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

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Introduction:

Radiation therapy has been used for many years to treat various types of cancers [1, 2]. The maximization of therapeutic benefit for radiation treatments is essentially dependent on the delivery of the prescribed dose to the planning target volume (PTV), while the dose received by the surrounding organ at risk (OARs) is simultaneously minimized. To achieve this goal, it is significantly important to either accurately specify the spatial localization of all pertinent structures or calculate the absorbed dose [3]. According to reports 50 & 62 of the international commission on radiation units (ICRU), the error in radiotherapy treatment, including contouring, treatment planning and dose calculation, patient positioning, and dose delivery, should be less than 5% [4-5]. In order to address this level of accuracy, several task groups over the past decades have extended systematic quality assurance (QA) protocols for three-dimensional (3D) radiotherapy treatment planning systems (TPSs). Various recommendations have been raised by those reports for specific QA of a TPS, which includes anatomical and beam descriptions, dose calculations, as well as data output and transfer. The most important part of the QA is based on comparing measured and calculated dose distributions for inhomogeneities- the so-called inhomogeneity correction factors (ICFs). For inhomogeneous geometry, the task is challenging and time and resource intensive. Some results of such measurements may be found in the literature [6-9]. To facilitate the QA procedure, it is convenient if ICFs are measured by one user and used by another. This work aimed to investigate how much ICFs depend on the beam quality- the tissue-phantom ratio (TPR20,10) for external beam radiotherapy treatment plans.

Materials and Method:

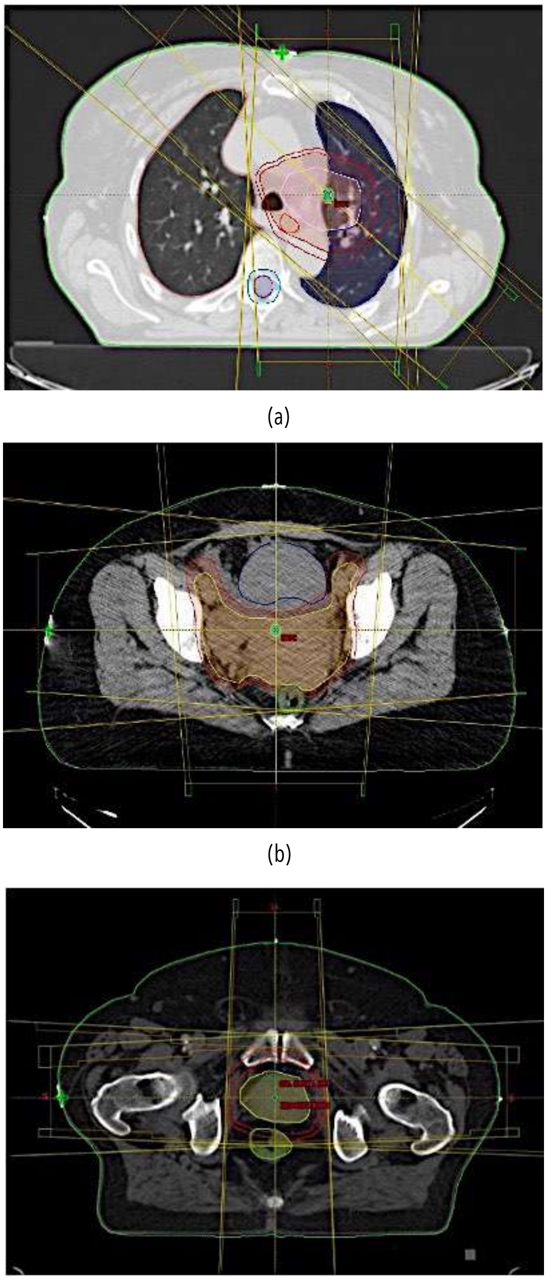
To assess the dependence of ICFs on beam quality index ($TPR_{20,10}$), 6 MV and 15 MV photon energies were considered. The range of $TPR_{20,10}$ values were as follows:

for 6 MV, k = -3, -2, -1, 0, 1, 2, 3

for 15 MV, k = -3, -2, -1, 0, 1, 2, 3

The $TPR_{20,10}$ values were obtained from the secondary standard dosimetry laboratory (SSDL) of Maria Sklodowska-Curie National Research Institute of Oncology, Warsaw, Poland [10]. The ICFs were calculated in Eclipse 13.6 (Varian Medical System, Palo Alto, California, USA) TPS with the anisotropic analytical algorithm (AAA) for photon beam energies described by the quality indexes given above.

Ninety patients with lung, gynaecological and prostate tumours were selected (thirty patients for each tumour site). The goal was to investigate the influence of tissue inhomogeneities on dose distribution. All patients were treated with a 3DCRT technique with a Varian Clinac 2300CD linear accelerator incorporating a 120-leaf MLC at the Maria Skłodowska Curie Memorial Cancer Centre and Institute of Oncology, Warsaw, Poland. An example of the treatment plans for lung, gynaecology and prostate tumour cases are illustrated in figure- 1 (a), (b), and (c). These treatment plans were recalculated for each beam quality without any beam modifier. ICFs were calculated for each beam angle individually. Each dose distribution was calculated with and

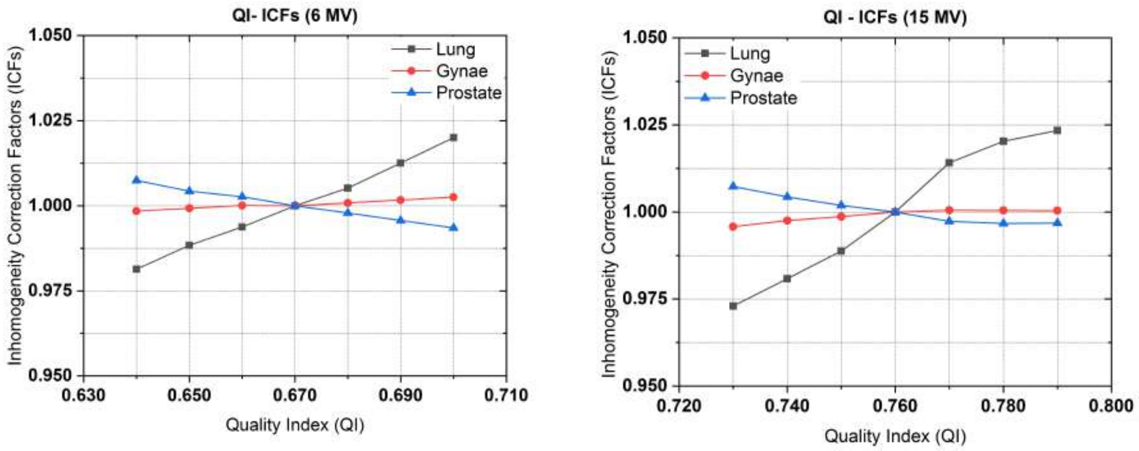


(a)

(b)

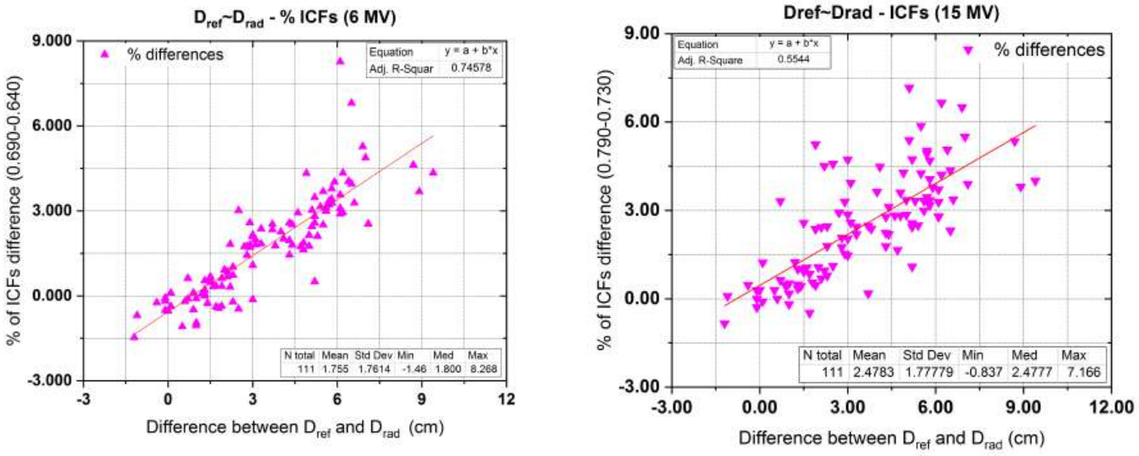
(c)

Figure 1: Shows comparison of the doses received by PTV and OARs.



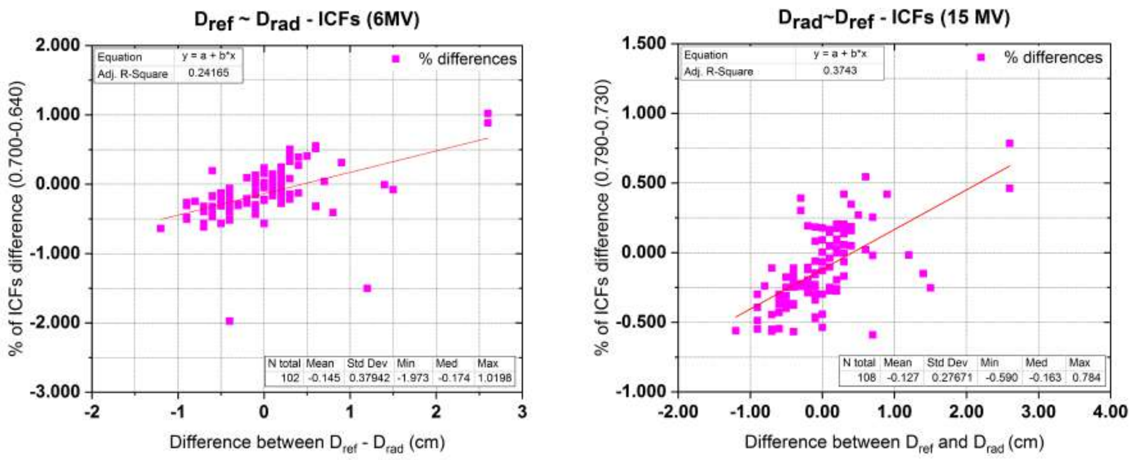
(a) (b)

Figure 2: ICFs as a function of QI for a beam angle for lung, gynaecology and prostate tumour treated with 3DCRT technique for 6 MV (a) and 15 MV (b) photon energy. The absolute ICFs for the QI of 0.670 were 1.233, 1.051 and 0.916 for Lung, Gynae and Prostate tumor respectively. The absolute ICFs for the QI of 0.760 were 1.117, 1.032 and 0.940 for Lung, Gynae and Prostate tumor respectively.



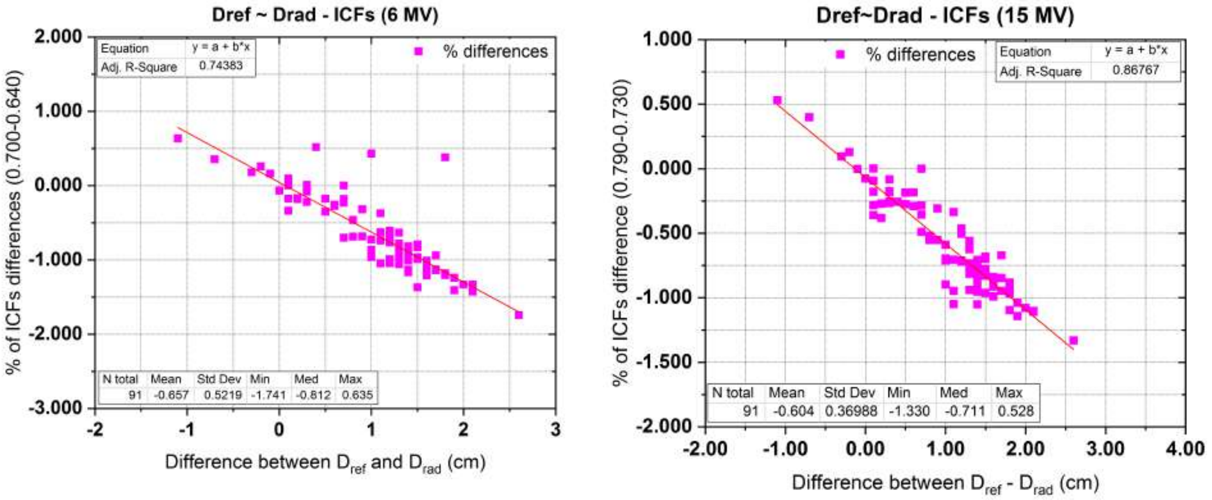
(a) (b)

Figure 3: 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 6 and 15 MV photon energy. The ICFs differs up to 8.2% over the QI range for Lung 3DCRT treatment plans.



(a) (b)

Figure 4: Percent of ICFs difference as a function of the difference between physical (D_{ref}) and radiological (D_{rad}) depths for 30 Gynaecology 3DCRT treatment plans for 6 and 15 MV photon energy. The difference between reference and radiological depths, the ICFs differ up to 2.0% over the QI range.



(a) (b)

Figure 5: Percent of ICFs difference as a function of the difference between physical (D_{ref}) and radiological (D_{rad}) depths for 30 Prostate 3DCRT treatment plans for 6 and 15 MV photon energy. The difference between reference and radiological depths, the ICFs differ up to 2.0% over the QI range

without an inhomogeneity correction to obtain the ICFs. For each case, the ICFs were calculated at the isocenter.

The dependence of ICFs on the energy spectrum was investigated as a function of physical depths (D_{ref}), radiological depths (D_{rad}), and the difference between D_{ref} and D_{rad} (D_{ref}-D_{rad}).

Results and Discussion:

Figures 2(a) and 2(b) present the ICFs calculated for lung, gynae and prostate treatment plans for 6 MV and 15 MV X-rays. The data were normalized to the QI = 0.670 for 6 MV and the QI = 0.760 for 15 MV. Calculation of ICFs was performed for several field sizes with the AAA method for 6 MV and 15 MV X-rays for lung, gynaecology and prostate are presented in Figures 3(a) and 3(b); 4(a) and 4(b); 5(a) and 5(b); respectively. The data were normalized to the QI = 0.670 for 6 MV and the QI = 0.760 for 15 MV.

Conclusions:

The influence of energy variations on inhomogeneity correction factors for gynaecology and prostate is rather small. However, emphasis must be given to lung cases as the study found a relatively higher discrepancy with the beam quality.

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