

## Assessment of the Margin Simulations of Random and Systematic Errors in Radiotherapy

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### Abstract:

**Purpose :** During treatment, the most important errors are setup error and organ motion leading to day-to-day variations. There are many ways to define the margins required for these errors. In this article, an overview of errors is given in radiotherapy and margin recipes, based on physical and biological considerations. Bladder and Rectum motion is treated separately.

**Materials and Methods:** Patients receiving RT for a Pelvis cancer a Linear Accelerator (LA) equipped with a camera-based EPID were considered for inclusion in the study. Only patients receiving RT with anterior-lateral portals were included.. Only patients with at least 8 sets of portal images were included in the data set. A total of 15 patients with bladder cancer treated 3DCRT have met the inclusion criteria on which 186 images and 558-point positions were available for analysis. Rotational errors were not assessed in this study..By using the acquired images the magnitude of the systematic and random error was determined in the vertical, longitudinal and lateral direction.

**Results:** Tumor displacement was found with a variation of 0.2 cm to 0.65 cm (max). In Cases Pelvis patients, the tumor motion was found to be varying widely in all directions .The random errors for vertical, longitudinal and lateral were (2.53), (3.57) and (2.61) mm respectively, and the systematic errors for vertical, longitudinal and lateral were (2.81), (3.37) and (2.85) mm respectively.

**Conclusions:** It is important to know the exact tumor motion to account for IM. Generalized IM increases the probability of not missing target and treating extra normal tissue.

**Keywords** –setup errors; Radiotherapy setup verification; systematic and random errors; Target Volume Assessment

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### I. Introduction

Before treatment planning, a planning computed tomography scan is made. In particular, motion of skin with respect to the internal anatomy limits the reproducibility of this step, introducing a systematic setup error. The second important error source is organ motion. The primary objective of this study was to define an optimal three-dimensional (3D) CTV-PTV margin to the clinical implementation of high-precision conformal techniques for pelvis radiation therapy. The tumor is imaged in an arbitrary position, leading to a systematic organ motion error. The image may also be distorted because of the interference of the scanning process and organ motion. A further systematic error introduced during treatment planning is caused by the delineation process. During treatment, the most important errors are setup error and organ motion leading to day-to-day variations. There are many ways to define the margins required for these errors. In this article, an overview of errors is given in radiotherapy and margin recipes, based on physical and biological considerations. Bladder and Rectum motion is treated separately.

#### 1-Target Volume Assessment

Treatment planning starts right after the therapy decision is made and radiotherapy is chosen as the treatment modality. The first step is to determine the tumor location and its extent. The target volume .

The definition of the target volume and of critical structures is a crucial and complex process in three dimensional conformal radiation therapy. In a planning system, based either on computed topography (CT) or magnetic resonance imaging (MRI), the radiation oncologist is required to outline the target volume to be irradiated, and the organs of risk to be spared, because of possible side effects.

Three-dimensional conformal treatment planning in radiation oncology is based on radiological imaging, CT and MRI. These investigative techniques show the anatomical structures with a high accuracy. Both CT and MRI image tumour tissue by taking advantage of the differences in tissue density (or signal intensity in MRI).

**2-Set-up displacements**

**2.1- Systematic error:** The systematic error describes a constant deviation in the patient setup in a given direction during the entire treatment due to preparation errors that will cause a constant shift in the dose distribution. This is illustrated in Figure 1. The systematic error is usually described and calculated in forms of a patient population and is considered to be composed of errors of target motion, setup, delineation and transfer and summarized according to Equation 1

$$\Sigma^2 = \Sigma^2_{\text{motion}} + \Sigma^2_{\text{set up}} + \Sigma^2_{\text{delineation}} + \Sigma^2_{\text{transfer}} \dots\dots\dots (1)$$

The elements refer to the standard deviation, SD, of the individual errors of target motion and deformation, patient set-up, target delineation and image transfer. The target motion includes variations that occur in the position and shape during treatment that can be caused by bladder filling, weight loss and tumor regression. The set-up error includes all errors that are introduced during preparatory stages of treatment planning. Target delineation refers the errors caused by little knowledge of the actual extent of the CTV margin needed to account for microscopic spread. Image transfer error describes deviations that can arise when transporting images between different systems such as the treatment planning system and the linear accelerator.

**2.2- Random error:** The random errors describe the deviation between treatment fractions that can occur in any direction during the course of treatment and will give rise to a blur in the dose distribution. The random error is defined according to Equation (2).

$$\sigma^2 = \sigma^2_{\text{motion}} + \sigma^2_{\text{set-up}} \dots\dots\dots (2)$$

In the equation the  $\sigma^2_{\text{motion}}$  is the SD of the random target motion and shape and  $\sigma^2_{\text{set-up}}$  is the SD of the random set-up error. For a population of patients the random error is defined as the root mean square of all standard deviations. Random errors occur during the treatment and are therefore considered to be execution errors. Offline protocols cannot correct for random errors and the margin used must take that into account.

**II. Material and methods**

**A -Dosimetric Instrumentation**

- 1) Linear accelerator–Varian model–high energy (dual energies) 6.0 and 15 MV photon beam and multi electron energies (6.0, 9.0, 12, and 15 MeV).
- 2) Treatment planning system used in this work of Eclipse Planning System Dosimetric. It is recommended by the IAEA for high precision electron dosimetry in radiation therapy.
- 3) Farmer Dosimeter model (2570 / 1B (# 1164)) Portal Vision aS500 with an Amorphous Silicon flat panel imager detector- and Phantom Automatic Water (PTW) for relative dosimetric measurements.

In the current study, the mechanical check for VARIAN linear accelerator should be initially obtained to ensure the suitability of the machine to perform the dosimetric measurements. The laser lines compromise the cross wires in the light field area should be checked. The isocentre point for gantry, collimator and couch rotation should be checked to ensure the machine is working properly. Then adjust the solid phantom at 100 cm SSD, and locating the 0.6 IC at the depth of maximum dose for each energy (1.5 cm for 6.0 MV), with zero degree gantry angle, zero degree collimator angle and zero degree couch angle according to IAEA protocol (TRS 398). Measuring pressure and temperature to calculate the factor  $K_T, p$  which estimate the effect of pressure and temperature on measurement .

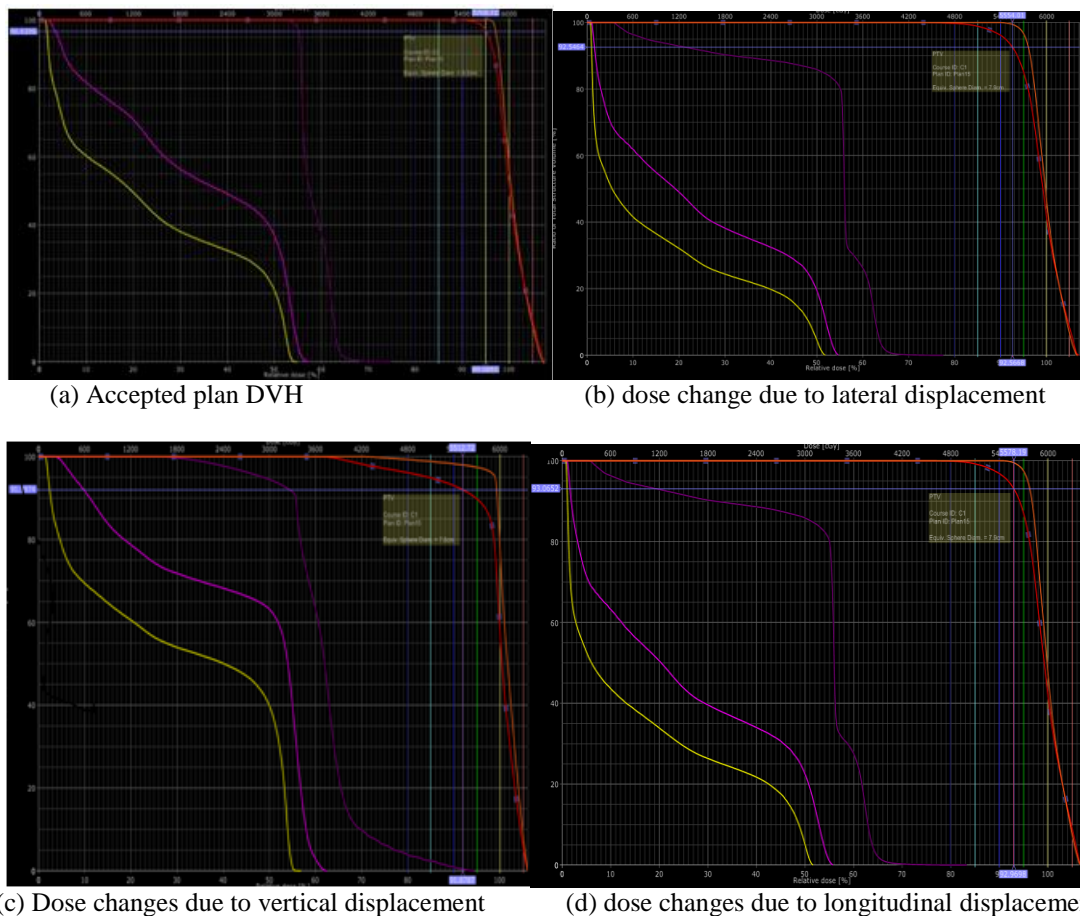
**B-Methods**

Setup and Internal motion can cause large variations in tumor position and these positional uncertainties lead to many random and systematic errors in the execution and planning of treatments. Therefore, an extra margin is added to the clinical target volume (CTV) to account for these errors inherent in the treatment and planning procedures. This final volume is named the planning target volume (PTV). A large PTV greatly limits the effectiveness of treatment as it restricts the prescribed dose and increases the volume healthy tissue that is irradiated. We adjust patient position to reference point which on the lead mark and then aligned the group of fields to the center of PTV then calculate the dose after approving plan for treatment .The plan is sent to the machine and by using simulator for moving patient to center of PTV .After setup patient on (LA) we take (AP&Lateral) portal image and compare with DRR .The portal images system was Portal Vision AS500 with an Amorphous Silicon flat panel imager detector type. The DRRs were generated in the Treatment Planning System (TPS) Varian Eclipse and the portal images were acquired in Varian Portal Vision system. The images were then matched and analyzed in ARIA application. Patients receiving RT for a Pelvis cancer a Linear

Accelerator (LA) equipped with a camera-based EPID were considered for inclusion in the study. Only patients receiving RT with anterior-lateral portals were included. Only patients with at least 8 sets of portal images were included in the data set. A total of 15 patients with bladder cancer treated 3DCRT have met the inclusion criteria on which 186 images and 558-point positions were available for analysis. Rotational errors were not assessed in this study.

### III. Result and Discussion

- The PTV coverage in highly dependent upon the displacement between origin setup and maximum displacement in Lateral direction (negative and position X.Y.Z). this data highly reflects on the quality of outcome of treatment and percentage of recurrences after treatment . Show figure (1.a), (1.b), (1.c) and (1.d).
- Where the figure (1.a) shows that accepted DVH without errors ,in the figure (1.b),(1.c) &(1.d) are shows the changes around thr PTV due to the setup displacement in different directions .



**Fig (1) :DVH Displacements x,y,z(a,b,c,d) – direction and PTV coverage percentage**

-The Inter-fractional setup errors in lateral, longitudinal and vertical direction show figure (2) for all 15 bladder patients' cancer. The figure show Variation for fifteen patients for average of setup displacement in different directions.

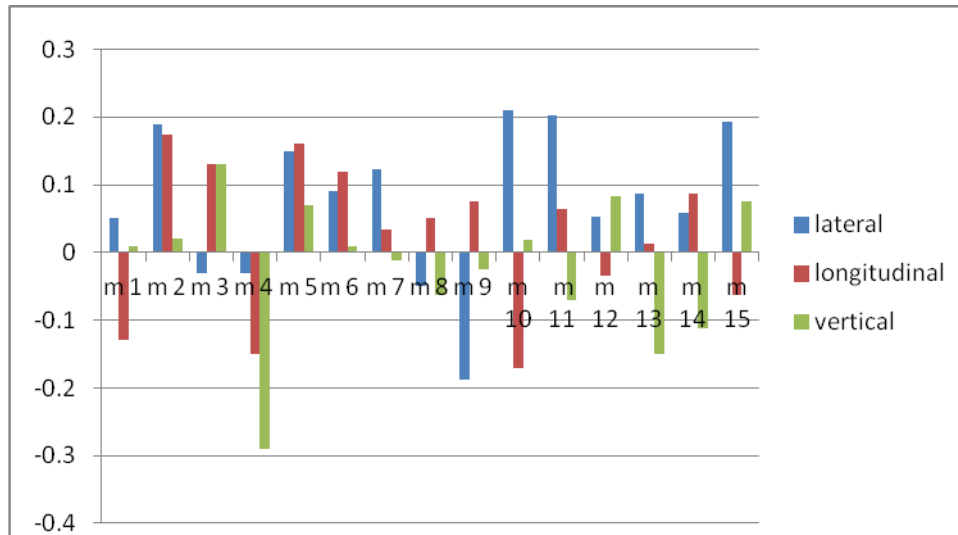


Fig ( 2 ) : Variation for fifteen patients for average of setup displacement in different directions

- The observed tumor motion. Tumor displacement was found with a variation of 0.2 cm to 0.65 cm (max). Show figure (3)

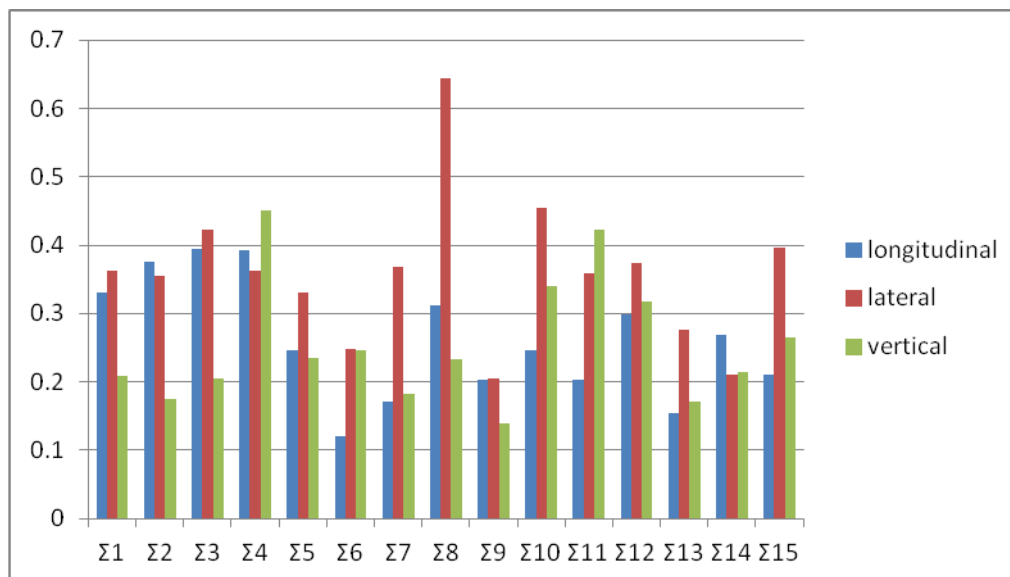


Fig (3): Variation for fifteen patients for systematic errors in different directions .

- The calculated SD of systematic and random errors for bladder cancer along with the study details are shown in Table 1.

Table (1) : Calculated SD of systematic errors and SD of random errors along longitudinal, lateral and vertical directions.

|   | LATERAL mm | LONG mm | VERT mm |
|---|------------|---------|---------|
| Σ | 2.85       | 3.73    | 2.81    |
| σ | 2.61       | 3.57    | 2.53    |

As stated, some of the published margin-generating recipes do not differentiate between random and systematic errors. Caution should be exercised while comparing data from different series as each group has used different model parameters to derive cumulative set-up errors. Different margin generating recipes lead to a different probability of target volume coverage in different population setting depending on the distribution of shifts. It is therefore suggested that before adopting any published margin recipe, factors that can potentially impact upon margins should also be taken into consideration.

The good set-up accuracy comparable with published literature achieved here for conformal radiotherapy for Pelvis tumors is also a reflection of the experience, training, commitment, and time available with radiation therapy staff at an academic radiotherapy unit that treats patients only on approved clinical trials. The 3D mean displacements though comparable with previously published literature, had a wide range at times leading to high individual displacements (>6 mm also). This would be unacceptable for high-precision techniques. Attempts are being made to reduce such errors by incorporating offline correction strategies whenever displacements are >3 mm in any direction. Furthermore, a commercially available infrared positioning system is also being prospectively evaluated to increase the set-up accuracy particularly for high-precision conformal techniques. An alternative method of improving the repositioning accuracy would be the use of indexed patient positioning systems and fixed couch inserts.

#### IV. Conclusion

It is important to know the exact tumor motion to account for IM. Generalized IM increases the probability of not missing target and treating extra normal tissue. The PTV must account for all interfractional as well as intrafractional variations throughout a treatment course.

It is not advisable to reduce the margins significantly. A careful approach to planning should be taken. Several sources of errors potentially remain, including (1) residual imaging artifacts, (2) setup variations, (3) delineation variations, (4) interfractional means tumor position variations and (5) treatment-induced changes in target size and motion patterns.

The target design eliminates systematic errors in CT imaging introduced by imaging a non-representative target position during a standard helical scan.

Anatomical changes over the treatment course require frequent QA to achieve accurate dose delivery using highly conformal radiotherapy techniques. The current study shows that considerable local displacement in each center load to achieve very high accuracy in treatment. The comprehension of Margin and QA in radiotherapy is important when designating PTV margins as well as tolerance levels for position and plan adaption.

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