An Introduction to Xeroradiography

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SUMMARY

The history and physical principles of xeroradiography are given. The advantages and applications of the technique are enumerated and a 'working' description of the essential components of the Xerox system included. Mammograms of exceptionally high quality have been produced with no difficulty, and with few problems. The unit has proved reliable.

S. Afr. Med. J., **48**, 2289 (1974).

HISTORY

Xeroradiography is the science of recording radiographic images electronically on a selenium plate.

Xeroradiography was invented by a physicist and patent attorney, Chester F. Carlson, in 1937. He based his invention on the principle of photoconductivity, i.e. some materials which are nominal insulators become conductors when they are exposed to light or ionising radiation. Using selenium as a photoconductor, he was able to reproduce a number of graphic articles, and with the aid of another physicist, Otto Kornei, successful images were made. The basic patent covering this reproductive process was issued in November 1942. In 1947, the Haloid Company, now the Xerox Corporation, obtained a licence for commercial development, and research was begun at the Batelle Memorial Institute.

Investigations in the medical field started in 1952 under John F. Roach of Albany Medical College, New York, who discovered that xeroradiography was as sensitive as medical X-ray film when used without intensifying screens, but was several times less sensitive than film combined with screens. Thus, with xeroradiography the radiation dose would be correspondingly higher for any examination where screens are normally used with film.

In 1956 a group at St Vincent's Hospital and Medical Centre of New York, under the direction of Francis F. Ruzicka jun., tried the xeroradiographic technique for hip pinnings in the theatre, but these experiments failed because of the primitiveness of the equipment available. They found their best results were in mammography, where the good visualisation of both the glandular elements and the soft tissues was a striking feature of the procedure.

Oliphant was the first to describe an effect he called 'pull in'. This represents the 'edge effect' of the Xerox workers.

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Date received: 3 July 1974.

In 1966 John N. Wolfe commenced experimental tests using an existent xeroradiographic unit. Employing a low kV technique, these experiments demonstrated the greater resolution in xeroradiography. This increase in resolution allowed identification of small structures, especially small tumours, while the superior 'edge effect' and the good detail recorded of all the structures within the breast, made a much more accurate over-all interpretation possible.

Encouraged by the results, a delegation of radiologists, headed by Wendell Scott, and financed by the American Cancer Society, asked Xerox to design a machine which could easily be operated, which remained clean and dry, and which could produce superb images regardless of climatic conditions. This became the Xerox System 125.

THE PHYSICAL PRINCIPLES OF XERORADIOGRAPHY

The principal element in xeroradiography is a re-usable photoreceptor plate, measuring approximately 24 × 36 cm. It consists of a thin photoconductive layer of selenium (130 W) adhering to an aluminium backing. The selenium layer is semiconductive. The selenium semiconductor is given a uniform positive charge by an ionising device, consisting of a number of electrodes and a grid, called a scorotron.

When the selenium plate is exposed to light or to radiation (X-rays), the semiconductor layer increases its electrical conductivity and allows the positive charge on the plate to discharge. Since the discharge of the plate varies according to the quantity of X-ray energy reaching it, an electric charge pattern, which corresponds to the density of the object being X-rayed, is left on the plate. This resultant charge pattern is the latent image.

A developer consisting of a blue powder called toner, is then aspirated on to the plate, to which it is attracted by the charge pattern in the form of a diffuse powder cloud. The aspiration is achieved by air jets which meter the toner into the developing chamber from a rotating disc inside a powder dispenser. The image thus formed is made permanent by transferring and fixing it by heat on a special paper. This is the xerogram (XR). An image in various shades of blue is produced. The dense regions of the subject being examined will strongly absorb the X-rays. This will allow less discharge from the plate and will lead to a stronger residual charge on the plate. More toner particles will be attracted to it and the area will therefore be dark blue in colour. Thin regions of the subject will allow the X-rays to pass through almost unaffected. These cause considerable discharge of the plate and little residual charge. Only a few toner particles will be attracted, and the area will be light blue in colour.

Edge Enhancement

This phenomenon is one of the most important features of xeroradiography, and it is the result of the fact that extra toner is attracted to the boundaries between areas having different amounts of electrostatic charge, i.e. areas of charge discontinuity. This edge contrast is most marked at the boundaries between highly charged areas and those with very little residual charge. Edge contrast is of particular value in mammography because the fine breast structures comprising the parenchyma of the breast are depicted prominently and in great detail.

Positive and Negative Modes

Both positive and negative modes can be used with the System 125. The positive mode is always employed with mammography and involves a slight increase in radiation exposure. The negative mode is used for all extremity examinations, for the larynx and pharynx, and for all bone work.

The mode selection is by a control on the processor which, by controlling the polarity of the charges on the plate and the development chamber by means of a wire grid, attract or repel the negatively and positively charged toner particles. For a positive image, the negatively charged particles are attracted to the controlling grid and to the plate above. For a negative image, the negative particles are repelled by the positive image on the plate and are deposited onto the discharged areas on the plate, while the positive particles move towards the body of the development chamber.

ADVANTAGES OF XERORADIOGRAPHY

The advantages of xeroradiography include the following:

(a) greater diagnostic accuracy is possible;
(b) interpretation is easier and more rapidly achieved;
(c) the radiographic work is simplified and there is the assurance of good quality images;
(d) exposure times are shorter and there is consequently less patient movement;
(e) a relatively low radiation dose, i.e. 1 - 1,5 rads per exposure.

APPLICATIONS

Xeroradiography has the following applications:

(a) fractures or any other sharp discontinuity;
(b) soft tissue and air passages;
(c) facial bones, temporomandibular joints and other overlapping areas;
(d) joints (both the soft tissues and the bone are very well portrayed).

THE XEROX SYSTEM

The Conditioner (Fig. 1)

This unit basically prepares the selenium plates for exposure. It will accept up to 16 plates through a slot (2), heat them in the relaxation oven (6), so that no ghost image is retained on the plate, and store them until required. When a plate is needed an empty cassette (3) is pushed into a slot (4), and this starts a transport mechanism which automatically pulls a selenium plate from storage, charges it to a high voltage by an ionising device (7) and then loads it into the cassette (8). The cassette is exposed to X-rays in the normal manner.

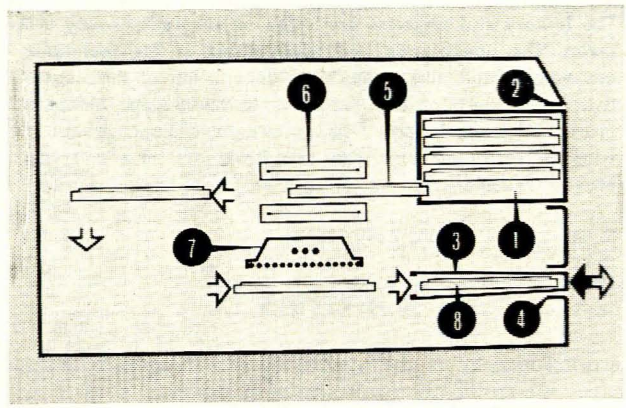

Fig 1. The conditioner.

The Cassette

This is a light-free, slightly flexible plastic container, which may be compressed if handled roughly. This will cause severe artefacts due to friction (discharge) on the selenium plate inside it. These cassettes must therefore be handled gently, and should only be held by their edges.

The Processor (Fig. 2)

The exposed cassette (1) is inserted into the slot (2) of the processor, where the selenium plate is automatically removed. In the development chamber (3) the plate is dusted with toner — a very fine blue powder which is negatively charged. This powder adheres to the positively charged plate and a visible image is produced. The plate

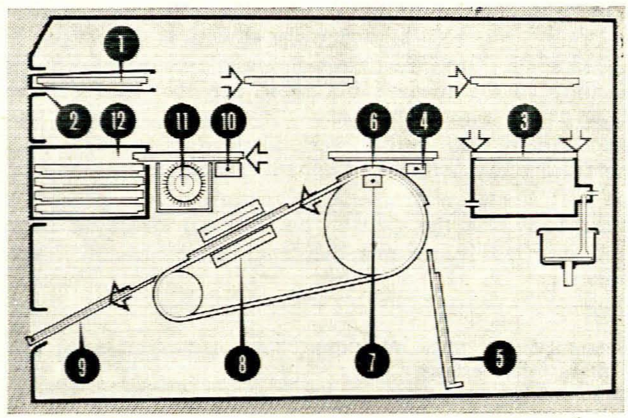

Fig. 2. The processor.

now moves forward to meet a sheet of special opaque paper (6) and the image is transferred onto the paper. The paper is then heated (8) to make the image permanent. Ninety seconds after the insertion of the exposed plate, the final print is delivered at the chute (9) at the bottom of the unit. Meanwhile, the selenium plate is cleaned by a soft rotating brush (11), and is stored in the storage box (12). When this is full, it is carried to the conditioner, and the cycle is complete.

The unit described is the Xerox System 125, which has recently gone into service in the Mammographic Clinic at the Johannesburg General Hospital. It is the first of its kind in Africa and indeed, except for Japan, in the southern hemisphere, and apart from a few minor teething troubles, it has proved to be very satisfactory. The xerograms produced are of exceptional quality, and our mammographic results will be published more fully later. Research work in bone and soft tissue radiology has also begun in the same department.

We wish to thank Rank Xerox (Pty) Ltd, Johannesburg, for their invaluable help.

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