Automated verification plan preparation and 2D-3D gamma analysis for proton patient-specific quality assurance

Danairis Hernandez Morales[1], Jie Shan[1], Wei Liu[1], Kurt E. Augustine[1], Martin Bues[1], Michael J. Davis[1], Mirek Fatyga[1], Jedediah E. Johnson[2], Daniel W. Mundy[2], Jiajian Shen[1], James E. Younkin[1] and Joshua B. Stoker

[1]**Mayo Clinic, Phoenix, AZ,** [2]**Mayo Clinic, Rochester, MN**

Abstract

Purpose: Physician-approved treatment plans undergo patient-specific quality assurance (PSQA) prior to beginning of treatment. For pencil beam scanning proton therapy, quality assurance is complex and time consuming, involving multiple measurements per field. We evaluated the PSQA process to identify routine steps that could be automated for a comprehensive and efficient workflow.

Methods: We used the treatment planning system's (TPS) capability to support C# scripts to develop an Eclipse Application Programming Interface (API) script to automate the preparation of the verification-phantom plan. The API script evaluated the gradient in the target volume of each verification field based on established criteria to identify adequate depth-dose profiles and depths for PSQA measurements as shown in Figure 1. A local area network (LAN) connection between our measurement equipment and shared database was established to facilitate equipment control, measurement data transfer and storage. To improve measurement data analysis, a Python script was developed to automatically perform a 2D-3D γ-index analysis between the measurement plane and the corresponding TPS in-water volume for each acquired measurement. We evaluated a subset of patient plans representing the various disease sites treated at our clinic with the previous and automated methods to quantify changes in efficiency.

Results: The device connection via LAN granted immediate access to the plan and measurement information for analysis using an online software suite. Automated verification plan preparation reduced the task time by more than 50%, decreasing the time from 5-20 minutes per field to 1-3 minutes per field. The γ-index analysis time reduction is more pronounced, being reduced by an order of magnitude for all disease sites. With these automations we observed an average overall PSQA time savings of 57% per patient plan.

Conclusions: Automating routine PSQA workflow elements improves time efficiency, reduces user fatigue and focuses efforts on evaluation of key quality metrics**.**

Verification plan preparation with ESAPI

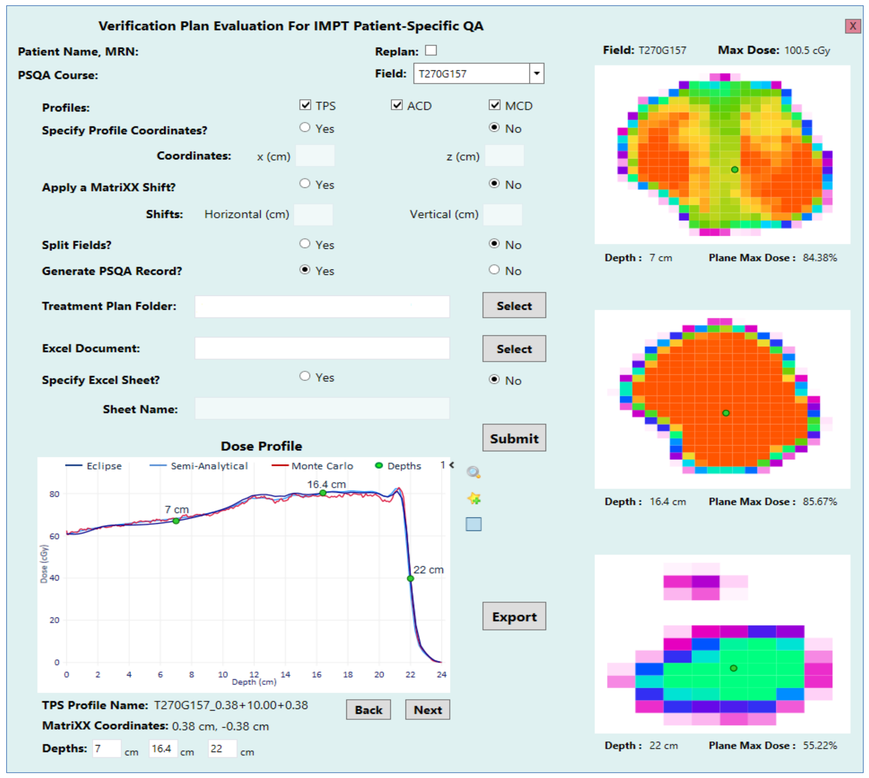

Figure 1. The ESAPI script interface performs an automated gradient evaluation of each verification field to identity a region for point dose and depths for planar measurements. Advanced features allow the user to interact with the search algorithm, displays visual feedback of planes selected for measurements and instantly exports the profile data for the TPS and second check dose calculations.

2D-3D Gamma analysis with Python

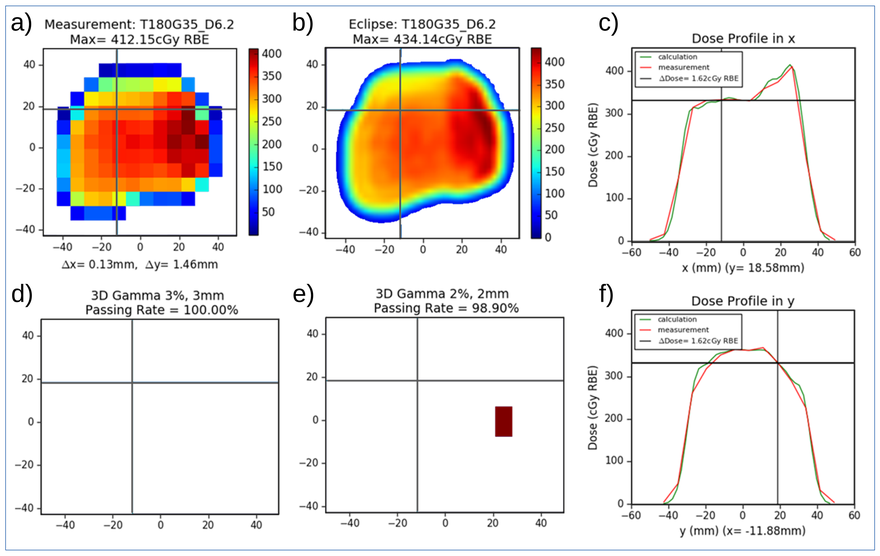

Figure 2. Automated 2D-3D gamma analysis report for field T180G35 at prescription depth of 6.2 cm a) acquired measurement plane, b) TPS plane at matching depth, c) dose profile along x direction, d) result of 3%, 3mm gamma analysis, e) result of 2%, 2mm gamma analysis and f) dose profile along y direction.

Changes in efficiency

Verification plan preparation with ESAPI:

- Display of depth dose profiles for user review
- Dose profiles automatically drawn and exported for TPS and second check doses
- Suggestion of proximal, prescription and distal depths for dose measurements
- Preparation completed in 1-3 minutes per field

2D-3D γ-index analysis script with Python:

- Image registration algorithm included to correct for setup positioning
- Additional degree of freedom finds depth-to-agreement distal to target
- Simultaneous 2%/2mm and 3%/3mm analyses
- Integrated summary report generation
- Analysis completed in 2-8 minutes per plan

Overall Time Savings:

- Average time savings of 57% per patient plan with automated PSQA tasks

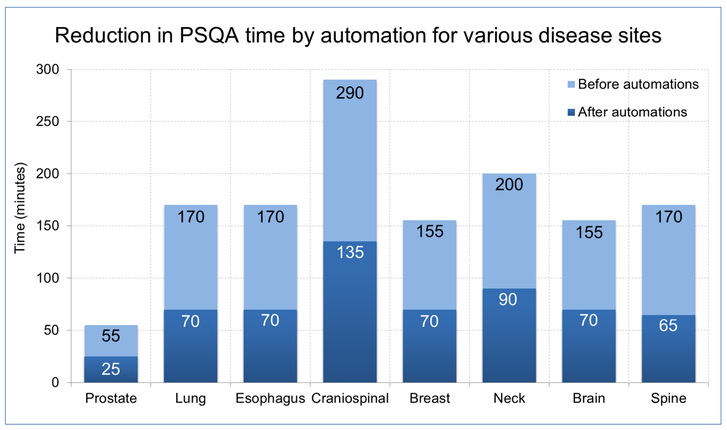

Figure 3. Comparison of the time spent on PSQA for various disease sites with manual and automated components.

References

1. Zhu XR, Li Y, Mackin D, et al. Towards effective and efficient patient-specific quality assurance for spot scanning proton therapy. Cancers. 2015; 7(2): 631-647.

2. Arjomandy B, Sahoo N, Ciangaru G, Zhu R, Song X and Gillin M. Verification of patient-specific dose distributions in proton therapy using a commercial two-dimensional ion chamber array. Med Phys. 2010; 37(11): 5831-5837.

3. Wendling M, Zij, LJ, McDermott LN, et al. A fast algorithm for gamma evaluation in 3D. Med. Phys. 2007; 34: 1647–1654.