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Displacements of fiducial markers in patients with prostate cancer treated with image guided radiotherapy: A single-institution descriptive study

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ABSTRACT

Aim: To describe daily displacements when using fiducial markers as surrogates for the target volume in patients with prostate cancer treated with IGRT.

Background: The higher grade of conformity achieved with the use of modern radiation technologies in prostate cancer can increase the risk of geographical miss; therefore, an associated protocol of IGRT is recommended.

Materials and methods: A single-institution, retrospective, consecutive study was designed. 128 prostate cancer patients treated with daily on-line IGRT based on 2D kV orthogonal images were included. Daily displacement of the fiducial markers was considered as the difference between the position of the patient when using skin tattoos and the position after being relocated using fiducial markers. Measures of central tendency and dispersion were used to describe fiducial displacements.

Results: The implant itself took a mean time of 15 min. We did not detect any complications derived from the implant. 4296 sets of orthogonal images were identified, 128 sets of images corresponding to treatment initiation were excluded; 91 (2.1%) sets of images were excluded from the analysis after having identified that these images contained extreme outlier values. If IGRT had not been performed 25%, 10% or 5% of the treatments would have had displacements superior to 4, 7 or 9 mm respectively in any axis.

Conclusions: Image guidance is required when using highly conformal techniques; otherwise, at least 10% of daily treatments could have significant displacements. IGRT based on fiducial markers, with 2D kV orthogonal images is a convenient and fast method for performing image guidance.

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1. Background

Prostate cancer is the leading cause of cancer incidence and the third cause of cancer mortality among Colombian males.[1] The role of radiation treatment in prostate cancer has increased in the last decade, since radiotherapy achieves a similar tumor probability control with a better toxicity profile when compared with radical prostatectomy.[2] Nowadays, the use of modern radiation techniques in prostate cancer treatment is widely recognized as a gold standard.[3] IMRT enhances conformity, which allows increasing doses administered to the tumor while diminishing doses administered to organs at risk.[4]

The higher grade of conformity achieved with IMRT can increase the risk of geographical miss[5]; therefore, a protocol of IGRT is recommended when using IMRT or other highly conformal techniques. It is well known that bony structures and tumor target volumes may have significant displacements in relation to the skin tattoos traditionally used for patient setup in conventional treatments; therefore, highly conformal techniques should be performed under new conditions such as IGRT protocols. IGRT applied on daily treatments can translate into a decrease in the margins required for PTV, which will finally turn into a reduced radiation dose for organs at risk and a consequent decreased toxicity.[6]

In traditional IGRT treatments, the patient can be daily aligned with conventional radiographs. This strategy reduces the geometric uncertainties, since it guarantees that bony structures are located in the same position. However, the tumor volume may have significant displacements in relation to the bony structures; hence, daily IGRT based on bony structures is not the ideal solution.[7,8] IGRT based on daily Cone Beam CT (CBCT) warrants that daily tumor anatomy coincides with the anatomy of the treatment plan; yet, it demands longer acquisition times and expertise in image fusion and co-registration. An intermediate alternative is to use fiducial markers inserted on the prostate as a surrogate of the tumor volume.[9] Fiducial markers have been traditionally considered as valid surrogates of a tumor volume, considering that seed migration after implantation is inferior to 1 mm.[10] When using fiducial markers, the image guidance can be performed based both on CBCT or conventional X-rays.[11]

2. Aim

The aim of this study is to describe daily displacements when using three fiducial markers as surrogates for the target volume in patients with prostate cancer treated with IGRT, and to determine the optimal margin required around the CTV based on our own practice.

3. Materials and methods

3.1. Patients

Data of 128 patients with primary prostate cancer treated with on-line IGRT and daily repositioning based on fiducial markers were included. Every patient with prostate cancer and an implanted fiducial marker was included in the study regardless of risk classification, age, use of hormonal therapy, or treatment technique (IMRT or 3D-conformal). Patients with hip replacement or with increased risk of toxicity derived from the implant (patients that had previously developed infections in prostate biopsies, under anticoagulation therapy, with a prosthetic heart valve, previous infectious endocarditis, or heart valve disease) were excluded from the study. Patients with treatments that included pelvic lymph nodes were also excluded from the study.

3.2. Fiducial markers implant

An oral and rectal enema and a clear liquid diet were prescribed the day previous to the insertion of fiducials. Antimicrobial prophylaxis was administered with oral ciprofloxacin, starting before the implant, twice a day for three days. Three cylindrical gold seeds were implanted guided by a transrectal ultrasonography using a biopsy needle and a brachytherapy template. Different kinds of seeds were used along the course of the study. Unstriated seeds 0.78 mm diameter and 5 mm in length were initially used, longer unstriated seeds of 8 mm were used afterwards, and finally, most of the patients were implanted with striated seeds of 0.78 mm diameter and 8 mm in length (we subjectively considered that the definitive position of the seed implant was easier to achieve when using striated seeds). The insertion of the seeds was designed in order to create two triangles: the first one in the antero-posterior projection with its base located on the prostate apex, and the other one on the lateral projection with its base located on the posterior wall of the prostate.

3.3. Simulation and volume delineation

A CT scan was acquired one week after seed implantation. An oral and rectal enema and a clear liquid diet were prescribed the day previous to the planning CT scan. Bladder contrast was used in all patients. Patients were simulated in a supine position with a foam immobilization device placed below the knees and a universal feet support cushion. The pelvic area was scanned at 3 mm intervals from the fourth lumbar vertebra up to the greater trochanter of the femur. The obtained image data sets were imported into the Eclipse® treatment planning system. The Clinical Target Volume was defined accordingly to the recommendations of the European Organization for Research and Treatment of Cancer (EORTC).[12] PTV was defined by using a tridimensional CTV expansion of 8 mm. Organs at risk were delineated according to international guidelines and included the rectum,[13] bladder[14] and femoral heads.

3.4. Radiotherapy treatment planning

IMRT or 3D conformal radiotherapy was prescribed. Dosimetric objectives for the PTV were: V90% $\geq$ 100% (100% of the PTV volume must receive at least 90% of the prescribed dose), V95% $\geq$ 95%, V107% $\leq$ 2%. Dosimetric objectives for bladder and rectum were V40Gy $\leq$ 60% (the volume of the rectum that receives 40 Gy must be inferior to 60%), V60Gy $\leq$ 40%, V70Gy $\leq$ 20%, V75Gy $<$ 15%. Femoral heads were restricted to