Function-Guided Planning In Liver SBRT Using Gadoxetic Acid–Enhanced MRI

Claire Zhang, PhD, Janell Dow, Madhava Aryal, PhD, Dan Polan, PhD, Borislav Hristov, MD, Joseph R. Evans, MD, Kyle Cuneo, MD, Randall K. Ten Haken, PhD, Martha M. Matuszak, PhD, Daniel T. Chang, MD, Yue Cao, PhD, Theodore Lawrence, MD, PhD and Lise Wei, PhD, University of Michigan, Ann Arbor, MI

UNIVERSITY OF MICHIGAN
RADIATION ONCOLOGY

MEDICAL PHYSICS COMMUNITY INSPIRATION INNOVATION IMPACT
2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

ABSTRACT

Purpose: To evaluate the dosimetric benefit of incorporating MR-based functional dose objectives into liver stereotactic body radiation therapy (SBRT) planning.

Methods: Fourteen patients with hepatocellular carcinoma (HCC) treated with SBRT underwent dynamic gadoxetic acid–enhanced liver MRI as part of an IRB approved treatment protocol. Voxel-based gadoxetic acid uptake rate (k1) maps were generated and registered to planning CT images. Function-guided plans were retrospectively generated by introducing additional optimization constraints to limit the volume of high-function liver receiving ≥5 EQD2Gy and ≥15 EQD2Gy. Function-guided plans were compared against clinical plans. Paired comparisons were performed using the Wilcoxon signed-rank test.

Results: Compared to standard clinical planning, function-guided planning resulted in measurable reductions in dose to functional liver regions. On average, k1 V5EQD2Gy and k1 V15EQD2Gy decreased by 8.4% and 7.8%, respectively, and the mean dose to high-function liver volume was reduced by 2.2 EQD2Gy. All functional dose metrics showed statistically significant improvement, with the largest effect observed for k1 V15EQD2Gy ($p < 0.001$). Target coverage was largely preserved, with only minimal reductions of 0.8% in PTV D95 and 1.0% in D99, both remaining within clinically acceptable limits.

Conclusions: This study demonstrates the dosimetric impact of incorporating gadoxetic acid–based functional mapping and MRI-derived functional dose metrics into liver SBRT planning. Function-guided optimization enables patient-specific sparing of high-function liver tissue with minimal changes in target coverage.

CONTACT

Lise Wei, PhD
liswei@umich.edu

INTRODUCTION

- SBRT is an effective treatment for hepatocellular carcinoma (HCC); however, toxicity risk increases in patients with large intrahepatic tumors and compromised liver function[1]
- Prior studies have shown that dosimetric metrics within high-function (k1) liver regions correlate significantly with post-SBRT changes in albumin–bilirubin (ALBI) score[2]
- Incorporating functional dose metrics into SBRT planning therefore has the potential to improve liver function preservation and clinical outcomes..[2,3]
- This work introduces a function-guided liver SBRT planning framework that directly integrates gadoxetic acid–enhanced MRI-derived hepatic function (k1) maps into the treatment optimization process.

METHODS AND MATERIALS

➢ *Patient cohort:*
Fourteen patients with HCC treated with SBRT were retrospectively identified.

➢ *Functional imaging and mapping:*
Dynamic gadoxetic acid–enhanced liver MRI was performed for all patients, and gadoxetic acid uptake rate (k1) maps were quantified to characterize regional hepatic function. High-function liver was defined as voxels with k1 values exceeding 10% of the maximum hepatic k1 value, applied consistently across all patients, and contoured as a high-function liver region.

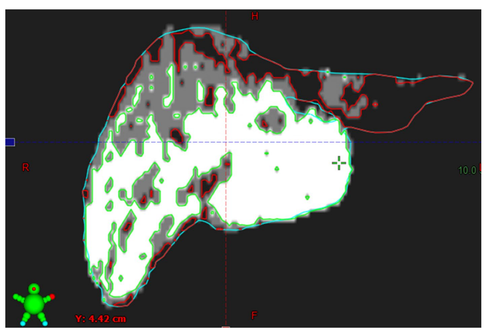

Figure 1: Example of k1 mapping from coronal view. High functional liver is contoured in green (bright area), and low functional liver is contoured in read (dark area).

➢ *Function-guided planning:*
Function-guided plans were retrospectively generated for each patient by adding dose constraints to the high-function (k1) liver region during plan optimization.

➢ *Plan evaluation*:
Function-guided plans were compared against clinical plans using planning target volume (PTV) coverage (D95% and D99%), functional DVH metrics (k1 V5 EQD2Gy and k1 V15 EQD2Gy), and mean physical and equieffective doses to the high-function liver region.

RESULTS

- All function-guided plans reduced the volume of high-function liver receiving either 5 EQD2Gy, 15 EQD2Gy, or both.
- The median [range] reduction in k1 V5EQD2Gy following function-guided planning was −6% [−45%, 7%]
- The median [range] reduction in in k1 V15EQD2Gy was −6% [−31%, 0%].
- All function-guided plans met clinical acceptable target coverage, with only minimal reduction of 0.8% in PTVD95 and 1.0% in D99.
- The degree of functional sparing depends on the relative size and spatial relationship between the target and high-function liver regions.
- Some patients demonstrated substantial functional dose reduction (Figure 2), whereas others showed minimal improvement (<1%) to maintain clinically acceptable target coverage.

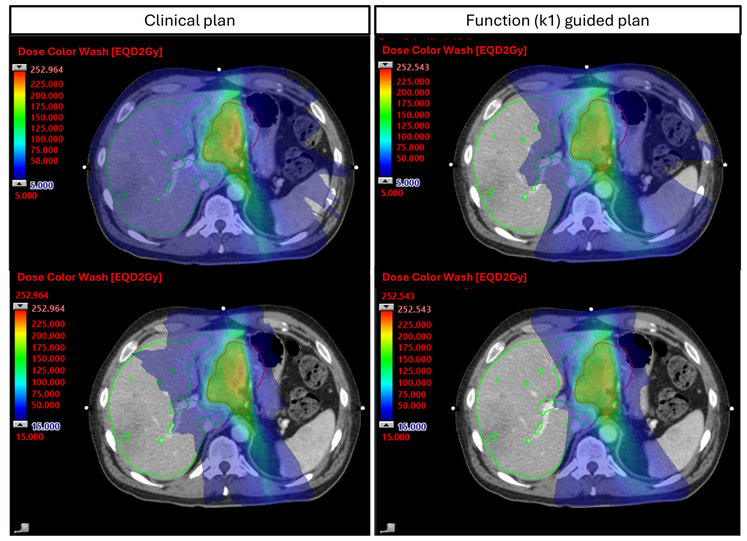

Figure 2: Illustration of substantial reduction of k1 V5EQG2Gy and k1 V15EQD2Gy using function-guided planning. The high function (k1) region was registered to CT images and contoured in green, and the target is contoured in red.

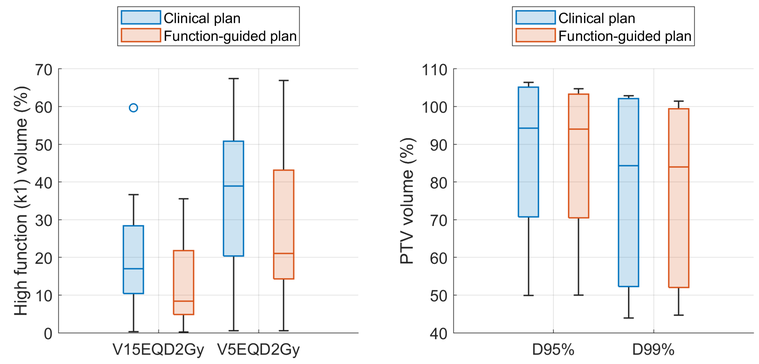

Figure 3: Boxplots of DVH comparison between clinical plans and function-guided plans.

DISCUSSION

- There is variations on the improvement of functional regions from the functional-guided planning. Patient selection is needed to choose the patients that will benefit most from it.
- We hypothesize that the degree of reduction of 5 EQD2Gy, 15 EQD2Gy is related to tumor size, location in the liver, and the distribution of the liver function, which we will investigate in future work.
- The relation between reduction of functional liver volume using function-guided planning with global patient liver function after radiation needs to be tested in a prospective clinical trial to further validate the effectiveness.
- Acquiring Eovist scan is not a standard of care and takes longer than standard MR contrast agent, using T1 mapping or perfusion parameters to represent liver function may be simpler and faster.
- This work is a preliminary study on a small cohort, results will be further validated in a large group.

CONCLUSIONS

- Our results demonstrate dosimetric advantages associated with incorporating gadoxetic acid–based functional mapping and MRI-derived functional dose metrics into liver SBRT planning.
- These findings highlight the potential value of developing predictive models to identify patients most likely to benefit from function-guided planning.
- Future work will focus on patient-specific factors and statistical modeling to optimize patient selection for function-guided SBRT planning in liver cancer treatment.

REFERENCES

1. Wei, Lise, et al. "The effect of stereotactic body radiation therapy for hepatocellular cancer on regional hepatic liver function." International Journal of Radiation Oncology* Biology* Physics 115.3 (2023): 794-802.
2. Wei, Lise, et al. "Assessing the relationship between mr-based functional dose metrics and post-stereotactic body radiation therapy albumin-bilirubin change." International Journal of Radiation Oncology* Biology* Physics 122.3 (2025): 690-697.
3. Tadimalla, Sirisha, Wei Wang, and Annette Haworth. "Role of functional MRI in liver SBRT: current use and future directions." Cancers 14.23 (2022): 5860.