Real-Time Patient Specific Quality Assurance
RT PSQA

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Introduction

Background

Patient-specific quality assurance (PSQA) is essential for verifying the data integrity and safe delivery of particle therapy treatment plans. Comparison of dose plane measurements with the treatment planning system (TPS) is the traditional standard for PSQA. Recently, new techniques, which are simultaneously more effective and efficient, have been implemented. Mayo Clinic Rochester has adopted such a process, which incorporates log file analysis of delivery records along with a Monte Carlo dose second check calculation.[1] In spite of these improvements, PSQA is still a resource intensive program, as it requires delivery of each plan before treatment. In a prospective real-time PSQA process, all checks are performed immediately prior to treatment.

Motivation

Real-time PSQA allows for increased clinical efficiency, as dedicated beam time is not required to delivery QA fields. Faster plan turnover, including the option for same-day delivery, is thus possible. Real-time PSQA capability also removes an important obstacle toward real-time adaptive planning, which would enable treatments to be customized on the fly to account for daily differences in patient anatomy and positioning.

Methods

Real-Time QA Process

Mayo Clinic Rochester, in cooperation with Hitachi Ltd., has developed a real-time QA process. Initially, a daily treatment localization image would be acquired with the patient on the treatment couch. Our facility is equipped with diagnostic quality CT-on-rails scanners in two of our treatment rooms, which provide the high Houndsfield Unit fidelity necessary for accurate proton dose calculations. Plan adaptation would be performed on this scan, and the quality of this adapted dose would then be verified using an independent dose calculation.

Aside from the re-optimization, the challenging aspect of real-time PSQA is confirming that the treatment machine will deliver the plan properly to the patient without a pre-treatment dry run. This is addressed by the procedure outlined in Figures 1 and 2. Once the Radiation Oncologist and Medical Physicist have approved the adapted treatment plan, it is transferred to an independent QA computer. In parallel, the plan enters the treatment preparation process, and is transferred first to the treatment machine's DICOM Worklist Manager (WLM). From here, it is translated into machine parameters, and is sent to the Treatment Control Station (TCS). Prior to delivery, a copy of these machine parameters are exported back to the QA computer, which uses an independent translation algorithm to convert the machine parameters back into DICOM format for comparison with the originally exported plan. This ensures that the plan about to be treated is the same one reviewed by the Radiation Oncologist, and that the integrity of the translation of the treatment field into machine code is verified. Following this verification by the QA computer, and the validation of the dose via the dose second check calculation, the adapted plan is ready for treatment.

Comments

- It is imperative that all translation rules undergo comprehensive QA testing. Comparison of post-delivery log files and an original DICOM plan is one element of this.
- Independence of the QA computer from the delivery system is vital for ensuring that systematic errors are detected.

Figure 1: Real-Time Proton PSQA Process Flow

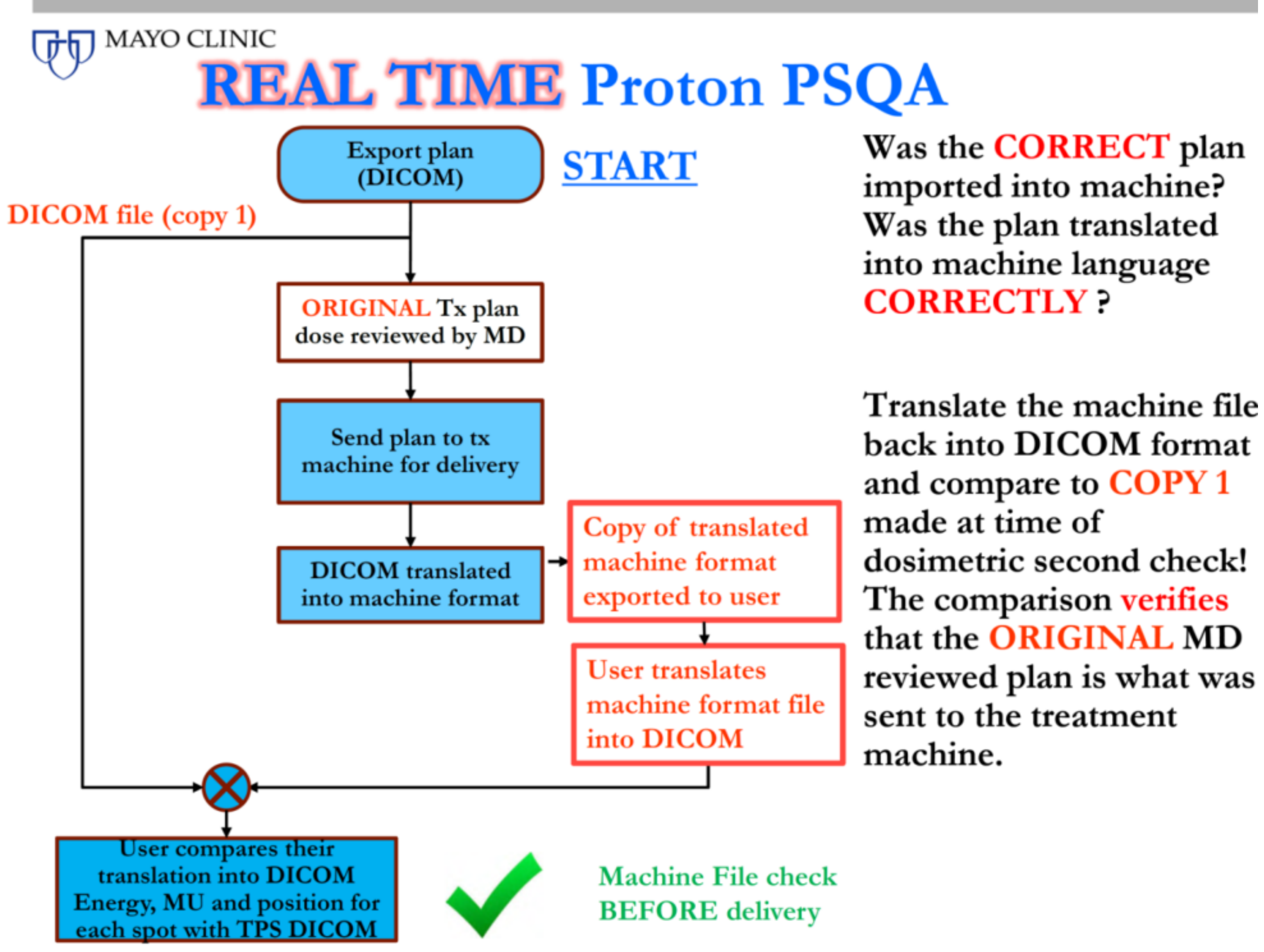

Fig.1: The process flow for the pre-treatment delivery verification of the proposed real-time PSQA procedure.

Figure 2: Real-Time Proton PSQA Systems

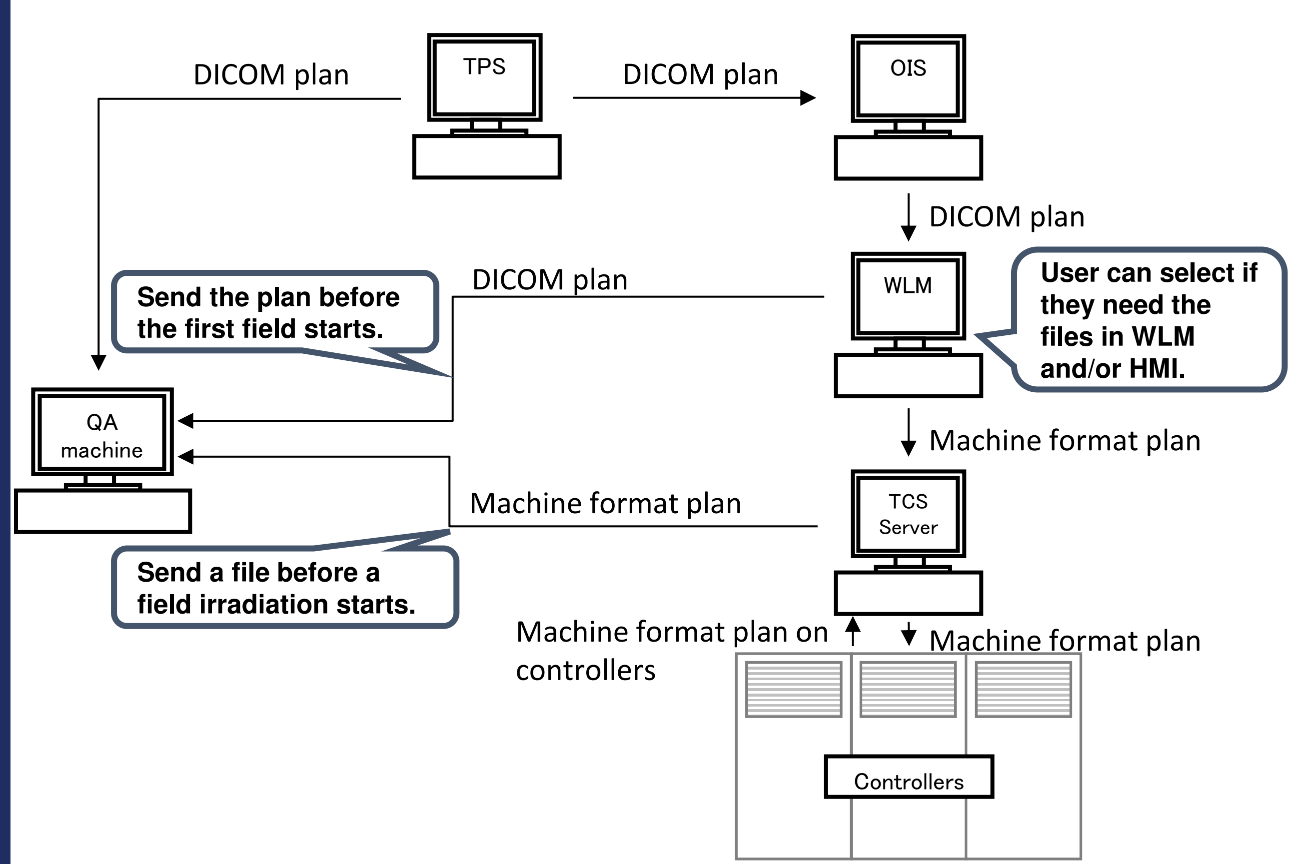

Fig.2: Diagram showing the flow of information between systems in the proposed real-time proton PSQA procedure.

Machine Parameters Validated in Real-Time PSQA

- Patient ID
- Treatment Machine
- Field Type
- Patient Name
- Field ID
- Field Name
- Cumulative MU
- Gating Flag
- Applicator ID
- # of Aperture pieces
- Range Shifter ID
- Ridge Filter ID
- Couch Top ID
- PRM Setting
- Beam Energy
- Beam Intensity
- Spot Position
- Spot MU

References

1. Johnson JE, Beltran C, Wan Chan Tseung H, Mundy DW, Kruse JJ, Whitaker TJ, Herman MG, Furutani, KM. (2019) Highly efficient and sensitive patient-specific quality assurance for spot-scanned proton therapy. PLOS ONE 14(2): e0212412. https://doi.org/10.1371/journal.pone.0212412