Dosimetric study of prostate brachytherapy, using Monte Carlo simulations and voxel phantoms

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Aim

The aim of this work is to develop an accurate computational model that estimates the absorbed dose and the dose-volume histogram (DVH) in the prostate and surrounding organs. The model will use Monte Carlo (MC) simulations and a segmented voxel phantom created from computational tomography (CT) images. The results will be compared with the values obtained from conventional treatment planning softwares.

Introduction

Prostate brachytherapy is a radiotherapy technique used in oncology whereby a set of sealed radioactive seeds are inserted in the cancer tissue in the prostate. In clinical practice, the absorbed dose in the prostate is determined using specific software. This technique allows to maximize the absorbed dose in the tumor and to minimize it in the healthy tissues. The TG43-U1 protocol of the American Association of Physicists in Medicine provides the recommendations for the methodology as well as the physical parameters required for an adequate characterization of the seeds used in prostate brachytherapy [1]. In clinical practice, the dose absorbed by the prostate is determined using treatment planning softwares that take in consideration the parameters mentioned above but not some possible abnormal cases like prostate oedema or changes in the positions of the seeds. In this study, MC simulations in a segmented voxel phantom [2] of a real patient are used to determine the absorbed dose and the DVH in the prostate in comparison with those obtained from a conventional treatment planning procedure. The advantages of using this new method to determine absorbed dose over conventional treatment planning will be discussed.

Materials and Methods

CT images of a 69 years old patient submitted to low-dose rate brachytherapy (LDR) in Centre de Cancérologie Paris Nord using Iodine-125 seeds (Amersham RAPID Strand 6711 NIST 99) were used to produce a voxel phantom. In the actual procedure were implanted 58 seeds in a prostate with 36.8 cm^3. The total activity was 32.132 mCi and the target dose 145 Gy.

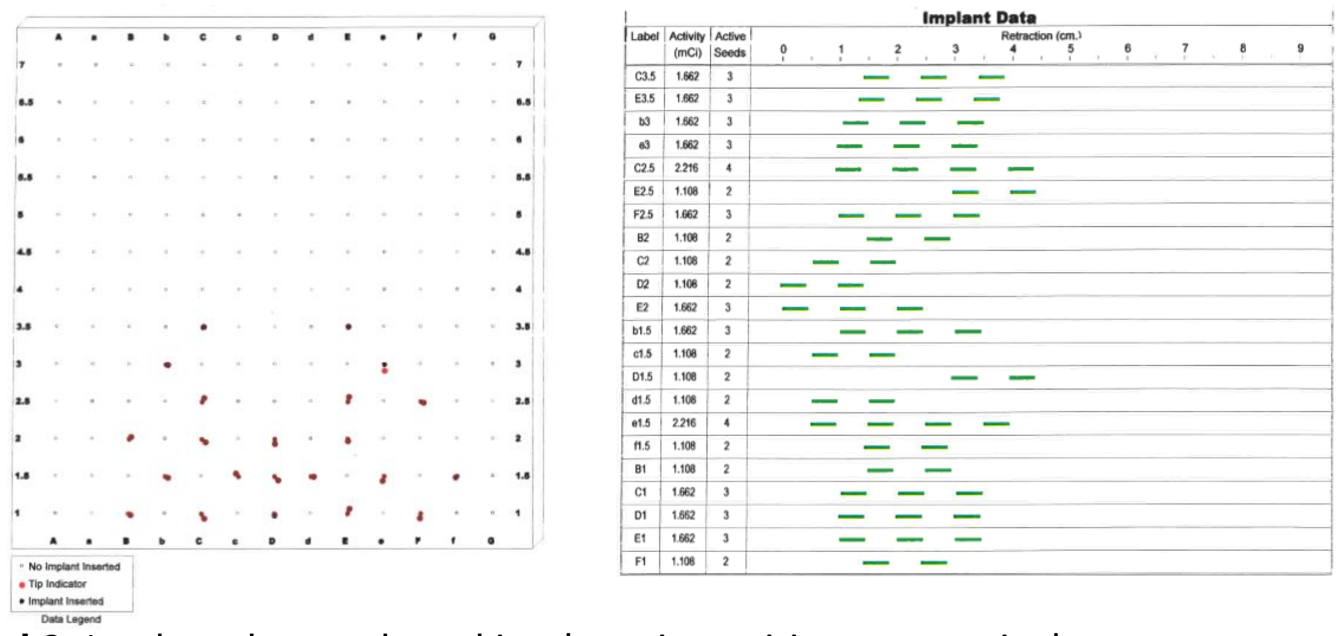

Fig. 1 and 2: Implant data and seed implant tip position, respectively.

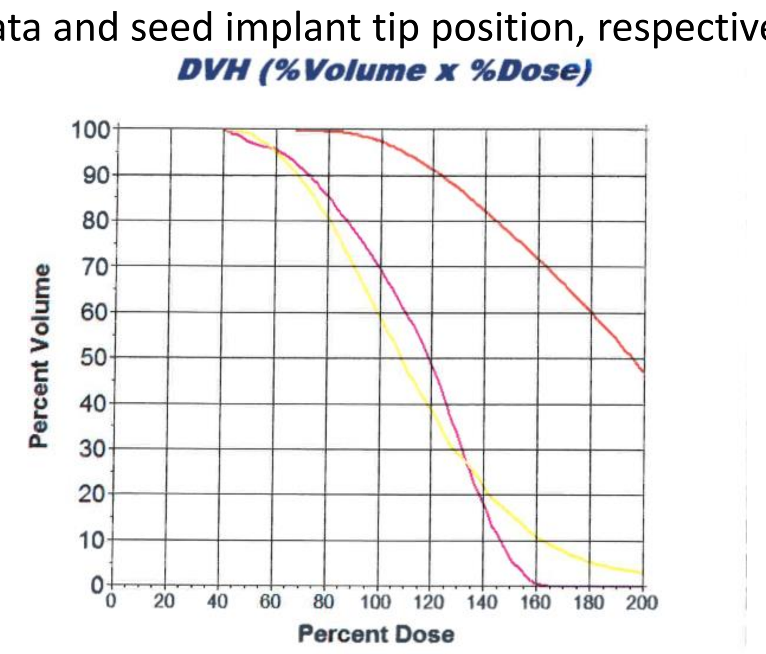

Fig. 3: Graphic of the DVH curves for the prostate (red), urethra (pink) and rectum (yellow) of a real brachytherapy treatment, using the software Interplant.

This was done with the software ImageJ, where regions of interest were isolated and segmented individually. The ImageJ also converts the phantom's images into MCNPX language.

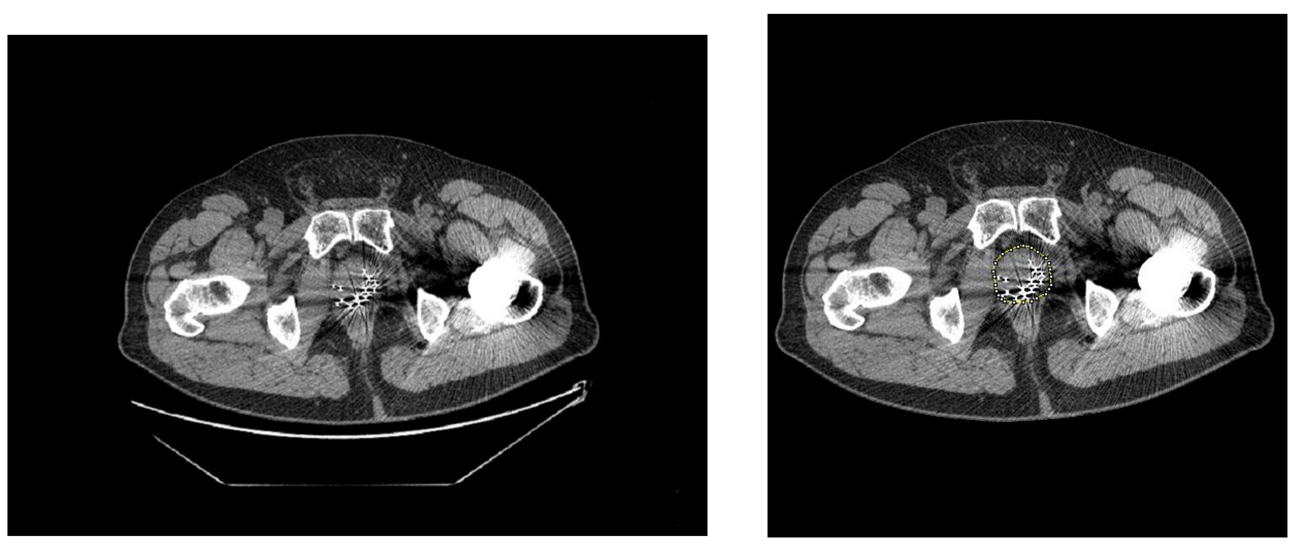

Fig. 4 and 5: (Right) A real CT image from a brachytherapy patiente, using the MicroDicom viewer software. (Left) Example of the segmentation of the prostate to create the phantom, using the ImageJ software.

The MC simulations were performed with MCNPX software. The clinical absorbed dose and DVH were determined using the software Interplant®.

The validation of the method was done placing a real arrangement of seeds into the GOLEM phantom – a standard adult male computational phantom.

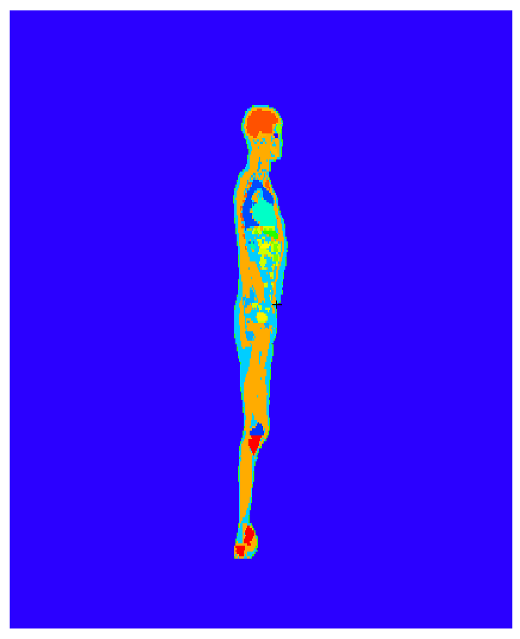

Fig. 6: Phantom GOLEM showned in the MCNPX software.

Results

The seeds were implemented using 3 layers of material as showned in Figure 7. The radioactive material in the inside is a cylinder of silver and in the outside is a layer of titanium. The middle is made of air.

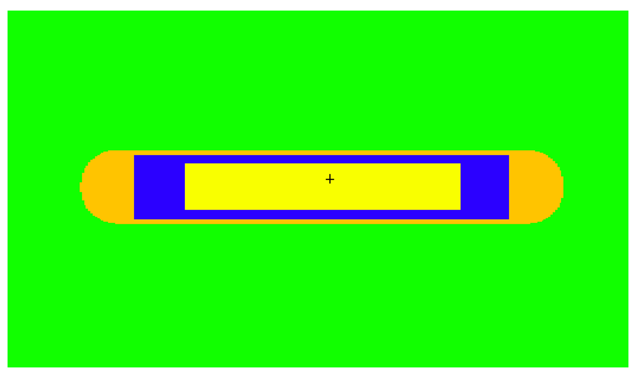

Fig. 7: Computacional seed implemented in MCNP software. In yellow is a 0.3 cm width and 0.025 cm of radius silver cylinder. In orange is a capsule of titanium with 0.45 cm width and approximately 0.045 cm of radius. In blue is the air inside the seed.

Two processes are beeing executed to validate the method. Since the shape and volume of the GOLEM's prostate is differente from the one from the patient, changes were made in order to the seeds fit into the organ. In the first process, the volume of the prostate was increased from 52.1 cm^3 to 96.95 cm^3 and the distance between seeds was fixed to 0.5 cm (in all of the three axes). In the second process, the volume was reduced to 36.8 cm^3 (equal to the pacient's prostate) and the distance between seeds was changed to 0.4 cm in Z axis and 0.3 cm in X and Y axes.

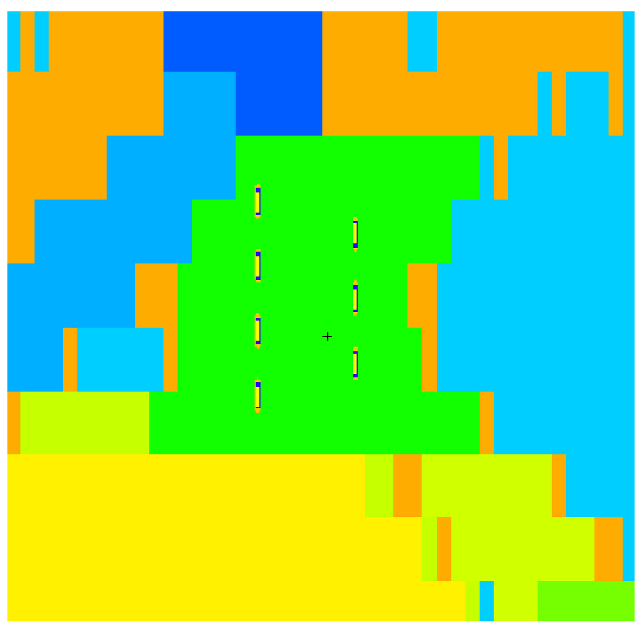

Fig. 8: A cut through the X axis, showing some of the seeds implemented in the GOLEM phantom in MCNP software.

The runs are beeing perform with $6x10^7$ particles to ensure the accuracy of the results, whicth can be adquired for the relevant organs using the F6 tally.

Conclusions

New results in the computational method and in the development of the phantom based on real CT images are expected in a few weeks. The recreation of the DVH curves showned in Fig. 3 is the goal of the process of validation implemented.

The work with the provided data will progress in the next months in order to discuss the differences between the conventional treatment planning used and this method.

References

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