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IMPROVED PORTAL FILM IMAGE QUALITY IN RADIATION THERAPY WITH HIGH ENERGY PHOTONS

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Abstract

Various metal screen-film combinations have been investigated in order to determine the best radiographic image. The quality of these different combinations has been evaluated by measuring the scattered to primary film dose ratio S/P. The S/P ratio increases with increasing atomic number of the front screen for 4 MV x-rays but shows no significant difference for 8 MV x-rays. For rear screens the S/P ratio is slightly increased for higher atomic numbers. A metal with an atomic number around 26–29 should be an optimal metal screen regarding quality aspects. A cassette of stainless steel has, in clinical use for portal and/or verification films, given very good images.

Key words: Radiotherapy, megavoltage, portal films, verification films, cassette, image quality.

Portal films or verification films, used in direct conjunction with the treatment, are important tools in obtaining good precision in radiation treatment and are also useful for documentation. With portal films differences between the simulator alignment and the alignment at the therapy unit can also be detected.

Portal films, using a high contrast industrial film with a gamma value of 6.5 placed in a cassette between two polished lead screens each 2 mm thick, was introduced clinically at Radiumhemmet in 1970 (1). A similar technique has been used at many other radiotherapy centers (2, 3). This combination of film and screens gives a relatively good contrast between soft tissue and bone, although the difference in attenuation is small at high energies. However, the use of an industrial film has caused a practical problem as, owing to its longer developing time, it cannot be processed in the same way as the ordinary diagnostic films. The cassettes containing lead screens were also too heavy for practical work. In order to overcome these difficulties, experiments were commenced with different light-weight metal and fluorescent screens in combination with an ordinary diagnostic film which could be processed in the automatic developer available in the radiotherapy department.

Background

Due to the rapid decrease of the photoelectric cross section with increasing energy, and high energy x-ray beams used for radiation therapy give less radiographic contrast than the low energies used in x-ray diagnostics. High energy photons interact mainly through incoherent scattering and pair production. The linear attenuation coefficient for incoherent scattering is proportional to the electron density in the object, which approximately corresponds to the density of the material. The difference in density for various organs is small, hence the difference in attenuation coefficient and object contrast will be low. An exception is a gas-filled volume, which has low density. In addition, secondary photons, compton electrons and electrons from pair production contribute to a deteriorated image. Image quality (film contrast) can be improved by decreasing the amount of scattered radiation which reaches the film. In order to evaluate the portal film in an appropriate manner, high radiographic contrast is essential.

When a film is exposed behind an object, the various thicknesses in the object will cause differences in transmission of the radiation and a varying optical density difference ΔD is obtained on the film.

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Droege & Bjärngard (4) showed that

$$\Delta D = \gamma \log\left(1 + \frac{\Delta P}{P}\frac{1}{1 + S/P}\right) \qquad \text{(Eq. 1)}$$

where P = absorbed dose in the film due to primary photons,
S = absorbed dose in the film due to secondary photons,
γ = gamma value of the film,
ΔP = the difference in the absorbed dose in the film due to primary photons behind and beside the contrasting object.

Equation (1) indicates that the radiographic contrast (ΔD) can be increased by decreasing the relative amount of scattered radiation, increasing the attenuation differences, and by increasing the gamma value of the film. The object contrast is for ionizing radiation (metal screens) given by the logarithm of the ratio of absorbed dose in the film behind and just beside the contrasting object, γ is the slope of the blackening, H&D, curve and the radiographic contrast is the product of these two factors. The fraction of x-ray photons interacting in a thin emulsion is generally very low. The poor absorption implies that the speed of the film is also low. In radiography the speed is often increased by a metal foil and/or a phosphorus screen in contact with the emulsion during the irradiation. A greater proportion of the incident photons is then absorbed and produces more electrons or light resulting in a higher system sensitivity.

According to Droege & Bjärngard (4) the S/P ratio between the absorbed doses in the film due to scattered and primary photons is for Co-60 gamma radiation and 4 MV x-rays almost constant if the screen is thick enough to stop irrelevant electrons and minimize the influence of scattered photons. For 8 MV x-rays the S/P ratio is virtually independent of screen thickness and material. McDonnel et al. (5) indicate that nothing is gained by increasing the thickness of the rear screen beyond 0.15 g/cm^2. Droege & Bjärngard state that rear screens do not improve contrast. A low atomic number rear screen may be used to eliminate artifacts from back-scattered radiation.

Material and Methods

Theoretically speaking Eq. 1, the radiographic contrast should increase with decreasing scattered radiation. In order to simulate and measure the relative amount of scattered radiation (S/P ratio) contributing to the film absorbed dose a 10 cm high lead block with an area of 1.0 × 2.5 cm^2 was placed upon a 15 cm thick polystyrene phantom (Fig. 1). The film densities have been converted into film absorbed doses using H&D curve before calculating the S/P ratio.

The lead block was carefully centered so that it attenuated almost all the primary radiation (for 8 MV the transmission is less than 1%) and the photographic density of the film behind the block was due to scattered radiation. In the experiments with 4 and 8 MV x-ray beams the following metal screens with atomic number between 13 and 82 have been used: aluminum, iron, copper, zirconium, molybdenum, tin, tantalum and lead in thicknesses between 0.8 and 1.7 g/cm^2. For practical reasons it was not possible to obtain screen material with the same thickness. The screens were placed in a vacuum cassette containing 0.41 g/cm^2 aluminum and manufactured by Kodak. When measuring the S/P ratio for the front screen as a function of the atomic number a 0.5 mm Cu screen was used behind the film. When measuring the S/P ratio for the rear screen a 1 mm Cu screen was used as front screen.

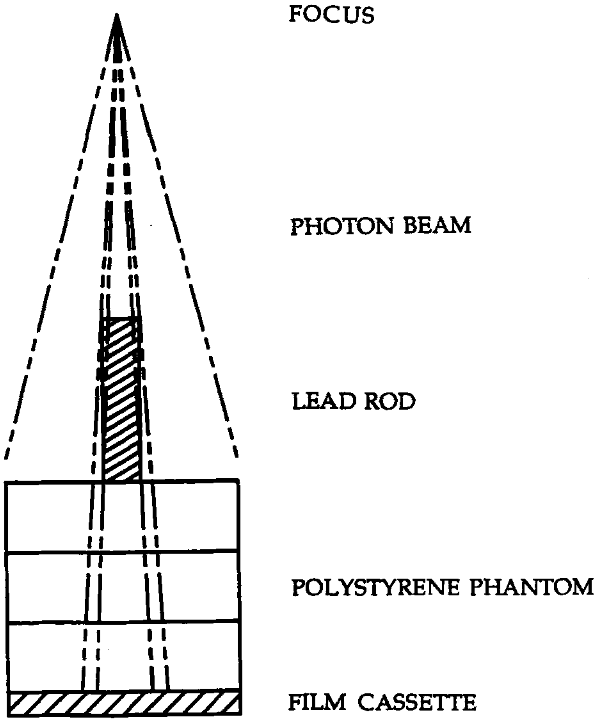

Fig. 1. Experimental set-up for measuring the S/P ratio. Focus phantom distance 100 cm, field size 20 cm × 20 cm. The phantom consists of 15 cm polystyrene. The lead block is 10 cm high with an area of 1.0 cm × 2.5 cm.

To benefit from the higher gamma value for light exposed films compared with x-ray exposed films, a fluorescent screen was in certain cases placed between the film and the metal screens. Focus-phantom distance was always 100 cm and the field size 20 cm × 20 cm. Kodak 'therapy localization film', type RP/TL5 was used, and developed in a Kodak M 8 developer with flood replenishment system (6) which has the advantage of giving reproducibly developed films in a processor that does not process a large volume of films.

For evaluation of the portal film image quality obtained by screens made of stainless steel, copper and lead a test phantom was made (7). The phantom consists of 13 polyvinyl chloride cylinders (PVC) with heights ranging from 5 to 26 mm diameter of 15 mm. A 3 mm wide and 3 mm deep track had been cut along the main axis of the cylinder. Thirteen cylinders were used, three radii being left blank. The cylinders were placed along different radial lines at distance from the center ranging from 4.5 to 6 mm and with the track in one of the following positions respectively: 3, 6, 9 or 12 o'clock. Films were exposed with the test object located 9 cm from the bottom of a 17 cm deep water phantom. Seven observers were asked to decide how many cylinders they could detect and in which position and track was located. The scoring system used to quantify the results of the observers was according to Lutz & Bjärngard (7).

Results

In Figs 2 and 3 are shown the ratios between the absorbed dose in the film due to scattered (S) and primary (P) photons as a function of the atomic number for the front and rear screens. For both front and rear screens the S/P ratio for 4 MV x-rays was constant for low atomic numbers but slightly increased for high atomic numbers. However, for 8 MV x-rays the S/P ratio for front screens showed no significant difference. For rear screens the S/P ratio slightly increased for high atomic numbers.

The results indicate that screens made of metals with atomic numbers 26–29 should be optimal regarding quality aspects. As the metal screen should have a resistant surface (an advantage lacking by copper) we constructed a cassette of stainless steel with a 2 mm thick front screen and 2 mm rear screen (Fig. 4). When handling the cassette it is very important to ensure a close contact between the screens and the film in order to obtain optimal reproducible images. Fig. 5 shows an image of a mantle field obtained by the new cassette placed directly in contact with the patient. Figs 6 and 7 give other examples of good portal film image quality obtained with this cassette. Fig. 8 shows a portal film taken in connection with a total body irradiation.

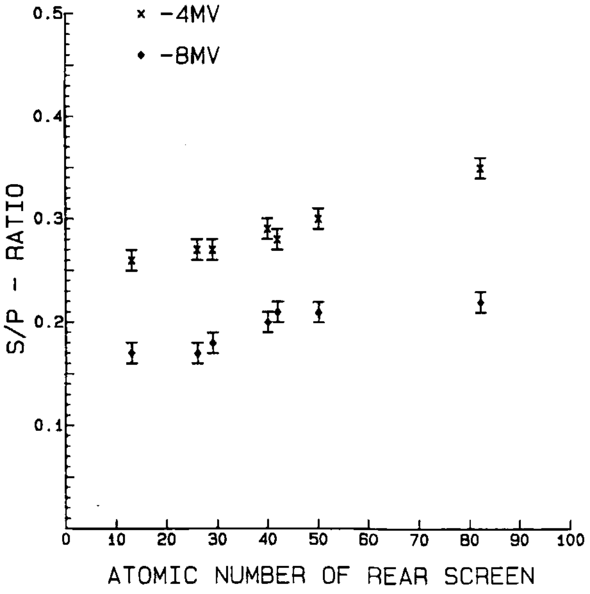

Fig. 3. The S/P ratio for the rear screen (0.5 mm thick) as a function of the atomic number for 4 and 8 MV x-rays. The front screen is 1 mm Cu.

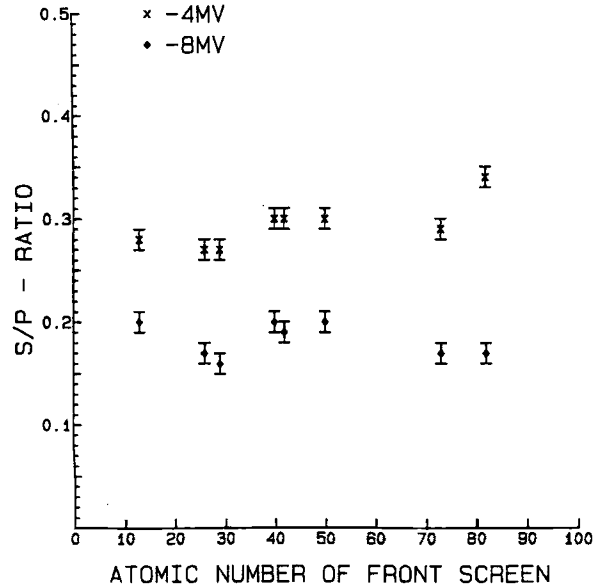

Fig. 2. The S/P ratio for the front screen as a function of the atomic number for 4 and 8 MV x-rays. Behind the film is a 0.5 mm thick Cu-screen.

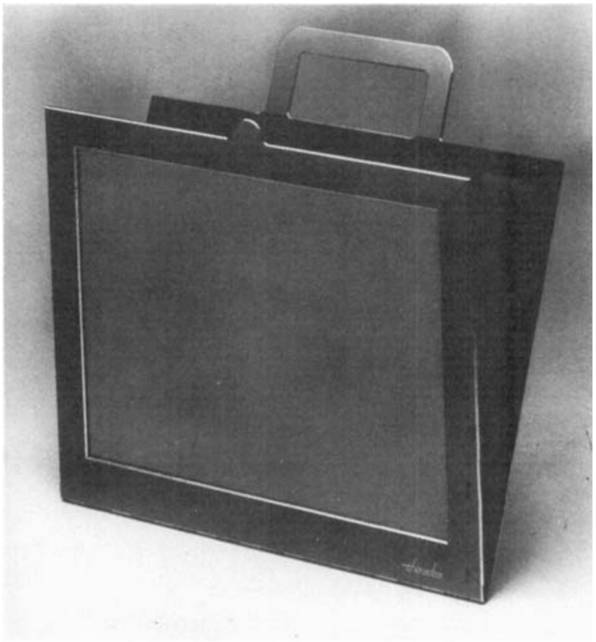

Fig. 4. The stainless steel cassette.

Fig. 5. A portal film of mantle field using 6 MV x-rays.

Fig. 6. A portal film of the pelvis and part of the abdominal region using 8 MV x-rays.

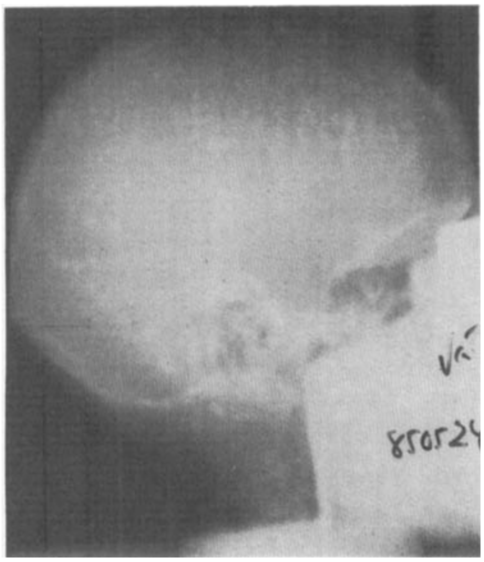

Fig. 7. A portal film of the head using 6 MV x-rays.

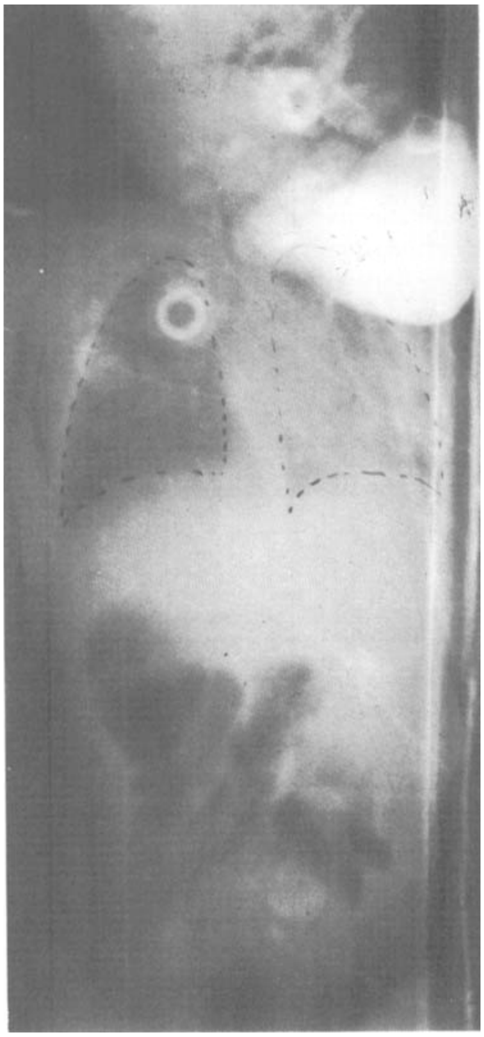

Fig. 8. A portal film used in connection with a total body irradiation using 4 MV x-rays. The film is used to determine the position of the lung shield.

Seven observers (a group composed of diagnostic radiologists, radiotherapists, physicists and technicians) evaluated individually the images obtained with the test phantom and stainless steel, copper and lead. The best radiographic contrast was obtained with stainless steel and copper screens. The resolution was superior with stainless steel and copper screens compared with lead screens.

Discussion

Different metal screen thicknesses (g/cm^2) were used in our experiments for determining the S/P ratio. The thicknesses were not optimal in every case, but nevertheless the curves presented in Figs 2 and 3 show a clear tendency in accordance with results reported by Droege & Bjärngard (4). When using a fluorescent screen in combination with a metal screen the therapy unit monitor setting has to be very low (1–2 units corresponding to an absorbed dose to the film of about 0.01–0.02 Gy). Therefore the film density will vary tremendously. With metal screens the monitor setting has to be increased by a factor of 10 in order to get the same film density. Thus the monitor setting is less critical. However, it is an advantage to use a sensitive fluorescent system when portal films are used in connection with total body irradiation. The SSD at these treatments is normally about 4 m and a fluorescent screen system requires a much lower exposure for the portal film, e.g. for control of the lung shield position (Fig. 8). For 8 MV x-ray beams a system with fluorescent screens is so sensitive that the film will be overexposed already at an absorbed dose in water of a few mGy. Using a less sensitive film can to some extent solve this problem. This kind of film is now available.

For obtaining good quality high energy radiographs an excellent film screen contact is important. To this end, stainless steel is clearly superior to lead and copper. In addition, by using stainless steel screens the cassette weight can be minimized, which is very important for the staff when a lot of portal films are taken.

For control of patient set-up in radiation therapy, portal films represent the simplest and most reliable technique. The described type of cassette has been in clinical use for portal films during the last years and has given images of good quality of the pelvic-, ear-, nose- and cranial regions. The good quality of the images has made it possible to interpret the films both easily and accurately. We are convinced that routine application of this cassette has improved the quality of radiation therapy in our department.

Our goal is to obtain portal films of even better quality by continuing to test our own and other manufacturers' cassettes in combination with different films. In addition, a film processor testing program is to be established in order to get portal films of reproducible and very good quality.

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