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Comparative analysis of image guidance in two institutions for prostate cancer patients

Tomasz Piotrowski[a,c,*], Slav Yartsev[d,f,g], George Rodrigues[e,g,h], Tomasz Bajon[b]

[a] Department of Medical Physics, Greater Poland Cancer Centre, Poznan, Poland
[b] 2nd Radiotherapy Department, Greater Poland Cancer Centre, Poznan, Poland
[c] Department of Electroradiology, University of Medical Sciences, Poznan, Poland
[d] Department of Physics, London Regional Cancer Program, London Health Sciences Centre, London, ON, Canada
[e] Department of Radiation Oncology, London Regional Cancer Program, London Health Sciences Centre, London, ON, Canada
[f] Department of Biophysics, University of Western Ontario, London, ON, Canada
[g] Department of Oncology, University of Western Ontario, London, ON, Canada
[h] Department of Epidemiology and Biostatistics, University of Western Ontario, London, ON, Canada

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ABSTRACT

Aim/Background: The analysis of systematic and random errors obtained from the pooled data on inter-fraction prostate motion during radiation therapy in two institutions.

Materials and methods: Data of 6085 observations for 216 prostate cancer patients treated on tomotherapy units in two institutions of position correction shifts obtained by co-registration of planning and daily CT studies were investigated. Three independent variables: patient position (supine or prone), target (prostate or prostate bed), and imaging mode (normal or coarse) were analyzed. Systematic and random errors were evaluated and used to calculate the margins for different options of referencing based on the position corrections observed with one, three, or five imaging sessions.

Results: Statistical analysis showed that only the difference between normal and coarse modes of imaging was significant, which allowed to merge the supine and prone position sub-groups as well as the prostate and prostate bed patients. In the normal and coarse imaging groups, the margins calculated using systematic and random errors in the medio-lateral and cranio-caudal directions (5.5 mm and 4.5 mm, respectively) were similar, but significantly different (5.3 mm for the normal mode and 7.1 mm for the coarse mode) in the anterio-posterior direction. The reference scheme based on the first three fractions (R3) was found to be the optimal one.

* *Corresponding author at*: Department of Medical Physics, Greater Poland Cancer Centre, Garbary 15 Street, 61-866 Poznan, Poland. Tel.: +48 618850763; fax: +48 618850551.
E-mail addresses: tomasz.piotrowski@me.com (T. Piotrowski), Slav.Yartsev@lhsc.on.ca (S. Yartsev), George.Rodrigues@lhsc.on.ca (G. Rodrigues), bajonski@wp.pl (T. Bajon).

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Conclusions: The R3 reference scheme effectively reduced systematic and random errors. Larger margins in the anterio-posterior direction should be used during prostate treatment on the tomotherapy unit, as coarse imaging mode is chosen in order to reduce imaging time and dose.

1. Background

Prostate cancer patients usually exhibit a considerable target motion, both between treatment fractions, primarily due to changes in the bladder/rectal filling,[1,2] and during the treatment procedure itself caused by peristaltic motion and/or insufficient immobilization.[3–5] With the introduction of pre-treatment imaging (e.g., megavoltage CT (MVCT) on helical tomotherapy (HT)[6,7] or cone-beam CT (CBCT) on conventional linear accelerators[8]), combined with the ability to verify and correct patient position with respect to the plan, the planning target volume (PTV) margin can be safely reduced[9,10] allowing for more effective cancer treatment with higher prescription dose.[11] The benefits of dose escalation have been questioned recently by Schultz and Kagan,[12] but a smaller PTV margin allows for a better sparing of the sensitive organs for the same prescription dose.

Daily image guidance (IG) procedures based on MVCT or CBCT imaging are among the most effective methods of PTV reduction.[13,14] However, the benefits of daily IG should be weighed against the drawbacks of increased workload for staff and in-room time and imaging radiation exposure for patients.[15,16] Several groups investigated a possibility of reducing the number of imaging sessions,[17–25] but relatively small patient cohorts from a single institution included in the studies limited their results.

Pooling data from different cancer centers allow increasing a database for more rigorous statistical analysis, and finally allows to obtain more precise and non-biased results. It is possible if everything is performed in exactly the same way in participating institutions. However, in most cases there are several distinctions and analysis may become quite complicated and uncertain due to a variety of possible statistical approaches with not always clearly defined application requirements. Also, there is always a question of inclusion or rejection of a patient group that intuitively is quite different from the rest. The proposal of the managing and accurate analysis of data pooling was presented in our previous paper.[26]

2. Aim

The aim of this study was to analyze systematic and random errors based on pooled data from two institutions that included inter-fraction observations of prostate motion during radiation therapy. The inter-fraction patient position corrections were used to calculate the PTV margins for different conditions of the IG procedures and three options of referencing based on the position correction data from one, three, and five imaging sessions.

3. Materials and methods

An anonymized database including prospective data of 6085 megavoltage CT (MVCT) studies for 216 patients with prostate cancer was created after receiving institutional ethics approvals.

Tree sources of information to construct the final pooled database included: (1) an unpublished clinical trial database of prostate cancer palliative treatments (11 cases) at the London Regional Cancer Program (LRCP), (2) an updated version of radical treatments clinical trial database (145 cases) at LRCP,[13,20,21] and (3) a clinical trial comparing dose–volume histograms for the supine and prone treatment position of the prostate cancer patients (60 cases) from the Greater Poland Cancer Center (GPCC).[14,27,28]

The criteria for patient inclusion in the database were[26]: (i) radiation treatment on a helical tomotherapy (HT) unit with daily MVCT imaging (Accuray, Madison, WI, USA), (ii) patient compliance with the preparation procedure, (iii) automatic registration of the MVCT studies to the planning kVCT studies using "Bone and Tissue Technique", "Fine Resolution", "Translations Only" options, (iv) availability of data on manual corrections to the automatic matching, and (v) availability of final position correction shifts applied by the radiation therapists in the lateral (x-axis), cranio-caudal (y-axis), and anterio-posterior (z-axis) directions.

The MVCT scanning modes were 6 mm inter-slice distance (coarse) at the LRCP and 4 mm inter-slice distance (normal) at GPCC. Coarse imaging mode was chosen at the LRCP after phantom studies on various sites[29,30] and considerations of both scanning time and imaging dose reductions by 50% compared to the normal mode. No clinical assessments of different MVCT imaging options have been performed till now. All patients were asked to empty their bladder and drink 400 ml of water 1 h before the treatment and try to empty their bowels. The number of treatment fractions was 10 for palliative cases and ranging between 20 and 39 for radical cases at the LRCP, while all patients at the GPCC had 25 fractions of external beam radiotherapy followed by a brachytherapy boost.[31–33] The database included the following information for each patient: (i) the number of treatment fractions; (ii) daily correction shifts in the *x*, *y*, and *z* directions and their manual correction components; (iii) treatment position (supine or prone); (iv) the target for irradiation (prostate or prostate bed), and (v) MVCT imaging mode (normal or coarse).

Based on the collected data, analysis of the shifts obtained by the co-registration of planning kVCT and daily pre-treatment MVCT studies with three different options for referencing was performed. At the GPCC, the patients on the first day of treatment were positioned on the external marks (tattoos) made during planning a kVCT scan; an MVCT scan