The influence of the beam quality for high energy photon beams on tissue inhomogeneity correction factors for radiotherapy treatment plans

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Introduction

Treatment planning plays a very important role in preparation of external beam radiotherapy. Dose distribution should be calculated very precisely what is not easy task in case of presence of inhomogeneity such as lungs, oral cavities, the teeth, nasal passages, sinuses and bones. Therefore, using a treatment planning system (TPS) requires verification of dose distribution calculation before the first clinical application.

Motivation

Quality control of TPS in inhomogenous absorber is not an easy task. This is usually carried out by comparison of measured and calculated Correction Factors (ICFs) for inhomogeneities (the ratio of doses in the inhomogenous and homogenous phantom). The energy and spectrum of photon beams used in the clinic are not very different. It might then be hypothesized that ICFs measured by one user may be used by another one if quality index (QI) of both beams are similar.

Methods and Materials

The differences of QI of 6 MV and 15 MV accelerators installed in Poland in 2015 (Varian, Elekta) was checked (see Figure 1). The maximum difference of QI ($TPR_{20,10}$) was 4.2% and 2.2% for 6 MV and 15 MV, respectively.

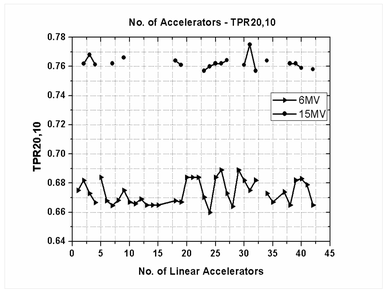

Figure1: $TPR_{20,10}$ as a function of different linear accelerators for 6 and 15 MV

- Ninety patients with lung, gynaecological and prostate tumors (thirty patients for each tumor site) treated with a 3DCRT technique with a Varian Clinac 2300CD linear accelerator, and twenty lung patients with stereotactic technique with a Varian TrueBeam accelerator were selected.
- For 3DCRT plans, the ICFs were calculated for a range of beam qualities. $TPR_{20,10}$ was in the range of 0.670±3%, and 0.760±3% for 6MV and 15MV respectively. For stereotactic plans, the ICFs were calculated with 6 MV FF beams ($TPR_{20,10}$ = 0.688) and X6FFF ($TPR_{20,10}$ = 0.632).
- Calculations were performed using Eclipse treatment planning system (TPS) with the anisotropic analytical algorithm (AAA).
- For all cases, for each single beam, the same dose was delivered to isocenter. The number of MUs were calculated with and without hererogeneity correction. The ICFs were the ratio of MUs.

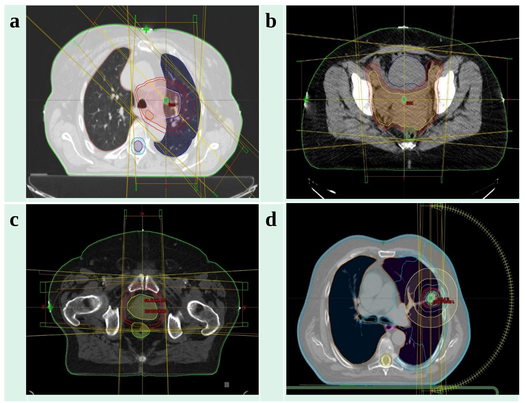

Figure 2: Example of 3DCRT and SRS treatment plans: (a) Lung 3DCRT; (b) Gynecology 3DCRT; (c) Prostate 3DCRT and (d) Lung SRS

- ICFs were also measured in a CIRS Tissue Simulation Phantom (thorax with lungs) for 5x5 and 10x10 field sizes with Varian TrueBeam (X6, $TPR_{20,10}$ = 0.688 and X6FFF, $TPR_{20,10}$ = 0.632) using PTW Unidose and Farmer ionization chamber.

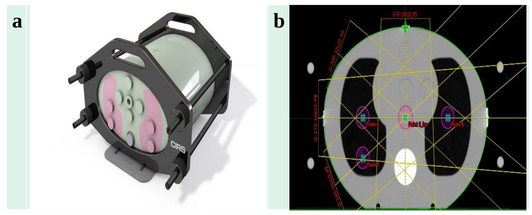

Figure 3: ICFs measurements with CIRS thorax phantom: (a) the CIRS Phantom and (b) the scan image with plans for calculations and measurements

Results and Discussions

Overall, ICFs increased with increasing beam quality for Lung and was alamost constant for Gynaecological tumours, while decreased for prostate tumours for both photon energies (Figure-4).

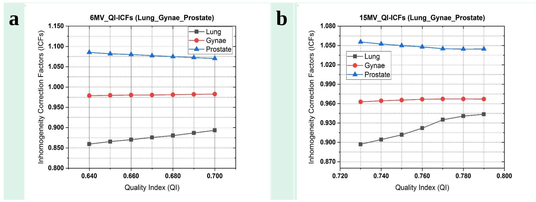

Figure-4 : ICFs as a function of beam quality for 6 MV (a) and 15 MV (b) energy for a Lung, Gynaecological and Prostate patient

For both energies, the 6% variations in $TPR_{20,10}$ led to average changes of ICFs of less than 3.0% for lung cases, and for gynecological and prostate patients, the mean differences of ICFs were less than 1%.

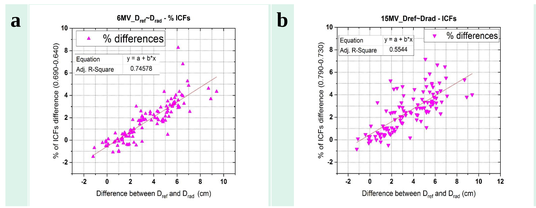

Figure-5 : Percent of ICFs difference as a function of the difference between physical (D_{ref}) and radiological (D_{rad}) depths for 30 lung 3DCRT treatment plans for 6MV (a) and 15 MV (b) photon energy

The difference of 5.6% of $TPR_{20,10}$ values between X6 and X6 FFF for lung SRS treatment plans led to a mean difference of ICFs of less than 2% (Figure-6a).

Measurements with the CIRS phantom also demonstrated differences of ICFs less than 6.5% between X6 and X6 FFF beams (Figure-6b).

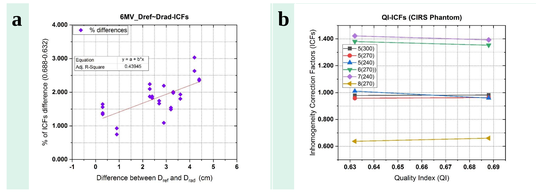

Figure 6(a) illustrates the percent of ICFs difference between the quality index 0.632 and 0.688 as a function of the of difference between physical (D_{ref}) and radiological (D_{rad}) depths for 15 lung stereotactic treatment plans; Figure 6(b) demonstrates the ICFs measured with CIRS Phantom as a function of quality index for a 10x10 cm² field size.

Conclusion

For most cases, for 3DCRT plans and stereotactic techniques, the influence of tissue inhomogeneity correction factors on beam quality variations is rather small.

However, a variation of more than 5% were observed for measurements with CIRS phantom for field size lower than 10x10 cm².

ICFs measured on one accelerator may be used with caution for another accelerator with similar energy provided quality control tests are performed.

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