Beam Parameters of Pediatric Plans with a Pencil Beam Scanning Proton System and Their Effects On Patient-Specific Quality Assurance

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1. INTRODUCTION

Proton therapy is one of the most advanced modalities in radiation therapy. When compared to photon therapy, proton therapy is superior in terms of maximizing dose to the target(s), while minimizing dose to the surrounding healthy tissues [1,2]. Pencil beam scanning (PBS) in which the beam is magnetically scanned across the target volume [3] can achieve optimum target dose conformality. Pediatric proton therapy presents unique technical aspects of treatment planning and beam delivery.

Prior to patient treatment, all proton plans undergo patient specific QA (PSQA). The commonly accepted PSQA measurements for proton therapy is to measure dose at different depths using a chamber array followed by a 2D or a 3D gamma analysis. [4] The dose map from the delivered beam is then compared with the calculated dose from the treatment planning system (TPS) using gamma analysis.

To our knowledge, no study has been performed on the effect of beam parameters on the passing rate of PSQA for pediatric patients treated with PBS proton therapy.

2. PURPOSE

To report beam parameter values of pencil beam scanning (PBS) proton plans for pediatric patients and to study their effects on the passing ratios (PRs) of PSQA. We included analysis of PSQA based on beam parameters such as range, modulation, MU, and the number of energy layers.

3. METHODS

- PSQA results for 280 pediatric patients, which included 1257 treatment fields, were retrospectively analyzed. Treatment sites were craniospinal irradiation (CSI) (81 plans), fourth ventricle (71 plans), suprasellar (63 plans) and a variety of other sites.
- 2678 measurements were included. Each measurement was performed with a commercial 2D detector array at a specific depth in a solid water phantom. Two or three depths (*d*) for each treatment field were measured. If a measurement failed, it was repeated at different depth(s).

3. METHODS (CONTINUED)

- All treatment plans were optimized using a commercial treatment planning system.
- A gamma passing ratio of 90% with 3%/3mm criteria was defined as the clinical tolerance.
- Beam parameters included in the analysis were range, modulation, single-field uniform dose (SFUD) or multi-field optimization (MFO), MU, number of spots, range shifter use and number of energy layers.
- MATLAB (2018a) and Excel were used to perform data analysis.

4. RESULTS

4.1: Reporting PBS proton beam parameters for pediatric patients

- In this work, we report beam parameter values of pencil beam scanning (PBS) proton plans for pediatric patients. Figure 1 shows frequency histograms of range (1a), modulation (1b), MU (1c) and number of spots (1d). The data shown in this figure include all 1257 treatment fields delivered with a PBS proton therapy system.

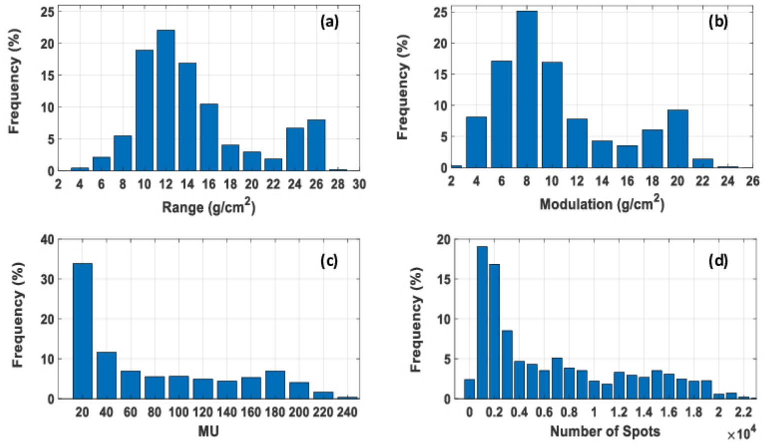

Figure 1: Frequency histograms of range (a), modulation (b), MU (c) and Number of spots (d) in 1257 proton fields delivered for pediatric patients receiving PBS proton therapy.

4. RESULTS (CONTINUED)

4.2: The effects of beam parameters on the passing ratios (PR) of PSQA

- The analysis revealed that 97% of the fields passed the QA. Figure 2 shows a scatter plot of the PRs plotted with respect to range and MU (2a), and modulation and MU (2b).

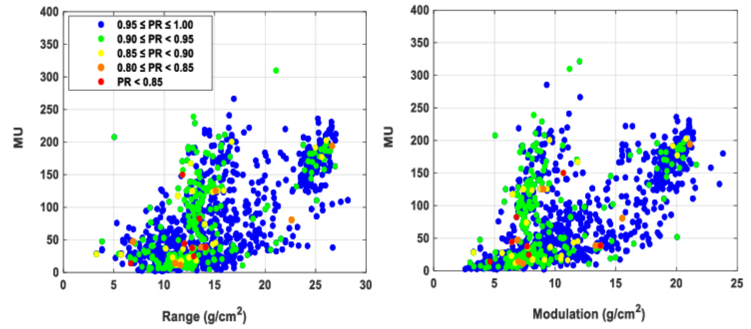

Figure 2: Scatter plots of the PRs as a function of range and MU (a) and modulation and MU (b)

4.3: Re-analysis of failed PSQA at planned depths of ±2 mm of the measured depths

- Among the treatment fields which had failed measurement depths (3%), 77 % were MFO fields. The low PRs were attributed to the complex intensity modulated dose distribution at the measured depths. This was confirmed by re-analysis of the measured data with calculation at depths ±2 mm from the nominal depths. When the measured data point failed the gamma analysis, a different depth was selected. Seventy percent of the originally failed data have passed PSQA when compared with the planned doses at *d*+2 mm.
- Figure 3 shows a box plots of the original failed data (a), failed data re-analyzed at *d*-2mm (b) and failed data re-analyzed at *d*+2mm (c).

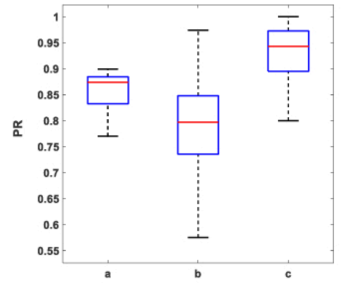

Figure 3: Whisker plots of the PRs of the original failed data (a), failed data re-analyzed at *d*-2mm (b) and failed data re-analyzed at *d*+2mm (c) The red lines represent the median PR. The lower and upper boundaries of the blue boxes represent the 25th and 75th percentiles respectively. The lower and upper whiskers represent the maximum and minimum PRs respectively.

CONCLUSIONS

- This work reports PSQA results along with beam parameter values extracted from our unique pediatric proton plans for various disease sites.
- Ninety Seven percent of the plans passed PSQA, and 70% of the fields that failed QA were MFO fields. The failure of these measurements was attributed to the complex intensity modulated dose distribution at the measured depths.
- When the measured data were compared with the planned doses at *d*+2 mm, most of the data passed QA. This systematic observation may suggest that the water equivalent thickness of the 2D commercial detector buildup material was larger than the actual value used for measurement.
- No strong correlation was found between the beam parameters and the PRs.

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