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Assessment of Radiation Therapy Positioning Margins

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Abstract. The objective of this study is to analyze the positioning uncertainties and assess the effect of dose distribution to fully optimize their margins. Using a treatment planning system to recalculate dose after the movement of the isocenter in different directions, the change in the dose distribution based on the number of images acquired in the positioning and size fields is analyzed. It is obtained an increase of the maximum dose up to 6%, 8% and 9% respectively on the lateral, longitudinal and vertical axis. The increased dose is of the order of 4% to 10 setup acquired images. This value decreases with decreasing field size. Any change in the positioning of the patient can have very serious consequences. It is therefore proposed that the positioning is controlled in the first three days and weekly with a maximum of 03 images every time.

Keywords: Radiotherapy positioning margins, Uncertainties, dose distribution.

I. INTRODUCTION

In external beam radiotherapy, because of the splitting and spreading, the treatment is delivered over several days. So, one of the challenges is the reproducibility of the patient's position at each session and for the duration of treatment in the same position as when planning irradiation of the tumor volume in order to spare any hazard of healthy tissue. To approach closer to that goal, adding a safety margin around the tumor (PTV: Planning Target Volume) is included in the positioning uncertainties in treatment planning [1]. Historically, the choice of these margins is empirical. There is no consensus on values, especially since they are potentially very different according to processing technique and repositioning mode used.

Today, even with the scientific and technological progress and although several studies have sought to establish margins models taking into account the different geometrical uncertainties and repositioning of different modes, and if clinical trials are underway or planned, the issue of reduced margins and its magnitude is still not fully resolved [2].

The purpose of this work is firstly check that the PTV margins are sufficient to address the errors related to patient repositioning for head and neck cancer and also analyze the positioning uncertainties and assess their effect on the dose distribution to optimize and fully validate their values and establish a positioning protocol.

II. METHODS

Studies of patients with nasopharyngeal carcinoma patients have been acquired at the University Hospital center -Ibn Badis- Constantine. Clinical practice is performed by means of the linear accelerator Clinac DHX 2300 using the treatment planning system 'Eclipse' (TPS) 10.0.28 Version (Varian Medical Systems) with an Algorithm Anisotropic Analytical (AAA). Processing technique comprises using a thermoplastic mask for immobilization, a PTV of 10 mm, a photon 6MV beam and five fields with

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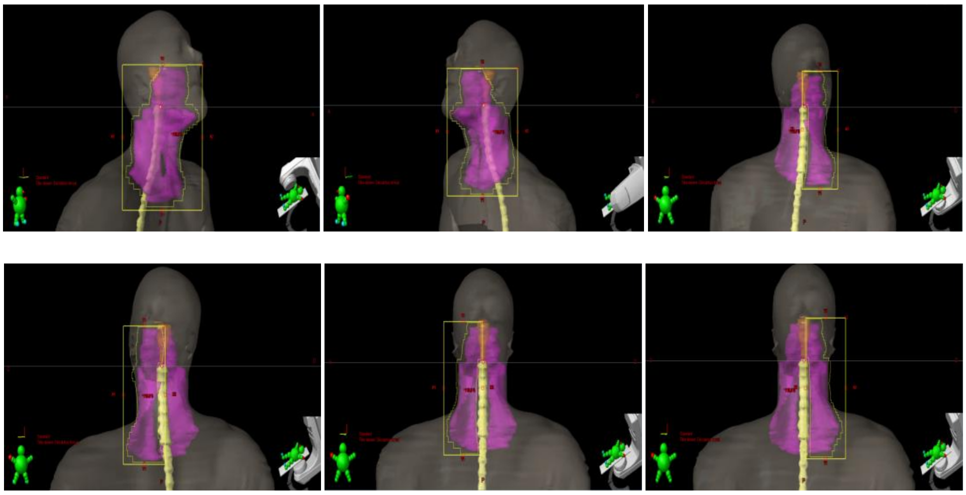
angles 50°, 150°, 180°, 210°, 310°. The plan normalization is made on iso-dose 95% to cover 95% of the volume.



Graph 1. Beam eye view of treatment fields.

II.1. Positioning Control during treatment and check the margins of PTV:

Three points were tattooed on the skin of patients to their positioning in the treatment machine. The quantitative measurement of the shift of iso-center between the Digital Reconstructed Radiograph (DRR) and portal image is performed with benchmarks defined relative to bony structures [3,4].

To compare the two modes by repositioning markers of skin or bone structures, check and confirm that the positioning margins used are sufficient and get an idea about the repositioning interval used in practice, we propose to evaluate the uncertainties geometric quantization based on repositioning mode considered tattoos or bones. For this, the positioning of 03 patients irradiated for nasopharyngeal cancer was monitored at 05 different days before treatment with two orthogonal images 0° and 270°, a single exposure with a 6MV beam and an opening of the fields based on the patient's anatomy.

II.2. Simulation of positioning uncertainties:

Using the TPS to recalculate the dose after-moving of the iso-center treatment in different directions, the analysis of the changes in the dose distribution can give a rough estimate of their effects on the treatment plan and to show the importance of correcting it.

Taking the plans of these patients and apply displacements in different directions (lateral, longitudinal, vertical) from 0 to 1 cm with step of 1 mm, on recalculate the dose and evaluate the maximum dose of the PTV and the organs at risk.

To simulate the movement of patient the iso-center treatment is moved from the treatment machine or in the opposite direction : laterally to the left (X+ axis) and right (the X- axis) to simulate the patient is moved to the right and the left respectively, vertically down (the Y - axis) and up (the Y+ axis) to simulate the patient is shifted up or down respectively and longitudinally towards the feet (the Z- axis) or to the head (the + Z axis) to simulate the patient is shifted either to the head.

The success of a radiotherapy treatment is based on a compromise between the risk of complications and recidivism. Therefore, evaluation of target volumes is not sufficient to judge a treatment plan, it is necessary to guide the dose to organs at risk.

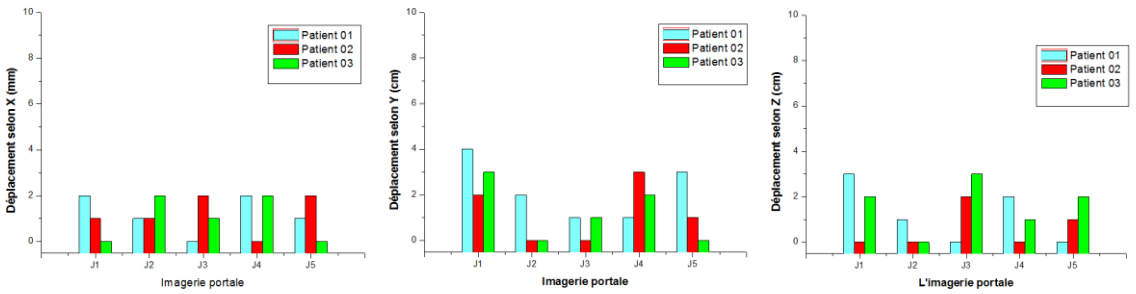
II.3. The dose received during repositioning:

For offsets, patients were relocated and a new control image was made: 1, 2, 3 and 4 times or more, according on the patient. With the imaging portal 1Monitor Unite (UM) is delivered in every picture, so we must study the dose during positioning to evaluate the effect of positioning images on the dose distribution and study the variation of this effect in terms of number images acquired and field size to limit the maximum number of images and to define a positioning protocol. For this, we simulate the positioning fields in the treatment plan and the dose is calculated for the acquisition of these images.

III. RESULTS AND DISCUSSION

III.1. Positioning control during treatment and check the margins of PTV:

The results obtained by quantification of different displacement during repositioning with portal imaging after positioning with lasers, according to three axes: lateral (X), vertical (Y) and longitudinal (Z) are described below:



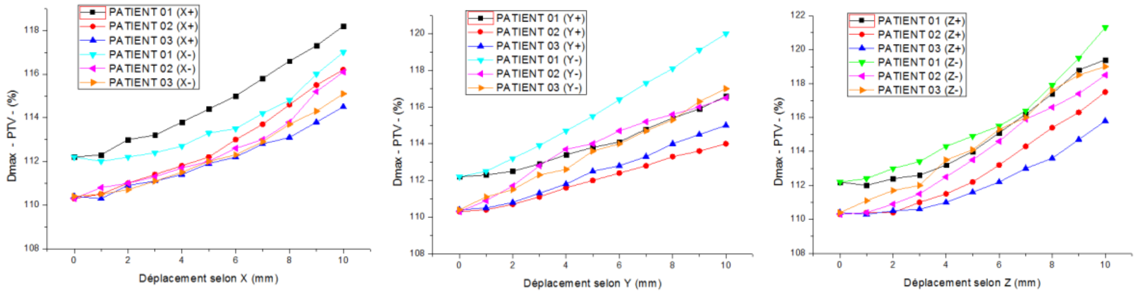
Graph 2. Quantification of displacement in mm of registration in each direction of space.

positioning controls on the three treated nasopharyngeal carcinoma patients and comparing the position with portal imaging and positioning with lasers showed deviations from 0 to 2mm in lateral (left-right movement), 0 to 4mm in vertical (table height) and 0 to 3mm in length (moving head-foot).

Note that there are small movements in all directions of space and the movements are different from one day to another either for the same patient or one patient to another so they are random. These displacements are lower to the positioning margins (10mm), therefore PTV margins used are largely sufficient, so they are acceptable but we can also diminish them.

III.2. Simulation positioning uncertainties:

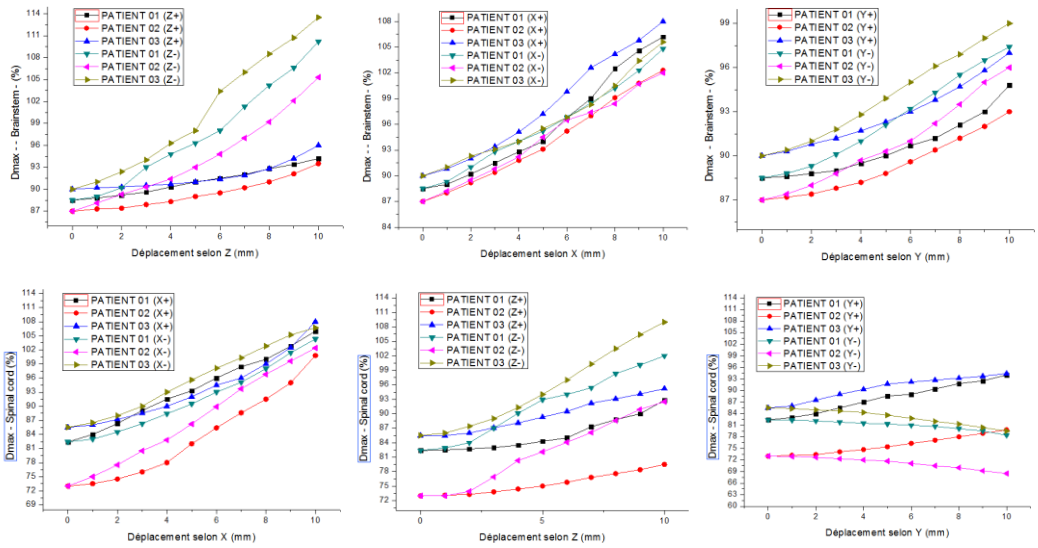
The results obtained after the iso-center displacement and the dose recalculated are shown below:



Graph 3. Representations of the maximum dose based on moving the iso-center lateral (X), longitudinal (Y) and vertical (Z).

These curves represent the variation of the maximum dose in percentage (%) received by the PTV according to the movement of the iso-center (mm) to the three directions (lateral, longitudinal and vertical). The maximum dose increases up to 6%, 8%, and 9% on lateral, vertical and longitudinal displacement respectively.

Two organs are chooses (spinal cord and brainstem) to assess toxicity in the event of a shift in patient positioning. For the previous of nasopharyngeal carcinoma patients with the same plans and the same offsets the maximum dose is be evaluated.



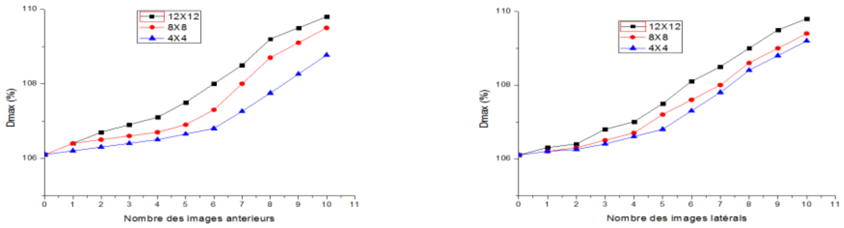
Graph 4: The maximum dose to the spinal cord and the brainstem according to movement of the patient for the three directions (lateral, longitudinal, vertical).

These curves represent the variation of maximum dose (%) received by the spinal cord and the brainstem according to the movement of the iso-center (mm) to the three directions. Any displacement - irrespective of the direction - gives more toxicity to these structures and this toxicity leads to a maximum dose that increases with increasing displacement up to 12Gy and

9Gy on the lateral axis, 6Gy and 4.5Gy on the vertical axis, 10Gy and 6.5Gy on the longitudinal axis, for the spinal cord and brainstem respectively

III.3. The dose received during repositioning:

To analyze the exchange in the dose based on the number of pictures acquired during positioning and size fields, one other plan is simulate with accounting the dose come from the setup images, the results is shown in the graph 5.



Graph 5*:* graphical representations of the maximum dose depending on images acquired during positioning.

It is observed that the dose increases with the number of acquired images of the order of 2.5%, 3.5 % and 4% or 3.0%, 3,5% and 3.8 % for 4x4, 8x8 and 12x12 cm with 10 anterior or 10 lateral images, respectively, and this increase decreases with the size of the reduced field.

IV. SUMMARY AND CONCLUSION:

This study shows a variation of the dose distribution when moving during treatment iso-center: for a given target volume, the increase in the maximum tolerated dose is 6%, 8% and 9% relative to lateral, longitudinal and vertical axes, respectively, with another variation on the organs at risk based on their position in the movement direction.

This study shows that for any movement, we distinguish that there are two risks: the first case under the irradiated tumor and reduces local control. In the second case, the organs at risk may be too irradiated produce an increased risk of complications. So, immobilization and positioning of the patient are critical parameters and any changes in patient positioning can lead to serious consequences on the chances of recovery and increase the risk of complications. Therefore, it is proposed that the positioning has to be controlled in the first three days and then once a week with a maximum of 03 images every time.

In our center, we use a margin of 10mm to the PTV. This study shows that we can optimize up to 4mm depending on the maximum value of the resulting margins. The results of other studies with a thermoplastic mask use 2mm [5-7] or 5 mm [8,9]. However, for maximum safety and because of several conditions (personnel, technique, equipment, etc ...), it is better to use margin of error of ± 7 mm.

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