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Dosimetry

In vivo alanine/electron spin resonance (ESR) dosimetry in radiotherapy of prostate cancer: A feasibility study

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Abstract

***Purpose*: We have developed a device to evaluate the potential of alanine/electron spin resonance (ESR) dosimetry for quality assurance in 3D conformal radiotherapy for prostate cancer. It consists of a rectal balloon carrying eight alanine dosimeter probes and two metal markers to document the exact position of the balloon. We measured the effects of an air-filled rectal balloon on the dose at the rectal wall and compared these results with the applied dose distribution of the treatment planning system.**

***Materials and methods*: During 10 fractions with 2.0 Gy per fraction, the accumulated doses were measured in 3 patients. The results of the ESR measurements were compared to the applied doses.**

***Results*: It was possible to insert the device without clinical complications and without additional rectal discomfort for the patients. The measurements of the dose accumulated at the anterior and the posterior rectal wall agreed with the applied dose within a mean deviation of 1.5% (overestimation of the dose) and 3.5% (underestimation of the dose), respectively. However, clinically significant differences between applied and measured rectal doses were seen in a patient with a hip prosthesis. In this case, the dose at the anterior rectal wall was overestimated by the TPS by about 11% and the dose at the posterior rectal wall was underestimated by approximately 7%.**

***Conclusion*: The method presented in this study is useful for quality control of irradiations in vivo.**
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Keywords: Radiation therapy; Alanine; Electron spin resonance; In vivo; Dosimetry; Prostate cancer

3D conformal radiotherapy for prostate cancer is a curative treatment option. Due to the close anatomical relation between the prostate and the rectum, proctitis as acute and late toxicity of radiotherapy is of major concern. In order to reduce the dose to the posterior wall due to scattered radiation, to enlarge the distance between the prostate and the major parts of the rectum and to fix the prostate gland in the pelvis, several studies tested and recommended the insertion of rectal balloons inflated with air during radiotherapy [1]. These balloons are placed into the rectum before each single fraction.

However, the placement of an air-filled rectal balloon directly behind the target volume raises several questions concerning the dose distribution. Comparable geometric set-ups were studied with film dosimetry in a water phantom [2]. A balloon inflated with 100 cc of air induced a dose reduction at the air-tissue interface of 60%, compared with the same geometry without the air cavity for a 15-MV photon beam and a field size of 2 cm × 2 cm. The dose beyond the interface recovered quickly and the dose reductions due to the air cavity were 50%, 28%, 11% and 1% at 2, 5, 10 and 15 mm, respectively, from the air-tissue interface [2]. Evaluation of the dose distribution using more portal films still showed a dose reduction of about 15% at the air-tissue interface with a rapid dose build-up at 1 and 2 mm (8% and 5% reduction) [2].

In this context, we performed in vivo measurements of the doses at the anterior and the posterior rectal wall during 3D conformal radiotherapy for prostate cancer with rectal balloons inflated with 60 cc of air, and compared the results with the doses calculated by the treatment planning system (TPS). The effectiveness of in vivo dosimetry has been reported before by MOSFET [3]. In vivo dosimetry is useful and feasible for quality assurance [4–6].

We equipped rectal balloons with alanine dosimeter probes. We chose alanine/ESR dosimetry because of the good water equivalence and the small size of its probes and because of the very weak dependence of its response on the radiation quality of therapeutic photon and electron beams (see, for example, [7]). No data or electric cables

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were needed. Its signal stability and dose rate independence are particularly suitable for in vivo measurements. Integrated dose measurements spread over some treatment fractions are possible and increase its accuracy. Alanine/ESR is an accurate dosimetry system from high doses (0.1–100 kGy) to radiotherapy-relevant low dose levels (1–10 Gy) [8]. The dosimeters are read out in a non-destructive manner, different from TLD. The rate of recombination of radiation-induced free radicals (fading) is low. If the probes are stored in a dry environment, the dose information is stable for more than a year. A further advantage for medical use is the non-toxicity of the alanine dosimeter probes. The feasibility of alanine dosimetry in daily clinical practice has been shown before [9].

Materials and methods

Patient treatment plans

Three patients with prostate cancer who received 3D conformal radiotherapy with prostate fixation by means of rectal balloons (60 cc of air) were included in this study. One patient had a hip prosthesis. All patients gave informed consent to quality assurance measurements.

The prescribed dose was 60 Gy, with 2.0 Gy per fraction. The primary target volume (PTV) included the prostate gland and seminal vesicles and contained 1 cm margins for patient positioning errors and internal organ motion.

For treatment planning, all patients received a CT scan in supine position with a rectal balloon that was equipped with metal markers for localisation purposes. On the basis of this data set, four fields were planned with beam angles of 0°, 90°, 180°, and 270°, for all three patients. Each field was treated with 20 MV X-ray beams, weighting 1:1:1:1. The dose distribution was calculated with Eclipse Version 6.5 (Varian Medical Systems, Helsinki, Finland), using the anisotropic analytical algorithm (AAA) with a grid size of 0.5 cm × 0.5 cm × 0.5 cm. The AAA is a 3D pencil beam convolution/superposition algorithm that uses separate Monte Carlo derived modelling for primary photons, scattered extra-focal photons, and electrons scattered from the beam limiting devices [10].

In vivo dosimetry

For in vivo measurements, the rectal balloons were equipped with alanine dosimeter probes (probe size 0.5 cm × 0.5 cm × 0.2 cm). Four alanine probes were placed on one side of the balloon, four on the opposite side (Fig. 1). The probes were shrink-wrapped in 0.18 mm thin polyethylene foil in order to keep them dry and to be able to affix them to the balloon. For reproducible positioning of the balloons, a special device was developed (Fig. 1). It consisted

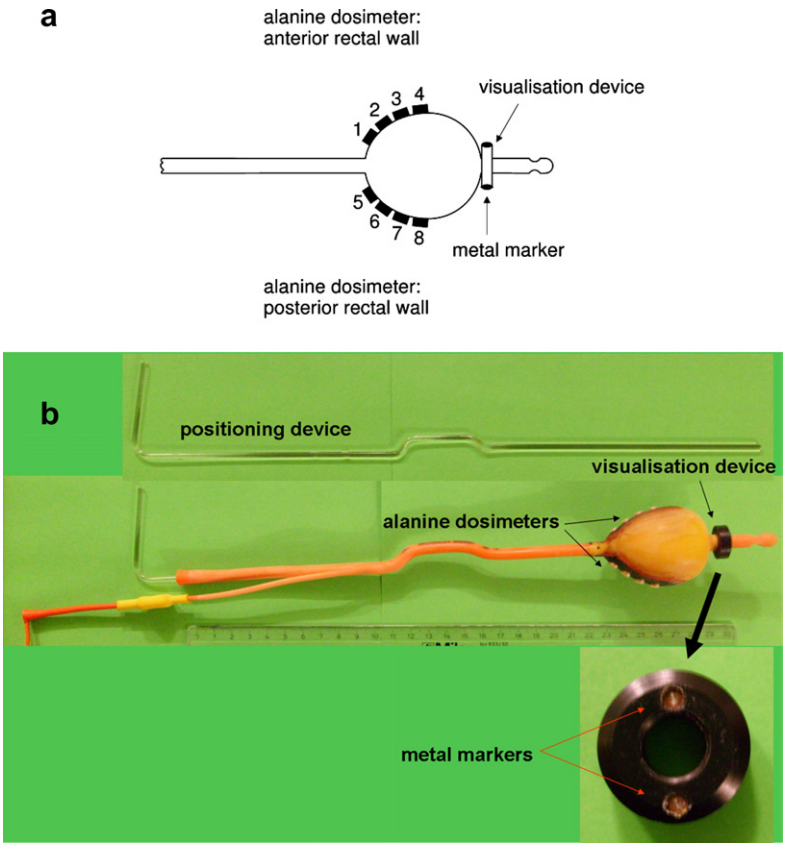

Fig. 1. (a) Sketch of the used rectal balloon equipped with alanine dosimeters. Four alanine dosimeter probes were placed at the anterior rectal wall (1–4) and: four alanine dosimeters at the posterior rectal wall (5–8). Note the visualisation device on top of the balloon consisting of two metal markers. (b) Picture of one rectal balloon equipped with alanine dosimeters. For illustration, the positioning device was inserted. At the top of the rectal balloon, the visualisation device with metal markers was added.