MR Guided Adaptive Radiotherapy Improves Target Coverage and OAR Sparing: Dosimetric Analysis of 1185 Adaptive Fractions and 4 Years Experience

Deshan Yang, Hyun Kim, Olga Green, Bin Cai, Lauren Henke, Jochen Cammin, Bruce Gu, Harold Li, H Michael Gach

Department of Radiation Oncology, School of Medicine, Washington University in St. Louis

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INTRODUCTION & AIM

Early data in limited patient numbers indicate MRI guided online adaptive radiotherapy (MRGRT) for abdominal cancers could spares critical GI OARs. This study assesses all previously adapted fractions of the Viewray (VR) Co-60 machine at our institution. Dosimetry metrics on patients' treatment day anatomy between adapted plans vs original plans are compared. The aims are to determine the reasons and corresponding rates necessitating plan adaptations and to quantify target coverage changes.

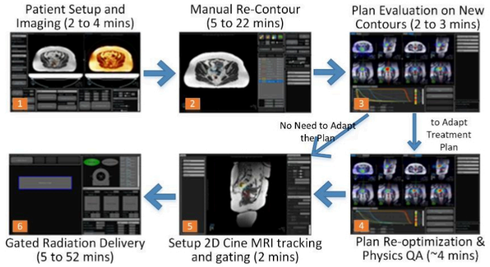

Fig. 1: MRIGART workflow and the average time by each step.

METHOD

All abdominal cancer patients (N=137) previously treated with MRGRT on the VR Co-60 machine from 2015 to 2019 are included. Sites were pancreas (98), adrenal (11) and unspecified abdomen (28). A total 961 (81.1%) out of 1185 fractions were adapted. Plan adaptation conditions were 1) the target was edited, or 2) any critical OAR constraints were violated, or 3) target coverage was significantly worse (V95 reduction >10%). For each adapted fraction, dose was calculated using a Monte Carlo engine for both the original plans and the adapted plans. MATLAB scripts were developed to 1) process treatment plan data files, 2) identify the case-specific targets and OARs, 3) compute DVH metrics (V95%Rx and D95% for the targets, and V>constraint for the OARs), and 4) analyze the results.

METHOD

Motivations:

Published studies of few patients' cases have shown the effectiveness of MRgRT on sparing abdominal GI organs. This large-scale study is designed to confirm such effectiveness over years, and to discover other potential positive or negative effects that haven't been reported, e.g. whether target coverages become worse on average on the adapted plans.

Key works:

1. A procedure (Fig. 2) was developed to automatically process the adapted plans for all previous adapted fractions.
2. MATLAB scripts were developed to implement the procedure, and to analyze the results.

Prior works to support this study:

1. Monte Carlo dose calculation engine for Viewray Co-60 plans [2,3].
2. MATLAB utilities to read and process Viewray treatment plan data files [3].
3. MATLAB utilities to read and process DICOM dose and DICOM structure files [1].
4. MATLAB utilities to compute DVH metrics from structure data and 3D dose volumes [1].

Additional details:

- DVH metrics are V95%, V100% and D95% to the tumor target (GTV for the most cases, and CTV for remaining cases)
- Critical OARs are stomach, duodenum, small bowel, large bowel, esophagus, spinal cord.
- Standard prescription dose and fraction settings are:
  - SBRT – 50 Gy in 5 fractions, OAR constraints are V36Gy < 0.5cc, spinal cord V25Gy < 0.5cc
  - Hypofractionation – 67.5 Gy in 15 fractions, OAR constraints are V50Gy < 0.5cc, spinal cord V40Gy<0.5cc

Discussion:

- Only the adapted plans on our Viewray Co-60 machine were covered so far because our current Monte Carlo dose calculation engine only supports the Co-60 machine. Plans on our Viewray MRI-Linac will be added before the AAPM 2020 meeting. Dose will be recalculated for the un-adapted plan inside Viewray TPS then exported for data processing. The manual data preparation and exporting would take a lot of efforts.
- Only pancreas, abdomen and adrenal cases were included because such cases accounted for >90% of all adapted treatments. Prescriptions and OAR constraints were very standardized for the included cases, and quite heterogeneous for the excluded cases.
- Only the simplest analyses are finished so far (see the Results). Results of more advanced analyses, e.g. to measure the inter-fractional OAR displacements case by case, will be ready before the AAPM 2020 meeting.

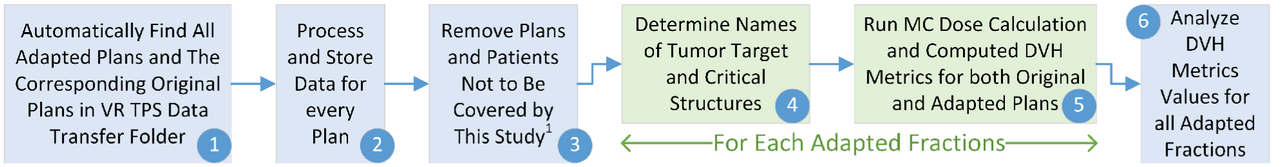

Fig. 2: The workflow for automatically processing and analyzing all Viewray Co-60 adapted fractions. At step 3, all plans except of pancreas, adrenal and non-specified abdomen cancers are excluded. Plans do not follow the standard fractionation and prescription dose settings were also excluded.

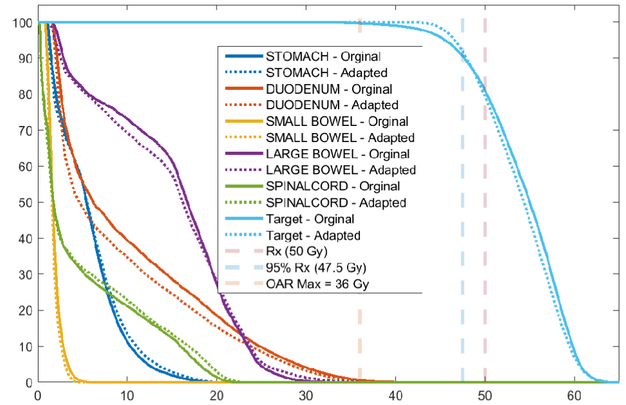

Fig. 3: DVH plots of an adapted case in which the 36 Gy constraint was not met by duodenum in the un-adapted original plan.

RESULTS

Data of 961 adapted treatment fractions were processed and analyzed. The analysis shows that 1) critical OARs were edited for 100% cases, 2) tumor targets were edited for 90 (9.4%) cases, 3) critical OAR constraints were violated for 870 (90.5%) cases by the un-adapted plans, 4) plan optimization objectives were edited for 33 (3.4%) cases and 5) all critical OAR constraints were met in all (100%) adapted plans, 6) target coverages were improved for 888 (92.4%) cases with the adapted plans compared to un-adapted plans that were normalized to meet OAR constraints.

A DVH comparison plot is shown in Fig. 3.

CONCLUSIONS

After more than 5 years, results continue to confirm that adapted plans provided significantly better target coverage while preventing violation of critical OAR constraints.

ACKNOWLEDGEMENTS

AHRQ grant R01-HS022888, NIBIB grant R03-EB028427.

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CONTACT INFORMATION

Dr. Deshan Yang. yangdeshan@wustl.edu