Feasibility study of a verification method for proton and carbon ion radiotherapy plan delivery accuracy check

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Abstract
Background All plan verification systems available for particle therapy are designed for pre-treatment verification. The plan delivery accuracy during treatment are unknown. The purpose of this study is to introduce a verification method and develop a software for proton and carbon ion plan delivery accuracy check.

Methods A program was developed using Matlab to reconstruct dose from beam parameters recorded in log files and compare the dose reconstructed with the dose calculated by treatment planning system (TPS). Ten carbon ion plans and ten proton plans were enrolled in this study for algorithm validation, sensitivity analysis and plan delivery verification. The dose reconstruction algorithm was validated by comparing the dose calculated by TPS with reconstructed dose using the same beam parameters. The sensitivity of gamma pass rate to spot size deviation, position deviation and particle number deviation were analyzed by comparing dose reconstructed from pseudo plans which have manually added errors with original plan dose. Then plan delivery verification using homemade software were done for the 20 actual treated plans.

Results A program for plan delivery verification was developed. For the validation of dose reconstruction algorithm, the mean dose difference between reconstructed dose and plan dose were 0.70% ± 0.24% and 0.51% ± 0.25% for carbon ion and proton plans, respectively. According to our simulation, the Gamma pass rate of carbon ion beam is more sensitive to spot position deviation and particle number deviation, and the Gamma pass rate of proton beam is more sensitive to spot size deviation. For the actual plan delivery verification using homemade software, the mean gamma pass rate were 99.47% ± 0.48%, 99.36% ± 0.50% and 99.48% ± 0.50% for carbon ion beams and 99.92% ± 0.13%, 99.96% ± 0.06% and 99.89% ± 0.13% for proton beams at three different depth of high dose region using 3mm/3% criteria.

Conclusions A software was programed and the algorithm was verified. The method we introduced and the software we made for plan delivery verification is feasible and reliable. The verification method presented in this study can be easily repeated in other hospital.

Full Text
Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Tables
Due to technical limitations, the tables are only available as a download in the supplemental files section.

Figures

Figure 1
Diagram of the beam application and monitoring system (BAMS) which consist of three ion chambers (IC and IM) and two multi-ware proportional chambers (MW). Spot size, spot position and particle number in each spot is measured by the BAMS and are recorded in log file.
User interface of the homemade software and an example of verification. Subplot titled “PBR” is the reconstructed dose in water-phantom at selected depth. Subplot titled “Vx Dose” is the dose calculated by TPS imported to the software. Subplot titled “pass rate” shows the gamma pass rate and spots do not pass the gamma criteria, which are in red color. Subplot titled “gamma histogram” shows the gamma index distribution. Left part are the buttons for data import and dose reconstruction and edit boxes for setting dose reconstruction and gamma analysis parameters. Right part are edit boxes for analysis results and buttons for data export.
Figure 3

Variation of gamma pass rate with the changes of spot size deviation level, spot position deviation level and particle number deviation level respectively. 3mm/3% criteria was used in Gamma analysis.

Supplementary Files
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table2.JPG