Patient Specific Quality Assurance: Transition from IMRT to IMAT

To cite this article: Jennifer O'Daniel PhD et al 2010 J. Phys.: Conf. Ser. 250 012050

View the article online for updates and enhancements.

Related content

- 2D AND 3D dose verification at The Netherlands Cancer Institute–Antoni van Leeuwenhoek Hospital using EPIDs
  Ben Mijnheer, Anton Mans, Igor Olaciregui-Ruiz et al.
- A note on the interpretation of the gamma evaluation index
  Crister Ceberg
- Semi- and virtual 3D dosimetry in clinical practice
  S S Korreman

Recent citations

- Reviewing three dimensional dosimetry: basics and utilization as presented over 17 Years of DosGel and IC3Ddose
  L J Schreiner
- Analysis and evaluation of planned and delivered dose distributions: practical concerns with - and - Evaluations
  L J Schreiner et al.
Patient Specific Quality Assurance: Transition from IMRT to IMAT

Jennifer O’Daniel, Ph.D., Shiva Das, Ph.D., Jackie Wu, Ph.D., Fang-Fang Yin, Ph.D.
Department of Radiation Oncology, Duke University Medical Center, Durham, NC
jennifer.odaniel@duke.edu

Abstract. The purpose of this study was to test a patient-specific quality assurance (QA) protocol for intensity-modulated arc radiotherapy (IMAT), and to evaluate the use of an intensity-modulated stationary radiotherapy QA device (2D ion chamber array). Thirty-nine IMAT treatment plans for brain, spine, and prostate were analyzed using 3 methods: ion chamber (1D absolute, n=39), film (2D relative, coronal/sagittal, n=8), and 2D ion chamber array (“ICA,” 2D absolute, coronal/sagittal, n=39) measurements. All measurements were compared to the treatment planning system (TPS) dose calculation with gamma analysis (3%, 3mm distance-to-agreement criteria) or absolute point dose comparison. The ICA measurements were also directly compared to film and ion chamber for validation. Absolute 1D measurements agreed well calculation (ion chamber: average deviation 1.4%, range -0.9% to 2.8%; ICA: average deviation 0.7%, range -1.8% to 2.9%). Relative 2D measurements also showed good agreement with calculation (>93% of pixels in all films passing gamma, >90% of pixels in all ICA measurements passing gamma). ICA and film relative dose results were highly similar (> 90% of pixels passing gamma in 94% of QAs). Coronal and sagittal ICA measurements were statistically indistinguishable by the paired t-test with a hypothesized mean difference of 0.2%. Ion chamber and ICA absolute dose measurements usually agreed well, but had disparities of 2-3% in 18% of plans. After validating the new IMAT implementation with ion chamber, film, and ICA, we reduced our QA from 5 (ion chamber, film, and ICA) to 2 measurements (ion chamber and single ICA) per plan. The ICA (Matrixx®, IBA Dosimetry) was validated in relative analysis mode, but ion chamber measurements are recommended for absolute dose comparison.

1. Introduction
With the recent clinical introduction of intensity-modulated arc therapy (IMAT), new patient-specific quality assurance (QA) procedures must be developed. Techniques can be adapted from patient-specific QA of static intensity-modulated radiotherapy (IMRT). However, the additional uncertainties due to the new delivery method, specifically varying gantry angle and dose rate, must be investigated. Film and single ion chambers are the “gold standard” for QA, and can be used to both validate IMAT implementation and the use of new QA measurement tools, such as a 2D ion chamber array ((Matrixx®, IBA Dosimetry, Bartlett, TN). Previous work has reported on novel 3D dosimetry techniques for the QA of IMAT treatment plans [1], on initial QA results for a small set of IMAT treatment plans using one measurement technique [2], on Monte Carlo simulations of IMAT treatment plans [3], and on an overview of implementing RapidArc at the University of Alabama at Birmingham [4]. However, a comprehensive patient-specific QA protocol based on results from a large number of
patients, multiple treatment sites, and using multiple measurement devices for cross-validation has not yet been presented. Additionally, while the 2D ion chamber array has been validated for IMRT QA [5-7], it has not been validated for IMAT QA with a large study. In this work we have explored an effective and efficient end-to-end QA protocol for IMAT and evaluated the suitability of an IMRT QA device (2D ion chamber array) for IMAT QA.

2. Materials and Methods

We extensively analyzed 39 IMAT treatment plan QAs involving multiple treatment sites (brain, spine, and prostate), and QA devices (cylindrical ion chamber (n=39), film (n=8), and ion chamber array (“ICA”, n=39)). All measurements were compared to the Eclipse v8.5 treatment planning system (TPS) dose calculations on hybrid QA plans (patient plan calculated on a CT image set of the QA device). Plans were delivered using RapidArc (Varian Medical Systems, Palo Alto, CA). For 2D analysis, gamma analysis was used with 3%, 3mm distance-to-agreement criteria and 5% of maximum dose threshold. Absolute 1D dose comparisons compared (1) the dose measured by the 4 central ion chambers in the ICA to the TPS dose calculated at those points and (2) the dose measured by the single ion chamber to TPS calculation. Measurements “passed” if the 1D dose agreed within 3% and the 2D comparison had > 90% of pixels passing the gamma analysis. The ion chamber and film results were also directly compared to the ICA measurements.

3. Results

Cylindrical ion chamber, film and ICA measurements each agreed well with calculation, indicating that the IMAT plans were deliverable within the mechanical and dose constraints of the linear accelerator (Table 1, Fig. 1, Fig. 2). Gamma analysis between film and ICA showed excellent agreement (Table 1). While in general ICA passing rates were high, the ICA measurement produced a lower passing rate than expected in the presence of high dose gradients (Fig. 3). Ion chamber and ICA absolute dose measurements showed a similar trend, but had disparities of 2-3% in 18% of plans (Fig. 4). Coronal and sagittal ICA measurements were statistically indistinguishable (Fig. 5). Through cross-validation of our QA devices, we were able to reduce from the initial 3.6hr QA procedure (3 film + 2 ICA + 1 ion chamber) to a 1.6hr reduced QA procedure (2 ICA + 1 ion chamber), and finally to our current streamlined 1.2hr QA procedure (1 ICA + 1 ion chamber).

<table>
<thead>
<tr>
<th></th>
<th>Film vs. Eclipse</th>
<th>Film vs. ICA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coronal</td>
<td>Sagittal</td>
</tr>
</tbody>
</table>
| Brain
| 1     | 98.8    | 99.0    | 93.1    | 98.4    |
| 2     | 99.5    | 97.2    | 97.2    | 89.0    |
| 3     | 99.4    | 97.4    | 96.3    | 97.3    |
| Prostate bed
| 14    | 97.2    | 98.9    | 94.6    | 97.0    |
| 15    | 99.1    | 99.6    | 95.3    | 96.8    |
| Prostate
| 23    | 97.8    | 99.6    | 97.8    | 99.1    |
| 24    | 97.6    | 99.5    | 99.5    | 99.4    |
| Prostate + SV
| 32    | 93.1    | 98.6    | 93.9    | 99.0    |
Fig. 1: Absolute 1D Dose Comparison: Measurement vs. Calculation

Fig. 2: Absolute 2D Dose Comparison: %Pixels Passing 3%, 3mm Gamma Analysis

Fig. 3: ICA Dose Overestimation in the Presence of a Perpendicular High Dose Gradient

Fig. 4: Ion Chamber vs. Ion Chamber Array

Fig. 5: Ion Chamber Array - Coronal vs. Sagittal
% Pixels Passing Gamma

Error bars = St Dev of 4 central ion chambers in array
4. Conclusions

By testing the IMAT implementation for 39 patient plans with ion chamber, film, and ion chamber array, we cross-validated our QA devices and were able to maintain an effective QA protocol while reducing the amount of measurements required. Ion chamber, film, and ion chamber array results all agreed well with the calculated dose, though the ion chamber array results could be unreliable when perpendicular high-dose gradients could not be avoided. Film and ion chamber array results agreed well. Cylindrical ion chamber and ion chamber array measurements were reasonably similar, but discrepancies of up to 3% were observed. Therefore we continue to rely on the cylindrical ion chamber for absolute dose comparisons. We have subsequently reduced our IMAT QA process from 5 measurements per patient (cylindrical ion chamber, coronal ion chamber array, sagittal ion chamber array, coronal film, sagittal film) to 2 measurements per patient (cylindrical ion chamber and single-plane ion chamber array).

References