3D Analysis of Intensity-Modulated Radiation Therapy Quality Assurance Measurement using a 2D Diode Array

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Abstract. Intensity-modulated radiation therapy (IMRT) quality assurance (QA) is often performed using a 2D device and compares measured and computed fluence maps to determine if a field passes or fails certain dose and position criteria. The effects of a measured deviation to the 3D patient spatial dosimetry and dose volume histogram (DVH) are largely unknown because they cannot be analyzed using commercial 2D array IMRT QA systems. We report an in-house treatment planning system (TPS) PLanUNC based 3D IMRT QA analysis approach that has been used in our institution for the past ten years when 2D fluence map IMRT QA failed. In this approach the measured 2D fluence maps are imported back to PLanUNC and used to re-compute 3D patient dosimetry including DVHs. The 2D fluence map IMRT QA criteria is that the measured dose for 95% of the detectors is within 5% of the planned dose, and that the distance-to-agreement be within 4mm (5%/4mm). 22 IMRT plans that had at least one field fail initial QA using MapCHECK 2 are examined using our 3D QA approach. The DVH analysis shows that 19/22 plans that failed initial QA were within 2% of the planned target and critical structure DVHs. 3/22 IMRT plans were found to have DVH difference greater than 2%. The 3D analysis of 2D IMRT QA result shows that when a fluence map QA fails for a single field, often it is clinically insignificant in terms of patient 3D dosimetry

1. Introduction

Pre-treatment IMRT QA measurement is necessary to insure patient safety and quality delivery of a radiotherapy treatment plan. Multiple commercial IMRT QA devices exist, and for step-and-shoot IMRT a 2D array of detectors is commonly used to measure radiation dose maps for all fields while keeping the gantry at 0 degrees [1, 2, 3, 4]. The acquired radiation dose maps are then compared to the dose maps created by the treatment planning software. The commercial IMRT QA product reveals if a field fails or passes a set comparison dose and distance-to-agreement criteria [5]. Currently, the ability to perform 3D dosimetric analysis and comparison is lacking, however commercial vendors are working to import 3D analysis [6]. Further, if an IMRT field fails, there are limited tools to determine the cause of the failure and to determine the effect of the failed field on the overall delivered dose. In this work, we present a method for in depth IMRT QA analysis that incorporates in-house software into our treatment planning system to analyze possible causes of QA failures and the 3D dosimetric result of 2D measured radiation dose maps.
2. Methods and Materials

IMRT QA
Currently we use the MapCHECK 2 for QA of step-and-shoot IMRT QA plans. The MapCHECK 2 has 1527 diode detectors spaced 7mm apart across a 26cm X 32cm 2D detector array. IMRT field dose maps are created by the treatment planning system and imported into the MapCHECK 2 analysis software. The MapCHECK 2 is placed on the treatment table and all IMRT fields are measured with the gantry at 0 degrees. The measured and planned radiation dose maps are compared, as shown in figure 1. Field passing criteria is set to 95% of detector points must be within 5% of the planned dose and have a 4mm distance-to-agreement, (5%/4mm). When an IMRT field fails QA, all of the patient’s measured IMRT intensity maps are imported to our treatment planning software PLanUNC to analyze the impact of the measured deviation in fluence maps on 3D patient dosimetry.

3D dose analysis of 2D IMRT QA Failure

When an IMRT field fails the 2D IMRT QA, the measured 2D dose map and the diode detector positions are exported to PLanUNC for 3D dose analysis. The MUs and/or the MLC leaf position of the initial treatment plan segments are adjusted in PLanUNC so that the resulting fluence map matches the IMRT QA measurement. This process creates a treatment place based on the IMRT QA. Then 3D dosimetry is compared between the original treatment plan and the IMRT QA based plan, as shown in figure 2. The IMRT plan is generally approved by the patient’s physician for clinical use if the deviation in corresponding target and critical structure DVHs are within 2%.

![Figure 1: MapCHECK2 comparison of planned (right) and measured (left) IMRT dose maps.](image1)

![Figure 2: Comparison of planned (red) and measured (green) DVHs for the tumor volume.](image2)
Results
We report the analysis of 22 IMRT QA measurements that failed the conventional 2D IMRT QA. Of the 22 failures, 19 were found to have treatment target volume DVH within 2% of the treatment plan. Of the 22 IMRT QA failures, 3 were found to have measured target DVHs differ the planned DVHs by more than 2%. All data is shown below in table 1.

| Patient | # Fields Failed (Total Fields) | Lowest % Points Pass | DVH % Difference |
|---------|-------------------------------|----------------------|------------------|
| 1       | 5 (8)                         | 75.7                 | 1.0              |
| 2       | 8 (9)                         | 80.9                 | 3.0              |
| 3       | 5 (8)                         | 71.5                 | 3.0              |
| 4       | 4 (8)                         | 75.6                 | 3.0              |
| 5       | 2 (9)                         | 93.3                 | 1.0              |
| 6       | 1 (7)                         | 89.5                 | 2.0              |
| 7       | 2 (7)                         | 57.5                 | 1.0              |
| 8       | 8 (9)                         | 83.4                 | 1.0              |
| 9       | 3 (7)                         | 91.8                 | 1.0              |
| 10      | 2 (7)                         | 91.5                 | 1.0              |
| 11      | 1 (9)                         | 94.2                 | 1.0              |
| 12      | 8 (9)                         | 88.7                 | 1.0              |
| 13      | 9 (9)                         | 79.4                 | 1.0              |
| 14      | 1 (8)                         | 84.5                 | 1.0              |
| 15      | 3 (7)                         | 78.6                 | 1.0              |
| 16      | 3 (8)                         | 70.9                 | 1.0              |
| 17      | 6 (7)                         | 80.8                 | 2.0              |
| 18      | 2 (9)                         | 70.2                 | 1.0              |
| 19      | 1 (7)                         | 90.6                 | 1.0              |
| 20      | 4 (5)                         | 84.5                 | 2.0              |
| 21      | 1 (9)                         | 85.8                 | 1.0              |
| 22      | 7 (8)                         | 82.1                 | 1.0              |

Table 1: Analysis data for the 22 patients analyzed. The number of failed fields, and total treatment fields is given. The lowest percent of detector points passed reveals the lowest passing rate for the failed fields. The DVH percent difference represents the difference between the measured and planned target and critical structure DVHs.

Conclusions
We have demonstrated that an in-house 3D analysis of conventional 2D IMRT QA is a useful tool to evaluate the clinical impact of the IMRT QA failure. We showed that only 3/22 plans that failed this criteria (5%/4mm) has an impact of more than 2% in treatment plan target and normal structure DVHs. Therefore use of a more strict passing criteria in 2D fluence map IMRT QA may not result in tangible clinical benefit.
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