Sensitivity in error detection of patient specific QA tools for IMRT plans

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Abstract. The high complexity of dose calculation in treatment planning and accurate delivery of IMRT plan need high precision of verification method. The purpose of this study is to investigate error detection capability of patient specific QA tools for IMRT plans. The two H\&N and two prostate IMRT plans with MapCHECK2 and portal dosimetry QA tools were studied. Measurements were undertaken for original and modified plans with errors introduced. The intentional errors composed of prescribed dose (±2 to ±6\%) and position shifting in X-axis and Y-axis (±1 to ±5\textmu m). After measurement, gamma pass between original and modified plans were compared. The average gamma pass for original H\&N and prostate plans were 98.3\% and 100\% for MapCHECK2 and 95.9\% and 99.8\% for portal dosimetry, respectively. In H\&N plan, MapCHECK2 can detect position shift errors starting from 3\textmu m while portal dosimetry can detect errors started from 2\textmu m. Both devices showed similar sensitivity in detection of position shift error in prostate plan. For H\&N plan, MapCHECK2 can detect dose errors starting at ±4\% whereas portal dosimetry can detect from ±2\%. For prostate plan, both devices can identify dose errors starting from ±4\%. Sensitivity of error detection depends on type of errors and plan complexity.

1. Introduction

Intensity modulated radiation therapy (IMRT) technique, represents the advanced form of three-dimensional conformal therapy. It is advantageous for patient treatments because it allows more conformal shaping of the dose to the target and significant gains in the sparing of normal tissues [3]. IMRT achieves desired dose distribution in a complex shaped volume by modulating the intensity map of each treatment field using multileaf collimator (MLC). The complexity in planning and delivery of radiation demands a high level of quality control both in the operation of the equipment and in the treatment delivery for individual patients [2].

Patient-specific QA (quality assurance) for IMRT plans can be done using various kinds of planar dosimeters such as films, diode arrays, ionization chamber arrays and electronic portal imaging devices (EPID). For 2D or 3D QA tools the gamma index combines dose difference and distance to agreement to the single parameter is commonly used for dosimetric evaluation of treatment plans.
According to different designs and configurations of QA tools, the capability of each detector is different. The sensitivity of each QA tool depends on the type and number of detectors, arrangement, and spacing between them. The purpose of this study is to evaluate the error detection capability of patient specific QA tools (MapCHECK 2 system and Portal Dosimetry System) used to evaluate the IMRT plans.

2. Materials and methods

2.1. Creating IMRT plans
Four clinical IMRT plans, two head and neck and two prostate, were selected. The plans were created using Eclipse Treatment Planning System-version 11.0.31 (Varian medical systems, Palo Alto, CA, USA). The six MV beams were employed with 9 field arrangement for head and neck IMRT cases while 10 MV beams with 7 fields were optimized and calculated for prostate IMRT plans. The head and neck plan represented the complicated plans and prostate as the simple plans.

From the copies of the original plans, the plans with intentional errors were created. The intentional errors were increasing and decreasing prescribed dose (±2, ±4 and ±6%) and position shifting in X-axis and Y-axis (±1, ±2, ±3 and ±5mm).

2.2. Measuring systems
The patient plans were calculated for EPID and MapCHECK 2 and delivered by using ClinaciX (Varian Medical Systems, Palo Alto, CA, USA, Inc). The original and edited plans were measured by EPID and MapCHECK 2 system. The EPID which was fixed with Varian ClinaciX machine was set at 100cm source to detector distance (SDD) and measured both original and modified plans. For the measurement with MapCHECK 2 which was placed on the patient couch and the SDD was set at 95.8cm and the solid water phantom of 3cm was added on its detector surface to acquire the 5cm water equivalent thickness. All measurements were saved in respective software for further analysis.

2.3. Analyzing the measurements
The gamma evaluation tool was available for analysis of the measurement for each QA tool. Firstly the dose distributions of the original plans were compared between those calculated from the TPS and from the measurement. In order to observe the error detection of QA tools, the measurements with intentional errors were compared with the original plan. The gamma index of 3% dose difference and 3mm distance to agreement with 10% threshold were used to set the evaluation criteria. The gamma evaluation pass rate was set at 95% and an error was considered detected when the gamma failure rate was higher than 5%. We then analyzed the gamma result of modified plans and evaluated the error detection capability of each QA tool.

3. Results
The result of 4 original IMRT plans measured with Portal Dosimetry and MapCHECK 2 system are shown in table 1. All the results were analyzed by using 3%/3mm gamma criteria. The pass rates were higher for the prostate plan compared to the head and neck plan. This was attributed to the increased modulation and irregular field shapes in the head and neck plan [5]. Even without error, the pass rate of head and neck was close to the acceptable pass rate of 95% because the beam configuration and tumor shape in head and neck was quite complicated compared with the prostate plan.

Table 1. The gamma results of 4 IMRT plans obtained without intentional error.

| Plan          | Gamma Passing rate (%) | Portal Dosimetry | MapCHECK 2 |
|---------------|------------------------|------------------|------------|
|               |                        |                  |            |

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3.3. Error detection by portal dosimetry system
As the head and neck plan was more complicated, the error detection in this plan was higher than in that of the prostate plan.

![Diagram](image)

**Figure 1.** The results for portal dosimetry system for (a) Position shift error in H&N; (b) Position shift error in prostate (c) prescribed dose error in H&N; and (d) prescribed dose error in prostate.

Error of position shifted in X-axis can be detected start from -1mm, +3mm and in Y-axis was -5mm and +1mm. In the prostate plan, the error detection started from ±3mm in both X and Y axis. Prescribed dose error in head neck plan that had a failure rate less than 95% can be observed in the dose increasing error of 2% and decreasing error of 6%. For the prostate plan, the dose started from -4% and +6% errors can be detected. The results for gamma pass measured by portal dosimetry system are shown in figure 1.

3.4. Error detection by MapCHECK 2 system
The MapCHECK2 system can detect error starting from -2mm and +3mm in X axis and +2mm and -3mm in Y axis for the head neck plan while MapCHECK 2 can detect the error starting from ±3mm in both axes for prostate as shown in figure 2. Even small error of 2% dose decreasing can be detected in head and neck plan but in prostate only starting from 4% the system can be detected.
4. Discussion

The portal dosimetry system is slightly higher sensitivity to detect the position shift error in both head and neck and prostate plans than MapCHECK 2 system because the portal dosimetry system can detect the smallest error of 1mm while the MapCHECK 2 cannot detect that magnitude of the error. For dose error detection, the portal and MapCHECK 2 has similar sensitivity. We observe that error detection depends on the type of plan under consideration. In head and neck, smaller errors can be detected whereas in the prostate plan, the error needs to be of a higher magnitude before it can be detected. The sensitivity to the introduced errors depends on the plan and the various systems can detect various errors, and some of the errors cannot be found with these systems [1].

5. Conclusion

Error detection of each QA tools depends on the error type, site, and shape of tumor location. The configurations of QA tools also play an important role in the sensitivity of error detection. The higher the resolution of QA tools, the better the sensitivity. From our results, we can conclude that portal dosimetry system has marginally higher sensitivity than MapCHECK 2 system because it is higher resolution than the MapCHECK 2 system, at least for the plans we considered.

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