appear that visual demonstration of calcification may have a higher accuracy index than detection on the subsequent viewing of the cine film.

This method of fluoroscopy has revolutionized the technique of arterial examinations, particularly in relation to selective catheterization of the renal and brachiocephalic vessels. The opacified curved polythene catheter is always screened during the examination of renal arteriography, firstly for correct positioning and subsequently, if necessary, for selective catheterization.

The brachio-cephalic vessels present an ideal field for selective catheterization and, indeed, it is my opinion that vertebral arteriography should only be performed *via* the femoral route. There is little doubt that the recognized dangers of needle displacement, resulting in dissection, extravasation or, even worse, injection into the neural canal, disappear. The medico-legal position of those undertaking cerebral vascular studies should be carefully examined, since there are at our disposal means to avoid, to a large extent, the calamitous results occasionally associated with blind injections.

Hysterosalpingography, bronchography and *gastro-intestinal studies* are facilitated and expedited by the use of image amplification — consequently lessening appreciably the overall stress associated with a busy radiological practice.

Myelographic procedures are likewise simplified and in *air encephalography* the correct intraventricular positioning of air can be ascertained immediately without resorting to initial time-consuming radiography.

The possible success of the alternative 300-line scanning adaptation of the portable television unit may well bring joy to our ever-impatient orthopaedic colleagues, by shortening the *Smith-Petersen pinning* procedure by an appreciable amount. It is hoped that the increased screen brilliance will render the lateral view of the femoral neck sufficiently clear for even the most critical.

Operative cholangiography. Closed-circuit television in the examination of operative cholangiography should be of great value. The portable image amplifier alone is not satisfactory, and is liable to irritate rather than help. It is perhaps pertinent to mention in this connection the effect of peritoneal intravasation of the water-soluble contrast media. This occurs on occasion during operative cholangiography, and may not be appreciated, since it is manifested by a progressive loss of radiotranslucency of the field. The inexperienced, as in our case, may interpret this as a failure of the amplifier or X-ray generator, instead of appraising the surgeon of the incorrect positioning of the catheter.

Fracture manipulations and *foreign-body removal* present obvious possibilities for rewarding use of this equipment, but the radiologist's diligence in preventing exposure of the manipulator's hands to radiation must continue unabated. On no account should orthopaedic surgeons, primarily, and others, be permitted to use this equipment without the presence of a radiologist.

Edholm *et al.*[3] have attested to the value of X-ray television in *percutaneous transhepatic cholangiography* in the patient presenting with obstructive jaundice. They have also found it to be of great value in *renal cyst puncture, renal biopsy,* and in *pyelo-* and *nephrolithotomy.* These applications are covered in an excellent supplement to *Acta Radiologica,* a small volume which should be within hands' reach of most radiologists. According to these authors the limit of visibility of oxalate and phosphate stones lies approximately at a diameter of 2 mm. Ureteric stones were apparently difficult to observe during their removal.

2. *X-ray Cinematography*

Cardiovascular. In this unit cine angiology has completely replaced serial static angiocardiography. This seems reasonable in the light of the fact that the average radiologist refuses to interpret a gastro-intestinal series without the benefit of screening. The heart being a far more dynamic and anatomically complicated structure than the stomach, it would appear even more illogical to ignore the advantage of continuous viewing afforded by X-ray cinematography. While the detail on a cine film is more than adequate for heart studies, it falls short of the level required in renal or cerebral arteriography and cinematography is therefore not used in these investigations.

I have not infrequently used cinematography for the demonstration of lesions of the *thoracic aorta* and the arteries arising from this vessel. Indeed it is of great value in obstructions at the thoracic outlet, with particular reference to the subclavian artery. Adequate density is often only seen during diastole in the aorta, and during systole in the brachiocephalic vessels. The overall period of opacification is also brief, thus continuous recording tends, at the cost of a slight loss of detail, to have some advantage by way of first-time registration of anatomical structures.

We have found that the 9-inch intensifier has slightly too small a field to encompass the *superficial femoral arteries* adequately at their origin, when bilateral simultaneous aortography and peripheral arteriography is undertaken. It is quite adequate for isolated femoral arteriography or aortography.

The swallowing mechanism and oesophagus. There can be little doubt that in all disorders of the swallowing mechanism, cine radiology is essential for the complete assessment of anatomical and functional derangements. Together with multisection tomography, radiology has become a formidable factor in contributing to the diagnosis of lesions in this region. Diagnostic detail is assured by the use of an ultrafine focus, a fine-grain film, and a high frame speed.

The gastro-intestinal tract. I have not used cinematography to any great extent in this field, but there is no doubt that on occasion it can be of value. The detection

of pulsatile movement in relation to hollow viscera, the assessment of peristaltic activity, and the mechanism of cardio-oesophageal function represent its known applications.

Temporo-mandibular joints and *dacrocystography*. On routine radiography the two extremes of movement are often registered in an abnormal joint. Cine radiology is diagnostic in that it reveals the unevenness of movement associated with a disrupted joint. The appearance is rather similar to a vehicle bumping over a cobbled road. Epstein,[5] in conjunction with our unit, has found cine studies to be of some value in outlining and demonstrating the physiological patency of the nasal duct. The duct is considered to be patent if the contrast medium, merely dropped into the desensitized eye, is demonstrated to be present in the duct and subsequently in the nose. The 5-inch intensifier with a slightly higher detail was found to be more adequate than the 9-inch unit for this examination.

Voiding cine cysto-urethrography. The Brenthurst unit of our practice has, over the last 3 years, undertaken a large number of these examinations. The results have been variously reported by Jordaan,[6] Berezowski[7] and Komins.[8] The examination, properly performed, is of great value, but since this subject was extensively dealt with in an earlier issue of this *Journal*,[9] it is unnecessary to comment further.

SUMMARY

In this paper I have attempted to indicate the value of a new radiological development in apparatus, and its application in clinical radiology. Some comment has also been made on variations of the basic installation in relation to the nature of the practitioner's work. It is also emphasized that further developments, which will enhance its present status and probably extend its scope, are to be expected.

I should like to express my appreciation to both the Philips and Marconi Companies for permission to reproduce illustrations of their equipment in this paper; to my partners and staff, without whose cooperation and participation our progress in this sphere of radiology would not have been possible; and to those clinicians who have shown an active interest in this development and who referred so many cases for our studies.

REFERENCES

1. Denny, M. and Tinker, A. (1960): S.Afr. Med. J., **34**, 852.
2. Stevenson, J. J. (1961): Brit. J. Radiol., **29**, 309.
3. Edholm, P. *et al.* (1962): Acta radiol. (Stockh.), suppl. 216.
4. Samuel, E. (1961): Personal communication.
5. Epstein, E. (1960): Personal communication.
6. Jordaan, J. (1962): Paper presented at the 4th Congress of the Urological Association of South Africa (M.A.S.A.), Cape Town, November.
7. Berezowski, A. (1962): Paper presented at the Central African Congress of Radiology, Bulawayo, May.
8. Komins, C. (1961): Film presented at the 3rd Congress of the Urological Association of South Africa (M.A.S.A.), Johannesburg, March.
9. Berezowski, A. and Komins, C. (1963): S. Afr. Med. J., **37**, 349.