A GPU-based Monte Carlo QA tool for IMRT and VMAT

Introduction
Quality Assurance (QA) for Intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) is important due to the complexity of both technologies. Current QA for IMRT and VMAT commonly performs dosimetric verification on geometric phantoms using ion chambers, 2D film dosimetry or diode arrays. Gamma index analysis is always reported for planar dose distribution comparison. This current QA procedure has three drawbacks. First, those measurements do not verify dose in actual patients, since phantoms do not represent patient geometry and tissue heterogeneities. Second, setting up the phantom and doing dosimetric measurements are time consuming and labor intensive. Lastly, there have been concerns that the gamma index analysis cannot reliably identify dosimetry accuracy. Hence, a low-workload 3D dosimetry verification procedure that employs patient geometry and has the ability to generate clinically relevant metrics such as dose-volume histogram (DVH) is highly desired.

The potential errors that should be checked in QA procedure before treatment include TPS plan dose inaccuracies, plan transferring errors and machine delivery errors. For all those tasks, we propose a GPU-based Monte Carlo QA tool. This tool employs a fast and accurate 3D GPU-based Monte Carlo dose calculation on patient image; and it is easy to implement in clinic and requires low workload. The details of the tool are described below.

Methods and Material
The workflow is shown in figure 1. First, we generate fluence maps at all beam angles from the initial treatment plan. A GPU-based Monte Carlo dose calculation package, gDPM, is employed for secondary dose calculation (SDC) on patient CT. This SDC is used to verify the TPS plan dose (PD) accuracy. Before the 1st treatment fraction, we deliver the treatment plan on a Linac without any phantom setup to obtain machine log files which record machine delivery information. With the log files, we extract actually delivered fluence maps at all beam angles and perform delivered dose calculation (DDC) using gDPM. The DDC and SDC are conducted by the same dose calculation algorithm, hence the difference between DDC and SDC indicates possible errors in data transferring and machine deliver. Lastly, the comparison between DDC and PD shows the accumulative errors from all possible sources. Moreover, a web application for this QA tool is developed for clinical use.

In this study, we use Varian TrueBeam trajectory file as an example, which logs the system’s delivery parameters every 10 ms. We use the full benefit of the small time resolution in the log files to generate actually delivered fluence maps at all beam angles. On the other hand, the plan fluence maps are only defined at control points in the initial plan.

In this QA tool, DVH comparisons and gamma analysis results are both used for dose evaluation part. The gamma analysis is done by a GPU-based 3D gamma index algorithm, gGamma. In this study, a 3% dose difference and 3 mm distance to agreement are used.

We have tested this QA tool on 6 patients, 4 VMAT and 2 IMRT patients. The mean values inside the 20% isodose line and percentage of voxels inside the 20% isodose line with $\gamma < 1.0$ are reported in the next section.
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<tr>
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<th>SDC vs PD</th>
<th>SDC vs DDC</th>
<th>DDC vs PD</th>
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<tbody>
<tr>
<td><strong>Mean Gamma(20%)</strong></td>
<td>0.022</td>
<td>0.021</td>
<td>0.048</td>
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<td><strong>Passing Rate(20%)</strong></td>
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<td>100%</td>
<td>99.95%</td>
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<td>99.65%</td>
<td>100%</td>
<td>99.74%</td>
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</table>

Table 1. Mean gamma values and gamma passing rates inside the 20% isodose line

**Results**

Table 1 shows the mean gamma values and gamma passing rates inside the 20% isodose line for 6 patients. We selected a typical VMAT prostate patient as an example. The secondary dose calculation, delivered dose calculation and plan dose distributions for this patient are shown in figure 2. Figure 3 shows the DVH for the three dose distributions. The results show that there is little difference between the three dose distributions.

**Conclusions**

We have developed a GPU-based Monte Carlo QA tool, which performs the secondary dose calculation using initial plan fluence maps, as well as, the actually delivered dose calculation on patient image using machine log files. This QA system doesn't need any phantom set up, thus requires low workload in clinics.

**Reference**