Experimental method to obtain scattering contribution in portal dose images

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Abstract

A method for evaluating scattered dose contribution in portal images acquired under clinical conditions (phantom-device distance of 30 cm) is presented. This method is based on radiographic film and ionisation chamber measurements and is valid for homogeneous polystyrene phantoms and square fields of different size. The portal imaging device consisted of a radiographic film placed between slabs of polystyrene under full build-up conditions (1.5 cm for 6 MV beam and 3 cm for 18 MV) and 1 cm of polystyrene backscatter material. First the primary dose image in the portal plane P(i,j) is obtained using a projection algorithm, then the scattered dose image S(i,j) is found by subtracting the primary dose image in the portal plane P(i,j) from the total dose image acquired in the portal plane T(i,j). The ratio S(i,j)/T between the scattered dose distribution and the dose value measured on the beam axis in the portal plane was found to be uniform within the radiation field for all the geometrical configurations of phantoms and fields studied. Under these conditions the mean value of the scatter fraction S/T evaluated within a ROI centred on the beam axis accurately describes the scatter fraction distribution S(i,j)/T within the whole radiation field. S/T ranges from 7.4% to 31.4% in the 6 MV beam and from 8.9% to 30.8% in the 18 MV beam. Finally an analytical method to evaluate the ratio S/T has been developed from the experimental results. It comprises phantom, accelerator head and portal imaging device contributions and depends on field size and phantom thickness.

KEYWORDS: Portal dosimetry, Scattered radiation, EPID, Portal imaging.

1. Introduction

Portal dosimetry is a recently developed technique [1]-[7] whereby the distribution of dose delivered to the patient is computed from the dosimetric information contained in a portal image. There are different approaches to this technique, the one we adopted consists of three stages: extraction of the primary dose distribution from the portal image, backprojection of the primary dose distribution inside the patient, evaluation of the 3-D dose distribution and comparison with the dose distribution computed by the treatment planning system (TPS). Backprojection techniques are based on the inverse square law and on exponential attenuation: as a consequence they have to be applied on the primary dose portal image. In this article we deal only with the first physical problem: the extraction of the primary component from the portal image to perform the backprojection correctly. To obtain an image only with the primary dose contribution, it is necessary to remove the scatter contribution from the portal image. On the portal imaging device, placed generally at some dozen centimetres from the patient, strike not only *Bremsstrahlung* photons generated from the accelerator target (primary radiation), but also photons scattered by the Compton effect in the jaws, in the patient and in the portal imaging device (scattered radiation).

In the last years the problem of scatter contribution in portal images has been investigated by a number of groups who tried to solve it developing techniques based on Monte Carlo simulations and convolution algorithms. Jaffray *et alii* [8] used Monte Carlo calculations and experimental measurements (6 MV photon beam) to characterise how the scatter and primary fluence at the detector plane were influenced by the scattering geometry and the energy spectrum of the incident beam. Swindell *et alii* [9] studied the scatter-to-primary ratio (SPR) for a 6 MV beam, using a Monte Carlo simulation; later they elaborated an analytical model of SPR, eventually they compared the simulation results with those supplied by the model. Essers *et alii* [10] evaluated the phantom scattered radiation contribution comparing the transmission dose rate values with the exit ones, using a 6 MV photon beam. McNutt *et alii* [3] used a convolution/superposition method to predict the dose throughout an extended volume, which includes a phantom and a portal imaging device; this method also enables the determination of the scatter and primary dose contributions (6 and 10 MV photon beams). Hansen *et alii* [11] removed the scatter signal in portal images using a forward convolution method, based on kernel generated by Monte Carlo simulations for a 6 MV beam. Pasma *et alii* [6] presented a method

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to calculate primary and scattered portal image components, using 6, 23 and 25 MV photon beams. Spies *et alii* [12] compared the direct measurements of scatter in portal images at a beam energy of 6 MV with results from a Monte Carlo scatter model; they also developed an analytical model based on simulation results which takes all important interaction processes into account. McCurdy *et alii* [13] developed a pencil beam algorithm for 6 and 24 MV beams which is able to predict the photon scattered fluence in the portal imaging device using homogeneous and inhomogeneous phantoms; the results obtained were compared with a Monte Carlo simulation. Later McCurdy *et alii* [7] presented a two-step algorithm which predicts dose deposition in arbitrary portal image detectors; the algorithm requires patient CT data, source detector distance, and knowledge of the incident beam fluence. Oznard *et alii* [14] validated an analytical approximation for the scatter to primary dose ratio (SPR) on the central axis against Monte Carlo results and experimental measurements for homogeneous and inhomogeneous phantoms. Finally Spies *et alii* [15] presented an iterative algorithm, which is able to extract the input beam profile from a portal image by compensating for the attenuation of the beam and subtracting the amount of scatter from the phantom. This method was tested for a homogeneous water-equivalent slab phantom and scatter was estimated using a superposition method based on precalculated Monte Carlo scatter kernels.

Unlike the studies reported, in this work an analytical method based only on experimental results was developed. This method allows one to evaluate simply and quickly the scatter dose distribution in portal dose images acquired with a portal imaging device. There are three sources of scatter in the portal image: radiation scattered by the collimators and filters in the accelerator head, radiation scattered by the phantom and radiation scattered by the portal imaging device. In this work the sum of these three scatter contributions was studied in presence of homogeneous phantoms that simulate the patient: in particular the scatter dependence on phantom thickness and square field size has been analysed. The analytical method, developed from measurements, describes the portal scattering dependence on phantom thickness and field size, and applies to a phantom-device distance of 30 cm (distance used in clinical routine in our hospital). The method could be applied to any commercial electronic portal imaging device (EPID). Finally the contribution of radiation scattered by the portal imaging device was analysed.

In this article each dose distribution (matrix 256×256) is indicated by a capital letter followed by the pixel co-ordinates (i,j) (e.g., P(i,j) stands for the primary dose distribution); while the dose values measured or evaluated on the beam axis are represented by capital letters (e.g. P stands for the primary dose on the beam axis).

2. Material and Methods

Measurements were performed using the 6 and 18 MV beams of a Varian Clinac 2100C accelerator for a range of field sizes (5×5, 10×10, 15×15 and 20×20 cm^2). Polystyrene phantoms of different thickness were used to simulate the patient: 10, 15 and 20 cm in the 6 MV beam and 10, 20 and 25 cm in the 18 MV beam. All phantoms were placed isocentrically (midplane at 100 cm from the source). This method requires images acquired in the phantom and also at the portal imaging device plane. Since for geometrical reasons it was not possible to acquire images in the phantom using our EPID (Varian Portal Vision v. 3.8), we used radiographic films to acquire both images in the phantom and at the portal imaging device plane. The portal imaging device used consisted of a radiographic film placed between some slabs of polystyrene with full build-up (1.5 cm for 6 MV beam and 3 cm for 18 MV) and a 1 cm polystyrene slab of backscatter material. Since the Varian EPID scattering factor falls between that of a miniphantom and a full phantom, a slab phantom (a thin slab of water-equivalent material with full build-up but without a substantial amount of backscatter material) may be a good option to approximate this EPID [16, 17]. Each measurement consisted of a radiographic film (Kodak X-OmatV) acquisition and of a dose measurement on the beam axis performed with a Farmer-type ionisation chamber (Capintec PR06G) connected to an exposure meter (Capintec mod. 192). For each choice of photon beam, phantom thickness and field size two sets of measurements were executed: the first at depth of maximum dose (d_m) in the phantom (Fig. 1); the second at depth of maximum dose (d_m) in the

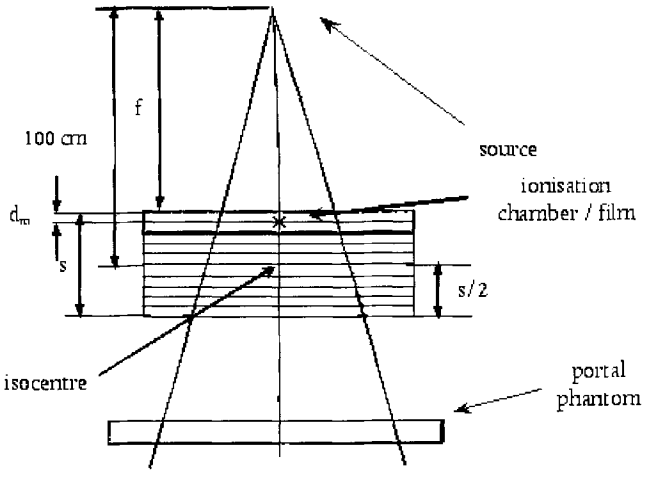

Fig. 1. Setup geometry for measurements at maximum dose depth d_m in the slab phantom.