

Analysis of gamma index using in-house developed heterogeneous thorax phantom

Abstract

Quality assurance (QA) before patient treatment plays a major role in complex radiotherapy (RT) treatment planning. Phantoms are the standard materials that are used for the pre-treatment QA of patients. Contemporary phantoms used in RT are mainly water-based, having simple geometry and of uniform density. These phantoms do not replicate the exact heterogeneities of the actual human body. The present work aims to evaluate the results of relative dosimetry performed on in-house developed heterogeneous thorax phantom (HTP) using an electronic portal imaging device (EPID). To perform the relative dosimetry, contours were drawn on HTP at three different locations and intensity modulated radiotherapy (IMRT), as well as Rapid ARC (RA), were generated on it to compare the fluence obtained on TPS as well as on linac machine. The gamma evaluation results indicate a strong correlation between planned and the measured fluence. We found the EPID-based QA done on HTP explore its property as a QA tool and it can further be used to perform patient-specific relative dosimetry.

Keywords: electronic portal imaging device, heterogeneous thorax phantom, quality assurance

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Abbreviations: QA, quality assurance; RT, radiotherapy; HTP, heterogeneous thorax phantom; EPID, electronic portal imaging device; PTV, planning target volume; TPS, treatment planning system; IMRT, intensity-modulated radiotherapy; SSD, surface distance; DTA, distance-to-agreement; FFF, flattening filter-free; HD_MLC, high definition multi-leaf collimator; DD, dose-difference; PTV, planning target volume; TPS, treatment planning system; EPID, electronic portal imaging devices

Introduction

The high-end radiotherapy (RT) treatment technique needs an accurate pre-treatment patient quality assurance (QA) before patient treatment.^{1,2} In order to evaluate any RT plan or a treatment procedure two important aspects must be taken into account, first, an exact environment that can simulate radiation interaction as that of the real body tissue and second an accurate pre-treatment plan verification system. Phantoms are those substitutes that stimulate the real body scenario and have been in use since the inspection of RT.³⁻⁵ Although considering that the majority of the human body consists of water, physical phantoms that are made of water or solid water equivalent materials are mostly used for the patient-specific QA.⁶⁻⁸ These phantoms are mostly used because of their cost-effectiveness and simpler designs. In contrast, knowing that apart from water, the human body consists of bones, soft-tissues, air cavities, etc. of varied densities, anthropomorphic phantoms now a day used for the more pragmatic and finer representation of the human body.⁹⁻¹⁰ Regarding the patient plan verification, absolute point dosimetry and relative dosimetry are the two techniques mostly used in RT. To perform absolute dosimetry, an ion chamber is used inside the homogenous phantom to measure the point dose at a given point, and the same is verified on the machine by replicating the similar set-up geometry. However, to perform the relative dosimetry, various dosimetric devices are being used such as films, imatrix, ion chamber arrays, or flat-panel electronic portal imaging devices (EPID). In relative dosimetry two-dimensional fluence calculated by TPS is verified with that of the two-dimensional fluence obtained and on the linac. Amongst the

all available equipment, EPIDs are the better option available to take real-time measurement along with good image resolution.¹¹

The present work aims to explore the QA properties of in-house developed heterogeneous thorax phantom (HTP) which represent the actual thoracic region of the human body.

Materials and Methods

To design the HTP average dimension of thorax regions of 40 adult patients was taken irrespective of their gender and age distribution. Materials used for the designing of HTP are chosen such that it replicates the radiological characteristics of tissues involved, which has been described earlier in detail.¹² Briefly, this phantom is made up of porous sawdust of pinewood (density: 0.24 g/cm³) to mimic the lung, honeybee's wax of density (density: 0.86 g/cm³) to replicate the soft-tissue region, and rib cage (density: 1.84 g/cm³) to represent the actual human thoracic bony cavity as shown in Figure 1.

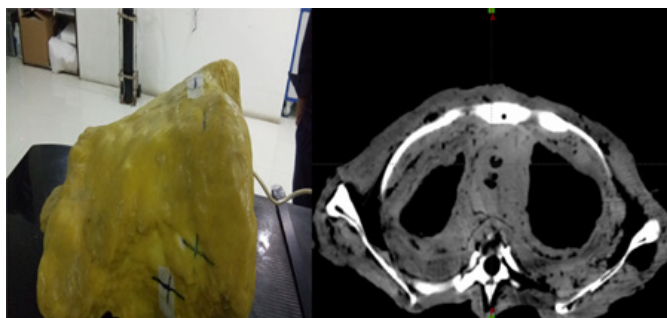


Figure 1 In-house developed heterogeneous thorax phantom.

CT images of the designed HTP with 3.0 mm slice thickness were taken on Siemens Biograph PETCT (Siemens Medical Systems, Germany). The corresponding CT images are then imported to the treatment planning system (TPS) eclipse version 13.7 (Varian Medical Systems, Palo Alto, CA, USA) to perform the relative dosimetry.

To verify the property of HTP as a QA tool, planning target volume (PTV) was drawn on HTP at three different locations; i) on soft-tissue region ii) at the boundary of lung and bone and iii) inside the lung region as shown in figure 2.

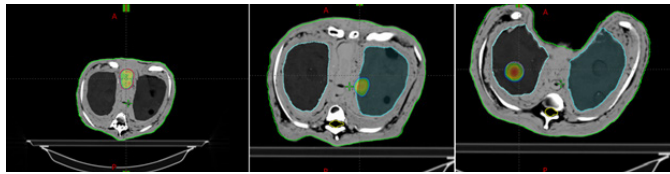


Figure 2 Target representation at three different locations inside the HTP.

Organs at risk (OARs) were also drawn along with the PTVs to evaluate the dose received by normal organs during RT. For each target, a plan was generated on a treatment planning system (TPS) using intensity-modulated radiotherapy (IMRT) as well as Rapid ARC (RA) technique and Acuros XB (AXB) version 13.6.23 was used for dose calculation. The 2D-fluence generated by TPS on EPID (precalibrated aS1200-Varian Medical Systems, Palo Alto, CA) was exported to the machine for further analysis. Using the same setup as that was used in TPS; exported plans were exposed on Edge linac

(Varian Medical Systems, Palo Alto, CA) equipped with flattening filter-free (FFF) beams for facilitating higher dose rate, high definition multi-leaf collimator (HD-MLC) (0.25 cm) along with jaw tracking technology.

All measurements were taken on the EPID detector calibrated for source to the surface distance of (SSD) 100cm. The data were taken for the same gantry and collimator position which was there actually in the plan. 2D fluence obtained by TPS and that on the machine was compared and analyzed using Omni pro software (IBA Dosimetry, Germany). Pixel-based passing criteria were taken for plan evaluation, $g \geq 1$ was considered as pass criteria whereas $g < 1$ was taken as criteria for plan failure. For the acceptance criteria, we chose tolerance: 1) dose-difference (DD) of 3% and distance-to-agreement (DTA) of 3 mm.

Results

In the previous study done by the author,¹¹ physical and radiological properties of HTP were studied and compared with that of the actual patient. In the present study, the utility and accuracy of designed HTP as a QA tool is studied. The results obtained from relative dosimetry are shown in Table 1.

Table 1 Results of all planning target volume locations

PTV Location	Technique	Area Gamma	Maximum Dose Difference	Average Dose Difference
Soft-tissue	RA	100%	11.1%	1.2%
Boundary of lung & bone	RA	99.9	13.7	1.6%
Inside the lung	RA	100%	19.7%	2.7%
Soft-tissue	IMRT	100%	18.2%	1.7%
Boundary of lung & bone	IMRT	100%	25.3%	2.3%
Inside the lung	IMRT	100%	23.8%	3.2%

From the above table, it is clear that for all PTVs inside the HTP, the results are well within the tolerance limits and the HTP can be used as a QA tool for relative dosimetric purposes. Figure 3 represent the result of gamma value analysis on EPID for one of the RA plan in the soft-tissue region.

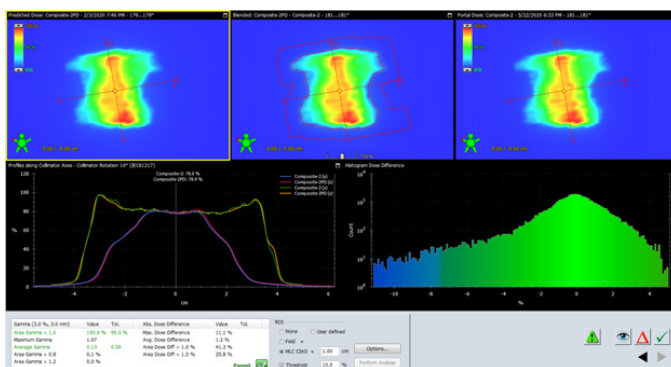


Figure 3 Gamma value analysis result for VMAT plan in soft-tissue region.

Discussion

The results obtained from relative dosimetry through HTP, which was based on the gamma-evaluation method showed that the fluence obtained on TPS and that obtained from the machine for all generated QA plans were matching as per the 3mm, 3% gamma criteria. Gamma index evaluations showed that no more than 3% of the points

within the range of 3mm had a gamma value larger than one.¹² The percentage of points satisfying the above passing criteria was found by comparing the TPS generated 2D gamma fluence with that of the fluence obtained on the machine.

Conclusion

The result of the current study indicates that EPID based relative dosimetry done on the HTP explores its property as a QA tool. Though in this study the contour was drawn on the HTP and the relative dosimetry was performed for the plans generated on it. But the further study can be carried out to perform patient-specific exit dosimetry on designed HTP to verify the patient's plans.

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