Kantonsspital Aarau

# DEPARTMENT OF RADIATION ONCOLOGY

# Correction of the Treatment Table Absorption in IMRT:

## Table Models in TPS and Measurements using an electronic 3D Detector

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## Introduction

Intensity modulated irradiations use all available gantry and possible table angles. The attenuation of the beam intensity by the table can be more than 7% in unfavorable situations (Lit1). The attenuation is therefore not negliable. It is rare to find identical table tops at CT scanners and treatment tables at Linacs. A possible solution is the introduction of an artificial structure with the shape of the table and given density which overrides the CT table in the DICOM image. Modern tables are constructed out of carbon fiber and have therefore very thin layers of dense material. The dense thin layers, the close distance to the Linac head and the distance to the patient cause several problems for the treatment planning system algorithms. We have investigated two different models for a treatment table by measuring the dose distribution with a 3D detector and comparing it to the calculated one using the gamma method (Lit2).

## Material and method

Calculations were performed on a Pinnacle P3 v 8.0m TPS (Philips Medical Systems, Madison USA) with 3mm calculation grid using the Collapsed Cone algorithm. The measurement phantom DELTA4 (ScandiDos AB, SE) has been scanned on a SIEMENS Open Sensation CT in helical mode. The density of the phantom has been overwritten with homogenous density to remove cupping and noise artifacts in the data ignoring the different density of the printed circuits. The value of the PMMA density has been adjusted to 1.14g/cm3 to give an effective depth of 12cm that corresponds to the physical radius of the phantom. It is well known that the physical density of PMMA differs form the one which should be used in TPS because of its different scatter properties compared to human tissue (Lit 3). The treatment plan consists out of 12 11x11cm2 fields between 30° and 290° gantry angle. At commissioning the TPS complied to the QA criteria (Fig 2) set in the recommendations (Lit 4). The TPS assumes a perfect radial symmetric fluence and therefore there will always some deviation. The measurement device DELTA4 by ScandiDos consists of two nearly orthogonal planes of semi conductor detectors in a cylindrical PMMA Phantom. One has to take into account the daily variation of the Linac output and the directional dependency of the semi conductors detectors for radiation measurements (Software ScandiDos vers. 2008 June).

Measurements were performed with a SIEMENS ONCOR Linac with a 82 leaf Optifocus MLC operated with collimator angle 0° (6MV Photons). The MLC is running against gravity, the worst case concerning mechanical play and gantry sag. The MLC relative calibration was done using abutting leaf sequences which allows to judge by eye an positioning error less than 0.5mm. Absolute MLC positions were measured in water with an ion chamber to a precision better than 0.5 mm. The remaining errors are mainly due to setup uncertainties of the detector.

The table top (SIEMENS ZXT, Reuther Medizintechnik) has a box shape construction. The upper and lower plates consists of two times 2 layers of carbon (d=1mm) and foam in between. The side walls consist out of 4mm thick carbon. In the longitudinal direction the table dimensions are constant and there are no construction materials for stiffening or as support.

Three different table models have been created using contouring and density overwrite (within the structure):

1. Simple Model: The density of the table was condensed to one 4mm thick homogenous layer.

2. CT Model: The table with its layers has been redrawn and the density set accordingly. Only the curved edges have been drawn edged.

3. Scanned Model: For comparison the carbon table top was taken of from the couch and scanned at the planning CT.

The plan data was transferred using DICOM-RT interfaces to the Delta4 system. The evaluation of the gamma index and the doses have been performed using the Delta4 software (Gamma index for 3% dose or 3mm spatial deviation).

## Results

The linearity of the dose measurement by DELTA4 is excellent. The regression coefficient for a linear relation is equal to one (range 10 - 1000MU). The angular dependence measured with the central detector of the phantom is plotted in Fig. 1. The shape of the variation and the amount of attenuation of +- 2.7% is due to the attenuation of the beam by the table top (verified by independent dosimetry). The spike at 140° gantry angle is the result of irradiating along a detector plane (angle not recommended by ScandiDos). The density of the phantom (PMMA body) had to be adjusted to match the absolute dose (depending on TPS HU to ED conversion and algorithm).

General to all models is: The geometrical dimensions of the carbon layers is similar to the resolution of the CT and smaller than the smallest possible calculation grid.

The Gamma index per field (gantry angle)

1. The Simple Model calculates correctly the attenuation of the beam so that the gamma index is always well below 1. (Fig 5) The distribution of the gamma index shows some dependence if the beam is attenuated by the table. The density of the attenuating material had to be fitted to the dosimetry.
2. The CT Model shows deficits already at the planning stage. Structures can only be contoured depending in position and size on the CT and calculation grid. The attenuation of the beam is less than expected and the distribution does not fit the measurement. This is visible in the gamma index which exceeds 1 in case the beam passes the table edges.
3. The Scanned Model shows similar problems like the CT Model because of the smearing out of the thin carbon layers. The Scanned Model distributes the mass over several pixel and reduces the density to 0.1 - 0.6 g/cm3 per pixel.

Gamma index overall

1. The Simple Model corrects the attenuation (fluence and absolute dose) such that the gamma index is better than 1 (Fig 4).
2. The CT Model (Fig 3) as well as the Scanned Model (Lit. 1) show clear deficits and a overall gamma index greater than 1. More important the absolute dose is not modeled correctly even when the beam passes only homogenous regions of the table top.

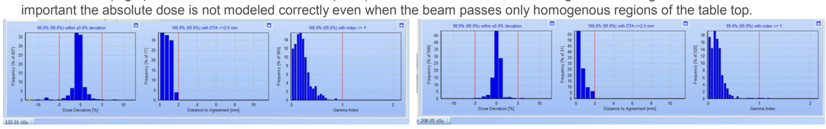

*Fig 5: Comparison of Simple Model to Measurement:Dose deviation, DTA and Gamma Index for 30°(left) and 120° (right) gantry angle.*

## Discussion

The analysis of the Scanned Model has revealed that the main problem for the absorption calculation in a commercial TPS is the voxel size of the original DICOM-Data and the calculation gride size. The thickness of the carbon layers in modern tables is of the same order as the voxel size. Depending on voxel position and carbon layer position the original mass density is distributed into several voxels which causes geometrical and density uncertainties. Usually the calculation grid is more coarse which means that the density per TPS voxel is even lower. In this case also the Hounsfield unit to electron density or physical density conversion gives incorrect results.

The CT Model has very thin structures which the TPS can not display or calculate because its calculation grid has twice the size (minimal structure size is equal to the minimal calculation voxel).

Within the Scanned Model every structure is of similar size to, or bigger than the calculation grid, but the dose grid and the density grid have to match.

The simple model shows good agreement if the beam does not pass through the table side edges. At the table edges the model shows deficits in the dose distribution because of the approximations it includes.

## Conclusion

•Only the Simple Model gives reliable results for most voxel sizes. Until more realistic table models have been developed fields partially passing through the table should be avoided.

•Manufactures of TPS have to implement tools to automatically import the table model into the patient CT scan. Calculation of the attenuation based on the DICOM data from CT scanner should be avoided fore tables with very thin layers.

•The attenuation of the beam by the table should be taken into account during IMRT calculations to avoid serious under dosage in the treatment volume. Treatment and verification should reflect the same setup which means they should be done under original gantry and table angles. Setup aids have to fix not only the patient but also the position on the table (lateral and longitudinal position).

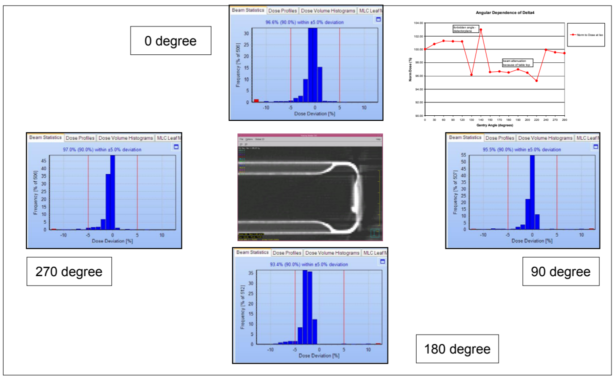


*Fig.1: Comparison of calculated (uncorrected for attenuation) and measured dose for a four field box (0°, 90°, 180°,270° gantry angle) shown as gamma index. The shift of the gamma index for the 180° direction shows the expected attenuation by the treatment couch. Directional dependency of the radiation dose measurement at the central detector. CT scan of the accelerator table top imported in the Pinnacle treatment planning system.*

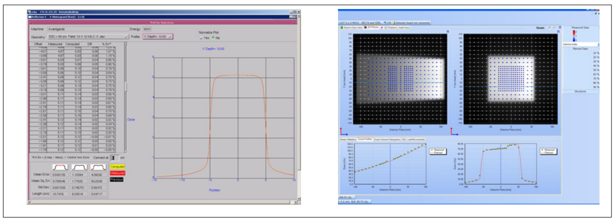

*Fig.2: Left Side: Comparison of measured and calculated beam X profile in Pinnacle. Differences are due to the assumption of a perfect radial fluence in Pinnacle and a real SIEMENS Linac. Right Side: Profiles calculated (Simpel Model) and measured for gantry angle 130°. The bump in the profile of the left detector plane is due to the attenuation by part of the beam by the table top.*

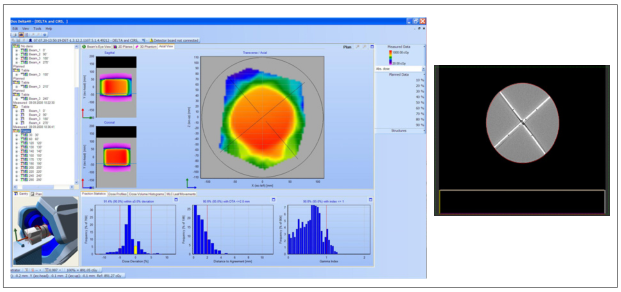

*Fig.3: Measurement compared to calculations for the CT Model. Scan of DELTA4 with the CT table model (bright lines represent the detector planes, density overwritten in TPS).*

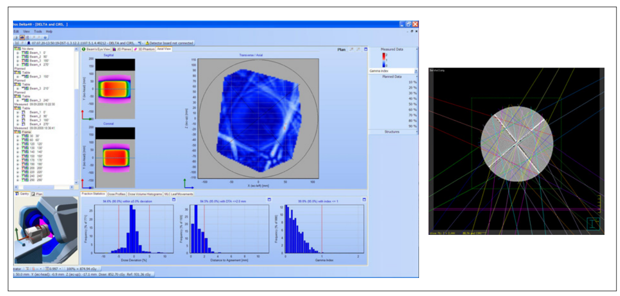

*Fig.4: Measurement compared to calculations for the Simple Model. Scan of DELTA4 with the CT table model (bright lines represent the detector planes, density overwritten in TPS).*

## Literature

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