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JOINT AAPM | COMP MEETING
MEDICAL PHYSICS COMMUNITY · INSPIRATION · INNOVATION · IMPACT

Radiation Dose Response of Renal Parenchyma Assessed by CT Contrast Enhancement Change Following Kidney Stereotactic Body Radiotherapy

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INTRODUCTION

Rationale/Impact: Preservation of renal function is critical in kidney Stereotactic Body Radiotherapy (SBRT). While clinical constraints typically rely on whole-organ dose metrics (e.g., mean dose), radiation nephrotoxicity is a local phenomenon involving complex parenchymal tissue changes that lead to functional decline.

- *Imaging surrogate:* Kidney parenchymal radiodensity (Hounsfield Units) on portal venous CT reflects iodine accumulation, a function of local perfusion and glomerular filtration.
- *Hypothesis:* The paired pre- and post-treatment contrast-enhanced CT scans can be analyzed, to quantify renal parenchyma functional changes in response to radiation dose for patients treated with kidney SBRT. Radiation-induced injury manifests as a measurable, dose-dependent reduction in local parenchymal contrast enhancement (ΔHU), potentially suggesting new dosimetric objectives for kidney functional sparing.

METHODS AND MATERIALS

We developed a pipeline to quantify local changes while mitigating technical variability:

- *Study cohort:* Twelve kidney SBRT patients were retrospectively analyzed in two prescription cohorts: 36 Gy / 3 fractions (n=6) and 40 Gy / 5 fractions (n=6).
- *Image processing:* Pre- and post-treatment portal venous phase CT scans were deformably registered. Post-treatment CT was normalized slice-by-slice to align mean abdominal aorta HU with the pre-treatment CT.
- *Parenchyma extraction:* Renal parenchyma was segmented on pre-treatment CT using a 20-200 HU density gate to exclude cysts and collecting systems.
- *Voxel analysis:* Voxel-wise enhancement change (ΔHU = Post - Pre) was summarized in 3-Gy dose-bin intervals to generate population-level dose-response curves.

RESULTS & DISCUSSION

Key findings:

- *Dose Response:* Both cohorts demonstrate a non-linear response where the reduction in enhancement appears to stabilize at high doses.
  - 36 Gy Cohort: Mean ΔHU decreased from approximately -7 HU in low-dose regions (<10 Gy) to approximately -16 HU at 22.5 Gy, with diminishing incremental change beyond this level (see Figure 1).
  - 40 Gy Cohort: Mean ΔHU remained near approximately -7 HU in low-dose regions (<15 Gy), then dropped sharply to approximately -20 HU at 26.5 Gy before plateauing (see Figure 2).
- Similar trends persisted in kidney-minus-PTV analyses, suggesting collateral parenchymal injury rather than tumor necrosis alone.

Interpretation and Future work: The observed "saturation" suggests that once a voxel exceeds a certain dose (approx. 22–26 Gy), local tissue function is maximally compromised.

- *Potential Planning Implication:* The observed non-linear dose–response suggests that limiting the volume of kidney receiving doses within the intermediate dose range (associated with the sharpest change in contrast enhancement) may be more relevant for kidney-sparing radiotherapy planning than focusing solely on high-dose regions where injury appears to saturate.
- *Future work:* These results are preliminary and limited by the small sample size (N=12). Validation against standard functional renal scans with expanded patient cohort is currently under way, and more comprehensive results will be presented at the APPM annual meeting.

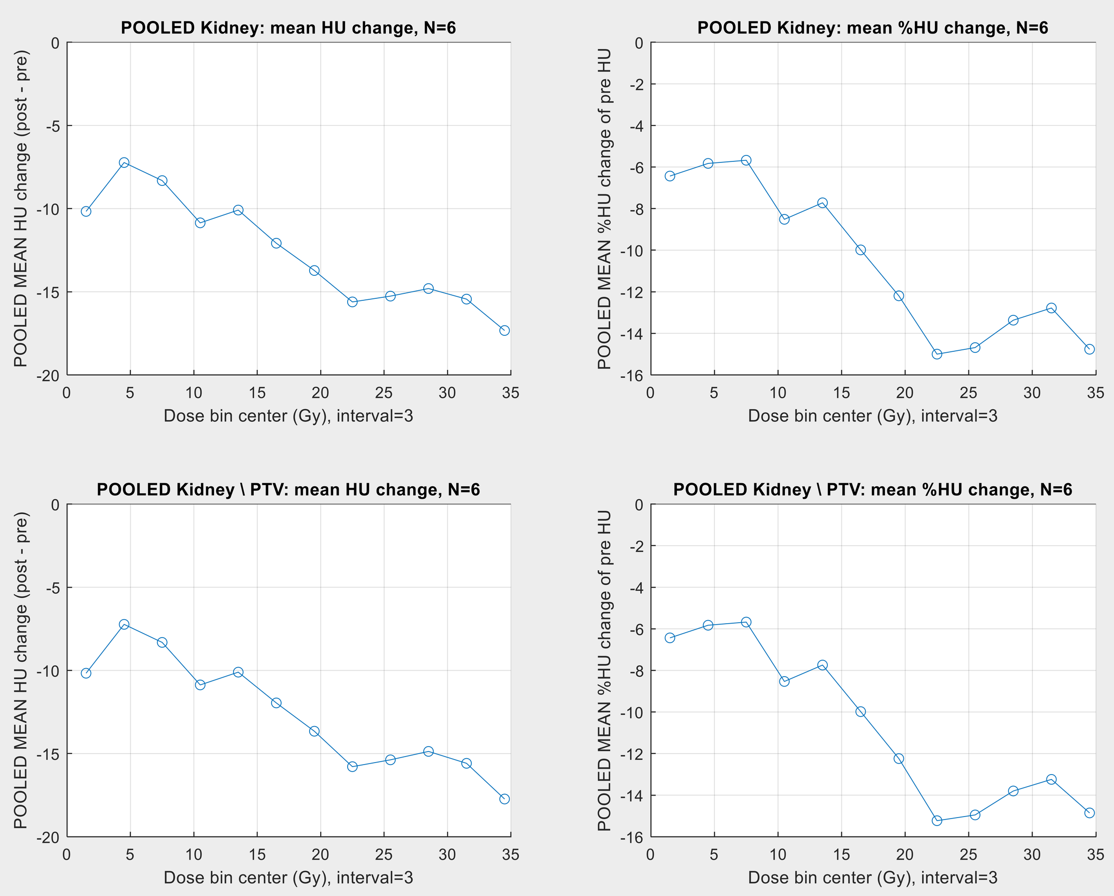

Figure 1: Mean HU change (left) and %HU change (right) for the 36 Gy/3fx cohort, showing a progressive decline that begins to stabilize at high doses.

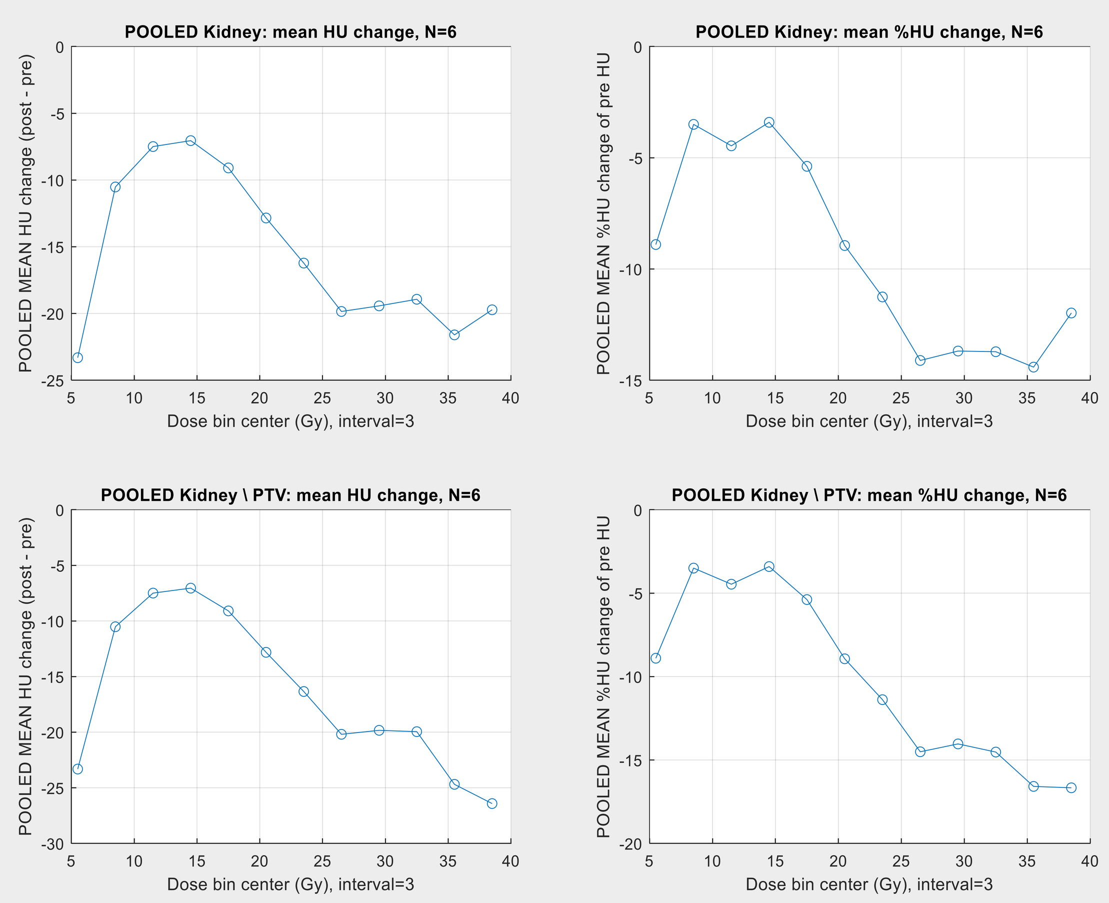

Figure 2: Mean HU change (left) and %HU change (right) for the 40 Gy/5fx cohort. A steep dose-dependent reduction is observed, flattening beyond 26 Gy.

(a)

(b)

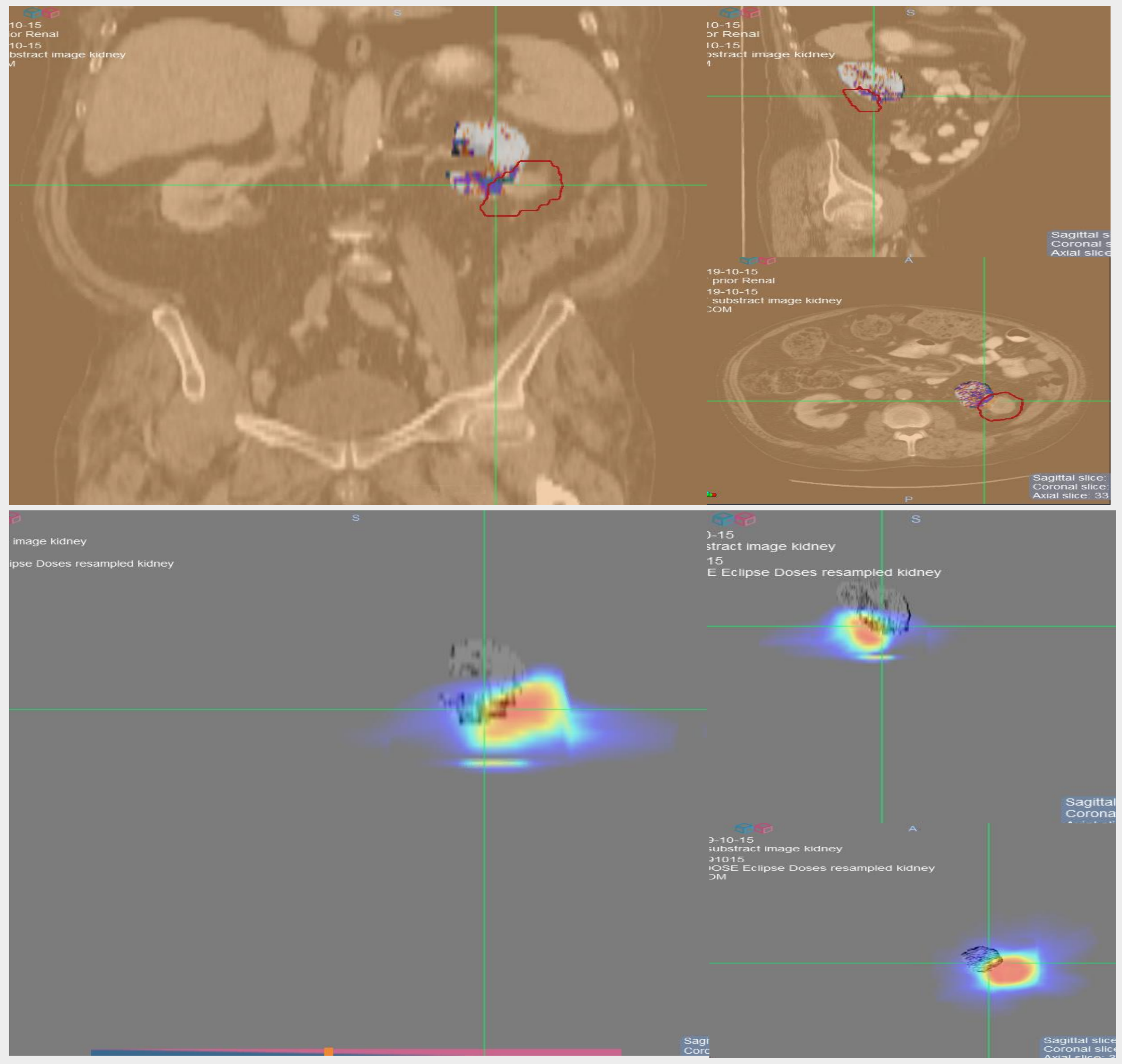

Figure 3: An example of the 3D view of the subtracted image overlaying with prior SBRT CT (a) and Dose (b).

CONCLUSIONS

Voxel-wise paired CT analysis demonstrates a dose-dependent reduction in renal parenchymal contrast enhancement following kidney SBRT. The non-linear dose-response suggests that limiting kidney volume receiving intermediate-dose ranges associated with the sharpest enhancement decline may be more relevant for kidney-sparing radiotherapy planning than focusing only on high-dose regions where injury saturates. However, this preliminary retrospective analysis is limited by small sample size (N=12). Validation against standard functional renal scans and expanded cohort analysis is underway.

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