

SCIENTIFIC NOTE

Prostate dosimetry in an anthropomorphic phantom

P. K. N. Yu¹, T. Cheung¹ and M. J. Butson^{1,2}

¹City University of Hong Kong, Department of Physics and Materials Science, Kowloon Tong, Hong Kong

²Illawarra Cancer Care Centre, Department of Medical Physics, Wollongong, Australia

Abstract

Four field prostate treatments are a standard treatment procedure in radiotherapy. Dose in the prostate and rectum region were calculated for 6MV and 18MV photon beams on an anthropomorphic phantom with a collapsed cone convolution method using a 3-D planning system. Validation has been performed with radiographic film and thermoluminescent dosimeters. Results have shown that the pinnacle planning system has accurately modelled doses delivered to a heterogeneous phantom with calculations and measurements agreeing within $\pm 3\%$ over most areas. When treating clinically, considerations such as the volume of bowel gas should be taken into account when planning. A sample of patient CT scans showed that in the absence of a heterogeneity correction, the error in estimated dose through the rectum could be as high as 8% in the presence of large volumes of rectal gas. Considerations, such as whether the patient undergoes another CT scan, the bowel gas volume ignored or assigned a specific density needs to be taken into account and brought to the attention of the radiation oncologists for accurate treatment.

Key words radiotherapy, prostate, dosimetry

Introduction

Prostate cancer treatment using external beam radiotherapy is widely used [1-3]. Calculations of doses delivered for conventional radiotherapy treatment for prostate cancer were performed on a Pinnacle 3 ADAC 3D treatment planning system which uses a collapsed cone convolution method for dose analysis. This convolution is based on convolution/superposition methods by Mackie et al 1985 [4] where the generated TERMA distributions are calculated first and then convolved with a kernel derived from Monte Carlo calculations. The kernels account for scattered photons and transport of charged particles. A modelled 6MV and 10MV x-ray beam were used which calculated depth dose results within 2% of measured dose for depths up to 30cm in water.

Materials and methods

An Alderson Radiation Therapy (ART) anthropomorphic phantom [5] (Radiology Support Devices Inc. 1904 East Dominguez Street, Long Beach, CA 90810) was studied for dosimetry within the prostate and rectal

regions with a four field technique. CT data for the phantom was obtained on a Siemens Somatom plus 4 spiral CT scanner (125 kV, 2mA) with 2mm slice separations. A Varian 2100C linear accelerator was used to produce 6MV and 10MV x-ray beams. Dosimetry was performed with Harshaw LiF Thermoluminescent dosimeters (TLD's), Kodak X-Omat V radiographic film and Gafchromic, radiochromic film. Lithium fluoride (LiF:Mg:Ti) extruded ribbons were used with a nominal thickness of 0.89mm. The TLD's were held in tissue equivalent cylindrical plugs located at various depths within the phantom. Most positions were within the target volume and rectum region as shown by positions of data points in figures 1 and 2. The TL dosimeters were individually calibrated and grouped into sets in which all TL dosimeters shared the same thermal history. In parallel to the phantom measurement, six TLD's from each set were irradiated to a known dose close to the estimated anthropomorphic dose. The unknown anthropomorphic dose was then calculated using the individual calibration factors of the chips and relating the readings to the readings of the detectors which had received the known dose. With this procedure, using a NE technology Rialto TLD reader with a two step readout cycle of 160°C for 10sec and 300°C for 10sec uncertainties from fading, thermal treatments, and variations of dose response due to radiation quality can be minimized, producing a reproducibility of $\pm 4\%$ (2 standard deviations of the mean) [6]. For TLD measurements, the isocentre of the prostate was calculated and dosed to 100cGy using a four field technique. Kodak X-Omat V radiographic film was also used for dosimetry. For radiographic film measurements, the film was positioned in between two phantom slices which related to the site of the prostate and rectal regions.

Corresponding author: M. Butson, Department of Medical Physics, P.O.Box 1798, Wollongong, N.S.W, 2500, Australia
Fax: 61 2 42265397, Email: butsonm@iahs.nsw.gov.au
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The two lateral fields were planned and irradiated with a 3° angle to the film but parallel to each other to minimise the effects of parallel film exposure [7]. A similar technique was used for the anterior and posterior beams. The phantom was tightly held together using tape and the screw threads provided to eliminate as much air gap as possible. For film measurements, a dose of 50cGy was delivered to the isocentre using a four field technique to produce optical density results in the linear part of the films response curve. Film results were analysed with a VIDAR VXR-12 scanner, which produces images in 4096 (12 Bit) levels of Grey. A scanning resolution of 423 microns was used for analysis. During image capture the film is passed over a fluorescent light and the image is focused on a 5000 element CCD array through a focusing lens. Optical density range is quoted by the manufacturer as 0-2.6 OD. This digitiser has been shown to be an adequate densitometer for radiographic film analysis [8]. Point dose measurements were also performed with radiochromic film [9]. Film pieces, 1cm x 1cm (Gafchromic MD-55-2) in size were positioned within the phantom at specific sites for dose assessment.

Results and discussion

Figure 1 shows the calculated Pinnacle dose as percentage dose of the isocentric dose and measured results in a profile from the anterior to posterior edge of the phantom across the prostate and rectal regions for a 6MV x-ray treatment. 0cm is defined as the isocentre/prostate centre. -8cm is the anterior surface of the phantom and 8cm is the posterior edge of the phantom. The results shown are for a 8cm x 10cm field without blocking. Shown is the target field and rectal region for dosimetry comparison. Errors in TLD and radiochromic film measurements are shown on the figure. Variations in measured dose for film measurements within the target region were $\pm 3\%$ with 5 films and percentage differences were larger outside the treatment volume in areas such as the rectum with variations in measured results reaching 7% from the mean. Results show that within the target volume calculated and measured results are similar within 2%. Dose in the rectal region produces approximately a 5% difference between the film, TLD's and the calculated results. Similar deviations outside the target volume were recorded for other field sizes. The calculated dose to the rectal region for all field sizes was always higher than the measured results but normally within the error limits of measurements performed. Figure 2 shows similar results for a 10MV x-ray beam using a 10cm x 10cm field size and a profile result from the anterior to posterior edge of the phantom. Once again, the dose to the target volume was similar for calculated and measured results. With the use of an anthropomorphic phantom, accurate dosimetry can be obtained for pelvis irradiations. When treating clinically, considerations such as the volume of bowel gas should be taken into account when planning. For a sample of 20

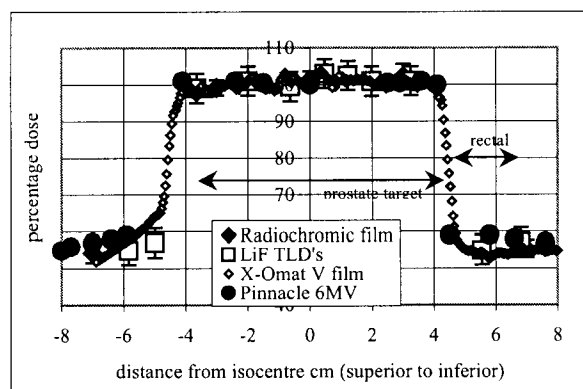


Figure 1. Percentage dose results calculated and measured for a 4 field 6MV x-ray treatment of the prostate region using a 8cm x 10cm field size. -8cm represents the anterior edge of the anthropomorphic phantom and 8cm is the posterior edge.

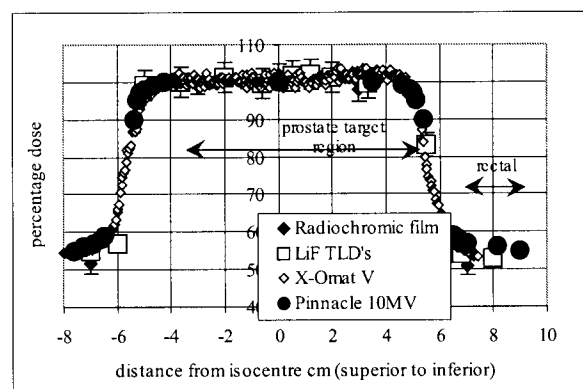


Figure 2. Percentage dose results calculated and measured for a 4 field 10MV x-ray treatment of the prostate region using a 10cm x 10cm field size. -8cm represents the anterior edge of the anthropomorphic phantom and 8cm is the posterior edge.

routine prostate patients at our centre the average percentage of distance in which bowel gas was occupying from the anterior to posterior edge of the patient at the isocentric slice was 5.4%. The smallest amount was 0% and the largest was 22% of the distance. This latter value relates to 5.7cm of the 26cm total distance from the anterior to posterior plane of the patient at the prostate isocentre. Calculating an estimate for dose error based on these numbers produces an 8% variation in rectal dose caused by the presence of bowel gas. Considerations, such as whether the patient undergoes another CT scan, the bowel gas volume ignored or assigned a specific density needs to be taken into account and brought to the attention of the radiation oncologists for accurate treatment.

Conclusion

The pinnacle 3D planning system has calculated doses within 2% in the target volume and 5% outside the target

volume in the pelvic region for small field irradiations using CT information and the collapsed cone convolution algorithm as verified with TLD, radiochromic and radiographic film dosimeters.

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