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XERORADIOGRAPHY IN RADIATION THERAPY

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In general irradiation of a patient is based on an individually prepared plan. This plan indicates among other things the anatomy of the patient, including the target volume and the position and angulation of the beams to be used. In order to carry out a series of irradiations adequately the instructions given on the plan must be followed correctly. It is also essential to correct the plan during the course of treatment if the anatomic parameters, the patient's dimensions or body contour for instance, are changed. For this reason a radiographic control of the validity of the irradiation plan is carried out at regular intervals. From the point of view of accuracy, it is advisable to perform these examinations in direct conjunction with the treatment unit and with the patient in the treatment position.

A radiographic method for high energy photon radiation suggested by JEVBRATT et coll. (1971) has been used clinically at Radiumhemmet for more than five years. The method utilizes an industrial film with $\gamma = 6.5$ placed in a cassette between two polished lead screens, each one 2 mm thick. This radiographic technique makes it possible to magnify radiographically the small differences in attenuation which exist between soft tissues and bone when high energy photon radiation is used. However, the industrial film originally used required a longer developing time than the one used for regular diagnostic film. The interchange between regular films and the industrial film required frequent changes of the developing time in the auto-

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matic machines. This led to the use of another technical film with a shorter developing time, but unfortunately this also gave a less satisfactory radiographic result. For this reason the possibility of using the xeroradiographic method for direct field control has been tested for high energy photon radiation, at ^{60}Co-units, a 6 MV linear accelerator and a 42 MeV betatron.

Method. The tests were performed with a Rank Xerox standard equipment (System 125) consisting of a charging unit and a developing unit. The plates are made of 2.5 mm thick aluminium, coated on one side with a 150 μm thick selenium layer. The cassettes are made of plastic material. The selenium layer can be charged to a surface potential of 900, 1 300 or 1 600 volts when the equipment is set for a positive xerogram. The standard format of the xerogram is 24 cm $\times$ 34.5 cm. The preliminary tests demonstrated that a surface potential of at least 1 300 volts was necessary to demonstrate the small differences in attenuation between soft tissues and bone.

The best results were obtained when the radiation exposure to the cassette was about 3 R. This exposure level is appropriate for all the energies used and means about half the dose used previously. The physical properties of the selenium layer (the photoconducting layer) have been described by BOAG (1973).

Results and Discussion

Previously, only a few reports on the use of xeroradiography for direct field control at high energy photon radiation, especially ^{60}Co-radiation, have appeared (WOLFE et coll. 1973, FINGERHUT & FOUNTINELLE 1974).

Figs 1 to 4 illustrate the clinical use of the xerographic technique. Fig. 3 demonstrates the decrease in the difference between the attenuation in bone and in soft tissue at high energies. The contrast in Fig. 3 is sufficient to locate the treatment beam.

Up to now the xerograms have been produced on non-transparent paper and viewed either in daylight or in normal electric light. Viewing cabinets are not appropriate. For demonstration in large groups it has been necessary to use reflected light with a TV camera and monitor. As this has some disadvantages the colour powder prints were produced on transparent copy paper of the type commonly used for over-head projectors. The transparent copies proved to be appropriate and convenient for clinical use, either demonstrated directly on a viewing cabinet or with an over-head projector. Also yellow, green, light blue and red transparent copy papers have been used. However, they may be improved by increasing the amount of colour powder or the adhesivity of the transparent paper.

Fig. 1. Xerographic control of a lateral field in a patient with a cerebral tumour treated with ^{60}Co-radiation, source diameter 2 cm. Parts of the plastic mask for immobilizing the patient are visible.

Fig. 2. Xerographic control of a lateral field. Patient with an epipharyngeal carcinoma treated with a 6 MV accelerator. A tin filter, 1 mm thick, was used.

Fig. 3. Patient with carcinoma of the lung (arrows) treated with 42 MV roentgen radiation. Direct xerographic control, 42 MV betatron. Tin filter used.

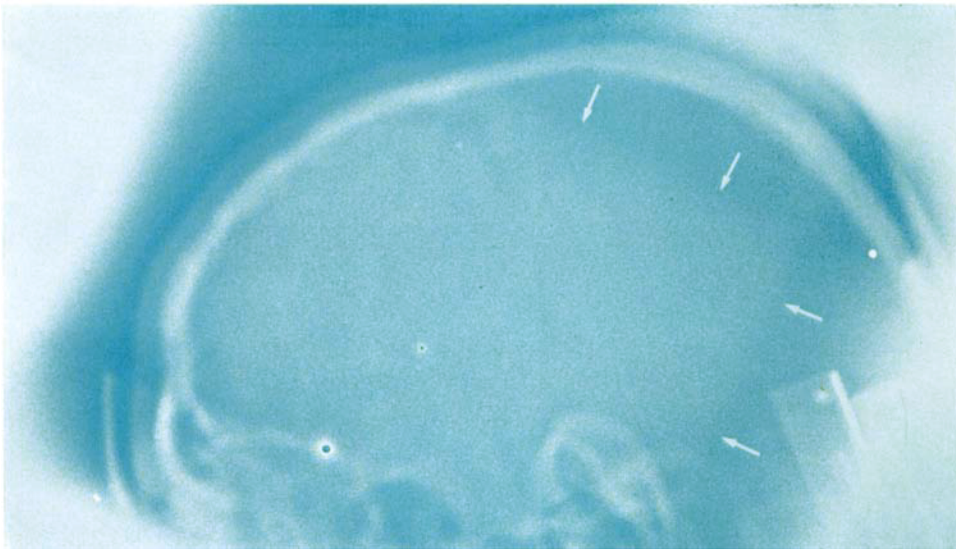

Fig. 1

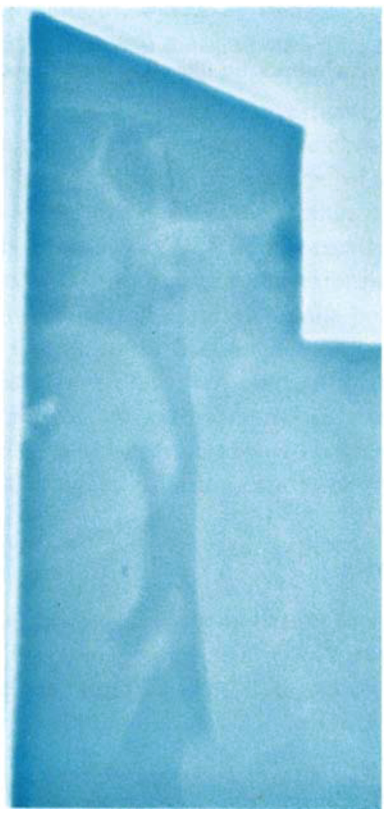

Fig. 2

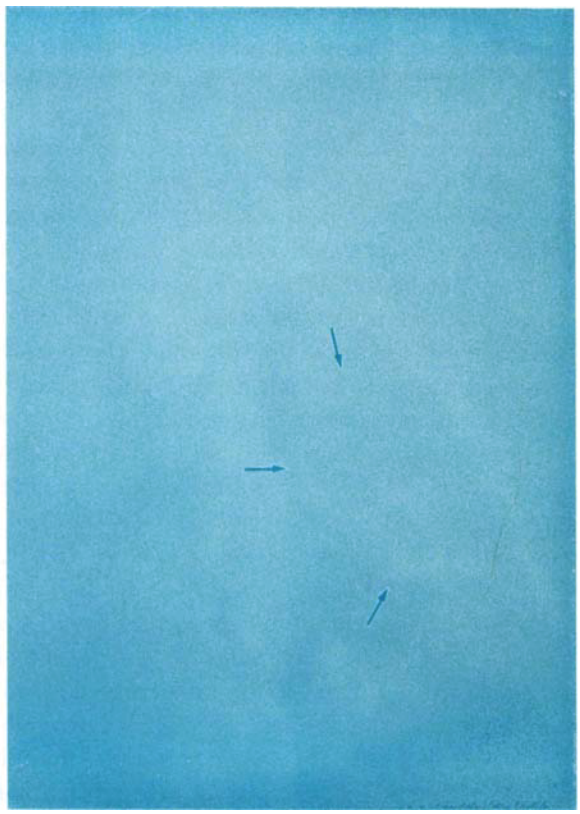

Fig. 3

(For legends see opposite page.)

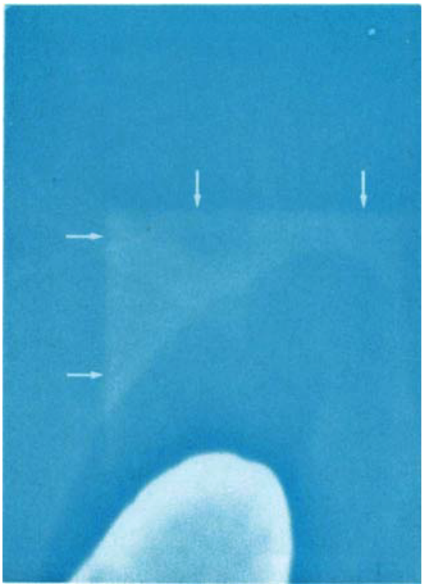

Fig. 4

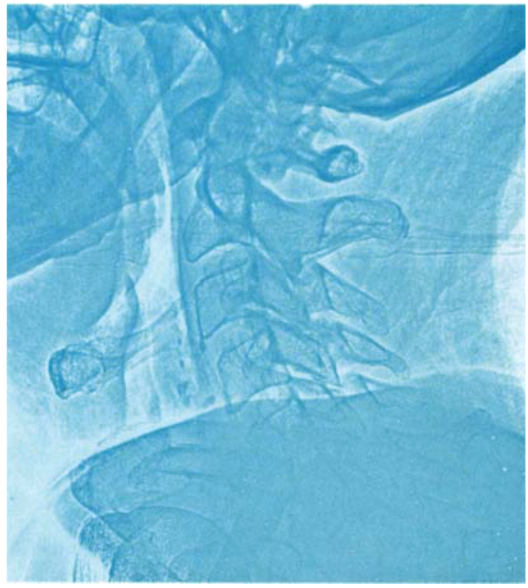

Fig. 5

Fig. 4. Xerographic control in a patient (Hodgkin's disease) treated with the mantle technique and a 6 MV accelerator. Part of the xerogram is covered with a one mm thick tin filter (arrows). Upper part of lead shield visible at bottom of figure.

Fig. 5. Xerogram at 120 kV for treatment planning.

In order to improve the image quality attempts were made to employ electron filters. It is well known that filter material of an atomic number between 30 and 50 reduces the forward directed electron scatter. Brass (Z=29) and tin (Z=50) have been recommended (SAYLOR & QUILLIN 1971, KHAN et coll. 1973, NILSSON & LIDBERG 1974). Tin of 1 to 2 mm thickness reduces the forward scattered electrons generated from 6 MV roentgen radiation interacting with low Z material by up to 30 per cent. A tin screen of this thickness between the patient and the cassette improved in general the xerograms. The efficiency of a tin screen for the filtration of scattered electrons is illustrated in Fig. 4, where part of the xerogram is covered by tin. If the radiation receiving side of the cassette could be made of tin instead of the present plastic material the result may be expected to be improved. The scattered electrons will normally produce a large number of charge-carrier pairs along their tracks in the selenium layer.

The aluminium base for the selenium layer is far from ideal from the point of view of minimizing the disturbing electron scatter. It would be advantageous if the manufacturer could provide plates with a metal base of an atomic number between 30 and 50.

The treatment planning usually includes determination of the size and location of the tumour, which, by FARMER et coll. (1962), was performed by the use of xeroradiography and a superficial, water cooled therapy tube with a small focal spot. The exposure factors were 120 to 140 kV and exposure times between 5 and 100 seconds. In the present investigation, diagnostic tubes and short exposure times were used. The best results were obtained at a tube potential of 120 kV. This potential was kept regardless of the type of examination with variation of the mAs value. The xerograms have a larger range of contrast as compared with conventional films. Thus a better soft tissue information is obtained, which in many cases gives an improved conception of the extension of the tumour. This is illustrated in Fig. 5 where the xerogram gives details both in the cervical spine and in the surrounding soft tissues. In the diagnostic energy range xeroradiography still requires a five to ten times higher dose than conventional radiography. Due to the fact that xeroradiography for the present purpose gives more information than conventional radiography, and since the exposed area will be irradiated for therapeutic purposes later on, the higher radiation exposures are not a contraindication.

Conclusions

Xeroradiography in radiation therapy offers at present the following advantages: (1) The cassettes are easier to handle than those provided with lead screens and industrial film. (2) The information obtained from direct field controls with high energy photon radiation is better as compared with other radiographic techniques. (3) The images may be analysed without viewing cabinets. (4) The preparatory examinations performed with xeroradiography give views with a large range of contrast and better information on soft tissue.

The method has the following disadvantages: (1) The cassettes are too soft, so that pressure marks easily occur if the patient rests on the cassette. (2) Aluminium as the base for the selenium layer and the plastic material in the cassette give an unnecessarily high image-destroying contribution of scattered electrons. (3) Only one size (24 cm × 34.5 cm) is available. (4) The costs are higher in comparison with conventional radiography. Due to the leasing system for the equipment the costs are higher particularly at a low work load.

SUMMARY

The xerographic technique has been introduced at Radiumhemmet for direct field control in therapy with high energy photon radiation (^{60}Co-unit, 6 MV linear accelerator and 42 MeV betatron). The xerograms are of a sufficiently good quality for this purpose. The advantages and disadvantages connected with the xerographic facilities at present available are discussed.

ZUSAMMENFASSUNG

Die xerographische Technik zur direkten Feldkontrolle bei der Therapie mit hochenergetischer Photonbestrahlung (^{60}Co-Gerät, 6 MV Linearbeschleuniger, 42 MeV Betatron) wurde im Radiumhemmet eingeführt. Die Xerogramme sind von genügend guter Qualität für diesen Zweck. Die Vor- und Nachteile im Zusammenhang mit der xerographischen Ausrüstung werden diskutiert.

RÉSUMÉ

La technique xérographique a été introduite au Radiumhemmet pour le contrôle direct des champs dans le traitement par le rayonnement de photons de haute énergie (^{60}Co, accélérateur linéaire de 6 MV, bétatron de 42 MeV). Les xérographies ont une qualité assez bonne pour ce contrôle. Les auteurs examinent les avantages et les inconvénients qui sont en rapport avec le matériel xérographique actuel.

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