PORTAL FILM CHARTS FOR A 6 MV LINEAR ACCELERATOR

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ABSTRACT – Localization errors frequently arise in the portal film technique due to over- or underdevelop films, for high energy radiotherapy machines. To guarantee the accuracy and reproducibility of the localization film technique portal film charts were introduced into the routine planning for the Mevatron 6MV linear accelerator of the Beilinson Radiotherapy Dept. Maintaining reproducible film processor conditions, two films were used: medical X-ray film Curix RPI AGFA and localization film X-OMAT TL Kodak, combined with front and rear copper screens of 0.5 mm thickness each. The sensitometric curves for each film-screen combination were obtained (optical density as function of cassette dose). The least square fitted O.D. curve was used to obtain the cassette dose which produces an O.D. of 1.6. A theoretical equation for the calculation of the dose at the cassette positions, beyond a water phantom, as function of field size, SSD, patient thickness and patient to cassette separation, was experimentally checked with a 0.6 cc Farmer ionization chamber coupled to a 2570 Farmer dosimeter. As a result portal film charts (expressed in MU) were constructed as a function of FS, air-gap and patient-thichness, and the best partition dose for the "double-exposure" technique was also established. The patient dose in the double exposure technique was compared to that delivered in diagnostic radiology procedures.

INTRODUCTION

The portal film technique plays and important role in the patient set-up for radiotherapy treatment, due to the frequent localization errors arising as a result of incorrect positioning or incorrect machine parameters. Althrough the portal films obtained with high energy radiotherapy machines suffer from an inherent poor image, as compared to that obtained in conventional radiography, they provide valuable information for the radiotherapist and the technician. In order to obtain high-quality portal films, it is necessary to choose the optimum film exposure. This depends on various parameters such as patient thichness, patient-

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film gap, field size, SSD, etc. It is necessary to generate tables with these parameters, which are called portal film charts. For each set of parameters the optimum dose in cGys at the film localization is measured.

The present work describes an analytical method to construct these charts for 6 MV linear accelerator, as function of the patient thickness, field size, SSD and air-gap. The selection of the best film-screen combination was greatly simplified by adopting the combinations used in industrial MV radiography for years. Also, a method to avoid the influence of the processor parameters on the film optical density is suggested. Both medical and localization films were used. The patient dose in the double-exposure technique was compared to that delivered in diagnostic radiology procedures in order to assess the possible radiation stochastic effects.

A. THEORY

The analytical method is based on the formalism developed by Khan (1984). The dose at the film can be separed, for calculation purposes, into two components. The first component consists of the dose due to photons from the primary beam and photons scattered from the collimators. The second component derives from photons scattered from the patient. The primary dose at the film position is given by:

$$D_{pr} = D_{max}\,(SSD,F) \times \left(\frac{SSD + to}{SSD + to + d + g}\right)^{2} \times TMR\,(O,d) \qquad (1)$$

Where:
SSD-source-to-skin-distance
F - side of equivalent square field, defined at the maximum build-up depth
D_{max} (SSD,F) - absorbed dose at the maximum build-up depth in cGy/MU
t_0 - depth of maximum build-up
d - patient thickness
g - air-gap between the patient's exit and the film position
TMR (O,d) - tissue-maximum ratio for OxO field and depth "d" in water.

The scattered dose is given by:

$$D_{scatt} = [TMR\,(F',d) - TMR\,(O,)d]\; D_{pr} \times \left(\frac{SSD + d}{SSD + d + g}\right)^{2} \qquad (2)$$

where:
TMR (F',d) - tissue-maximum ratio for a field size F'xF' and a depth "d"
F' - side of equivalent square field, defined at a distance (SSD + d) from the focus
The calculated total dose at the film is then obtained by summing up equations (1) and (2):

$$D_{FC} = D_{pr}(1+[TMR(F',d) - TMR(O,D)])\left(\frac{SSD + d}{SSD + d+g}\right)^2 \qquad (3)$$

With these equations, Tables 2 and 3 were constructed, giving portal film charts for two types of films.

B. EXPERIMENTAL

Two types of films were used: CURIX RPI medical film (AGFA) and X-OMAT TL localization film (KODAK).

The selection of the metal intensifying screens was based on the criteria of Domanus (1973): "For 5-10 MeV X-rays lead is not the best screen material. For the best radiographs the front screen should be either copper or tungsten 0.5 mm thick. Any back screen causes a slight deterioration in the image, but if a back screen is essential because of backscatter problems, it should be copper or tungsten of 0.5 mm minimum thickness". In our case we used front and rear screens of 0.5 mm thickness.

The range of optical densities of 1.3 to 1.8 is onsidered to give the best accepted portal film images, (AAPM (1984), Drocge (1985)) and an optical density of 1.6 was selected for comparison and calculation purposes.

The dose at the film location was measured with a Farmer Dosimeter model 2570 (Nuclear Enterprises), a 0.6 cc Farmer ionization chamber and a suitable build-up cap, in air. The film readings were performed with a Victoreen Digital Densitometer Model 07-424. Extensive measurements were performed with a water phantom and different imaging geometries, with the ion chamber and build-up cap attached to the position of the film cassette.

RESULTS AND DISCUSSION

Sensitometric curves

The characteristic curves for both films, with front and rear screens, are shown in Fig.1. The solid lines represent the best fitted curves obtained using a least square fitting procedure. The equations found were:

O.D. = 2.612 (1-exp[-0.556 D]) for the Curix RPI film (4)

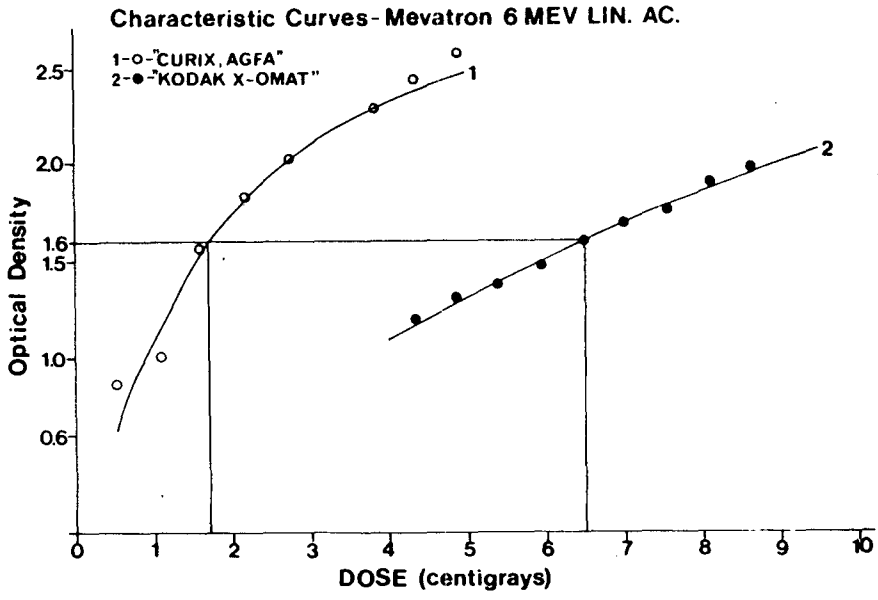

Figure 1. Characteristics curves for the 0.5 mmmCu front and rear screen combinations used.

O.D. = 3.502 (1-exp[-0.0941 D]) for the X-OMAT TL film (5)

Where:

O.D. - optical density, including base and fog
D - dose in the film (cGy)

From the equations (4) and (5) the doses required for an optical density of 1.6 are:

D = 1.7 cGy - CURIX RPL

D = 6.5 cGy - X-OMAT TL

Measurements with water phantom

The calculated doses with to = 1.5 cm and SSD = 100 cm [according to equation (3)] and the measured ones (in cGy/MU) are presented in Table 1. The quoted errors are one standard deviation of the mean measured values. Excellent agreement between the theoretical and experimental results was achieved with a maximum discrepancy of 15%.

Portal Film Charts

The derived portal film charts are presented in Table 2 and 3 for the X-OMAT TL and CURIX RPI films. The dose is expressed in monitor units (MU). Also presented (in parenthesis) are the partition doses for the double exposure technique. It was found that allowing 1/3 of the total dose for the portal radiography and 2/3 to the bigger field provides the best result, confirming the findings of Droege (85). The calculation of the required monitor units according to equation (3) does not pose any problem regarding the differences found for some situations, because in all cases the obtained optical densities fall in the recommended range 1.3 to 1.8.

Processing considerations

Because processing conditions have a strong effect on the developed density, it is necessary to check the sensitometric curve on a daily basis. In order to avoid this problem, a procedure suggested by Reinstein (1985) was adopted. It is based on the fact if the sensitometric curves are normalized to a reference dose, for example, the dose that produces an O.D. = 1.6 on the film, its parameters remain insensitve to developing changes. Then, by adopting a curve like:

O.D. = A $(1\text{-}e^{BD/D_{1.6}})$, the obtained fitted curves were:

$$O.D. = 2.612\,(1\text{-}\exp[-0.948D/D_{1.6}]) \quad (6)$$

$$O.D. = 3.499\,(1\text{-}\exp[-0.61D/D_{1.6}]) \quad (7)$$

for the CURIX RPI and X-OMAT TL films respectively.

Patient exposure

It is useful to compare the dose received by a patient during localization radiography to that received in a diagnostic radiograph. Firstly, in the double exposure technique some regions which will not be treated, could receive significant radiation doses. Secondly, there is a growing concern about the probable biological damage caused by such procedures.

Because the maximum dose is at 1.5 cm depth the 6MV linear accelerator, and in diagnostic radiology the skin exposure is taken as the comparative parameter for radiation protection purposes, it was decided to calculate the integral dose (kg.cGy) for each case. By applying the Mayneord formula for an antero-posterior distance of 20 cm, a field size of 30x30 cm^2, and SSD = 100 cm, integral doses of 155 kg.cGy and 41 kg.cGy for the X_OMAT TL and CURIX RPI films, respectively, were obtained. In a diagnostic examination of the pelvis, the skin dose is of the order of 2 cGy, Donagi (1977), and by the same formula, the obtained integral dose will be 11 kg.cGy. Therefore, one plevis portal film radiography is equivalent to 14 and 4 diagnostic radiographs, respectively, with the X-OMAT TL and CURIX RPI film.

CONCLUSIONS

A method for generating portal film charts for a 6MV linear accelerator was developed, based on known principles of industrial MV radiography and in the work of Droege (85). With the help of the analytical equations obtained for slow and fast films, it is possible to build charts for use in the isocentric technique, for different X-ray energies and for CO-60 machines. Finally, by the use of a normalized sensitometric curve, it is possible to avoid the strong dependence of the optical density to the processing conditions.

BIBLIOGRAPHY

AAPM Report No. 13. (1984) "Physical Aspects of Quality Assurance in Radiation Therapy" - May.

Domanus, J. (1973) "Industrial Radiography and Related NDT problems". Report No. B. 307 (173) - Danish Atomic Energy Commission.

Donagi, A., Leser, Y., Nave, M. and Lichter, A. (1977) Proc. of IV Congress of Int. Rad. Prot. Assoc. - Paris - April, pp. 1087-1089.

Droege, R.J. and Stefanakos, T.K. (1985) Int. J. Radiation Oncology Biol. Phys., Vol.11, pp. 2027-2031.

ICRP Publ. 33. "Protection Against Ionizing Radiation from External Sources Used in Medicine" Pergamon Press, 1982.

Khan, F.M. (1985) "The Physics of Radiation Therapy" - p. 182, Williams & Wilkins, 1984.

Reinstein, L.C. Personal Communication. Nov. 1985.