Delta IVIM MRI As a Biomarker of Radiation-Induced Parotid Injury for Spatial Radiosensitivity Mapping

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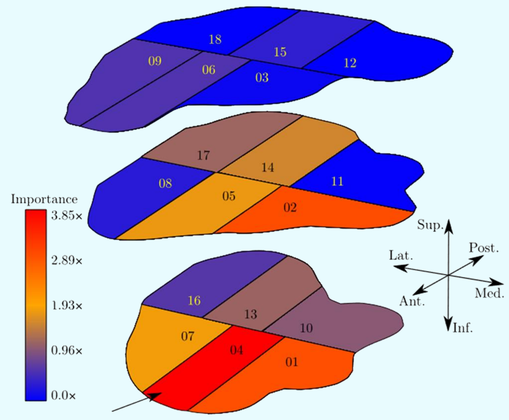
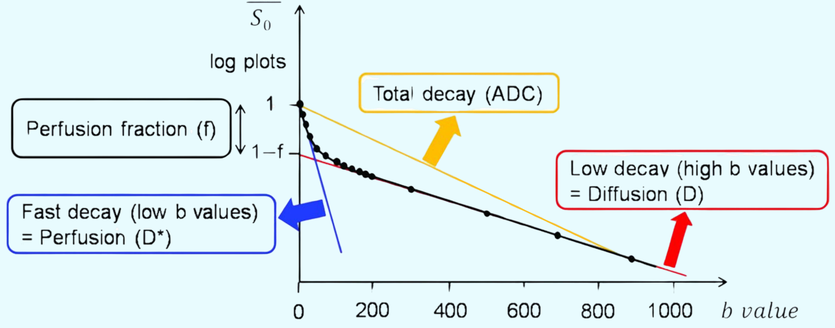
Question

Parotid glands are not uniform; can IVIM MRI show *where* they are most radiosensitive?

Introduction

- Chronic moderate-to-severe xerostomia affects roughly 30% to 40% of patients at 1-year post-treatment[1]
- Planning treats the parotid as **one uniform organ** → uses a single mean-dose constraint
- Clark's importance model predicts **caudal sub-segments dominate** salivary outcome[2]; however, it was derived from patient-reported outcomes, not from tissue
- **Intravoxel Incoherent Motion (IVIM)** separates **cellular (D)** from **vascular (D*, f)** response → ADC cannot





Conclusion

- IVIM parameters D* and D are **sensitive biomarkers** of radiation-induced parotid changes.
- Unlike conventional ADC, D* and D **separate perfusion from diffusion**
  - ➢ Potentially enables detection of radiation-induced vascular damage and cellular injury.
- Perfusion fraction (f) was **not** dose-responsive.
- Consistent spatial agreement with the importance model; larger cohorts needed for significance

Future Work

- Equal-volume sub-segments impose arbitrary geometric boundaries not based on the tissue biology.
- Habitat-based radiomics clusters voxels by their qMRI features, so each region reflects a distinct tissue micro-environment.
- Next: test whether habitat-derived radiomics can produce distinct radiosensitivity maps based on **D* and D** to distinguish between vascular and cellular damage

References

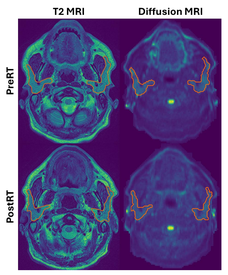
1. Nutting CM, Morden JP, Harrington KJ, Urbano TG, Bhide SA, Clark C, Miles EA, Miah AB, Newbold K, Tanay M, Adab F, Jefferies SJ, Scrase C, Yap BK, A'Hern RP, Sydenham MA, Emson M, Hall E; PARSPORT trial management group. Parotid-sparing intensity modulated versus conventional radiotherapy in head and neck cancer (PARSPORT): a phase 3 multicentre randomised controlled trial. Lancet Oncol. 2011 Feb;12(2):127-36.
2. Clark HD, Thomas SD, Reinsberg SA, Moiseenko VV, Hovan AJ, Wu JS. Heterogeneous radiotherapy dose-outcomes response in parotid glands. Converg Sci Phys Oncol. 2018;4(3):035001. doi:10.1088/2057-1739/aac8ea

Methods

1 Patients

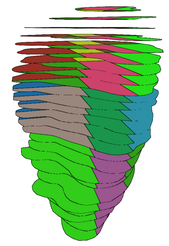
- 12 Head & neck cancer patients receiving curative (chemo)radiotherapy
- Sex: 1 f, 11 m
- Age: 62 ± 8
- Tumour location: 9 oropharynx, 3 nasopharynx

2 Data Acquisition



- DW-MRI before and after treatment with 16 b-values
- Segmented bi-exponential fit
  - D, D*, f
  - Δ = post − pre
- 4 patients excluded from D*/f (sequence change)

3 Sub-segmentation



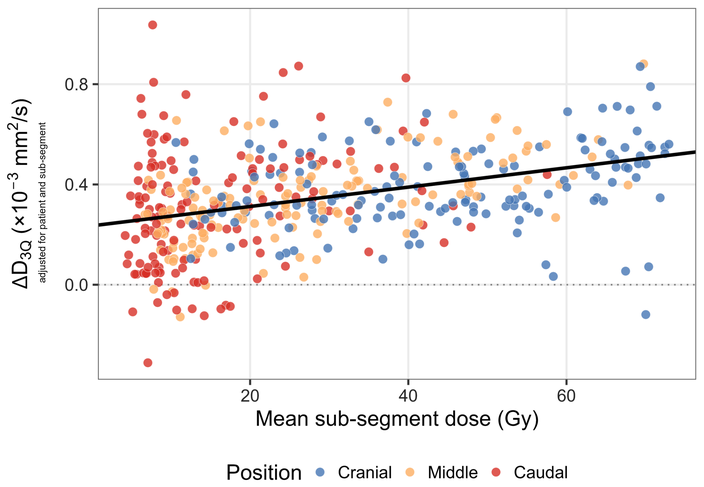
- Each gland → **18 equal-volume sub-segments**
- Mean and max dose per sub-segment
- **432 observations**

4 Analysis

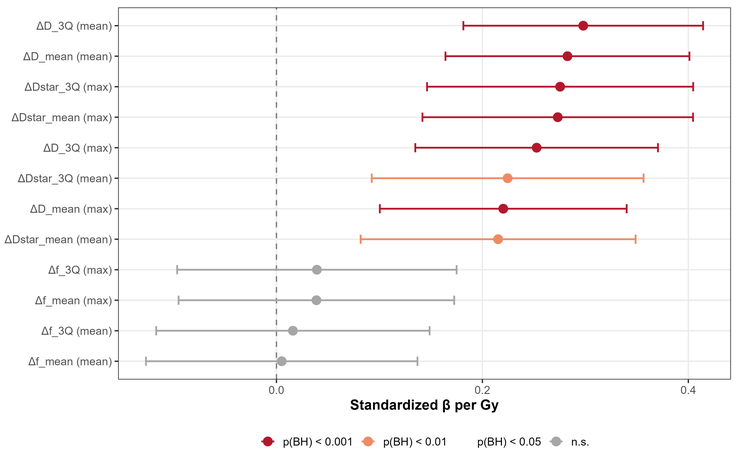
- Mixed-effects models: Δparam ~ dose + (1|patient) + (1|sub−segment)
- 12 tests, Benjamini-Hochberg (BH) corrected
- **Radiosensitivity** = response beyond what dose predicts

Results

ΔD_3Q vs mean dose: standardized β = 0.298 (95% CI 0.182 to 0.414), p(BH) < 0.0001

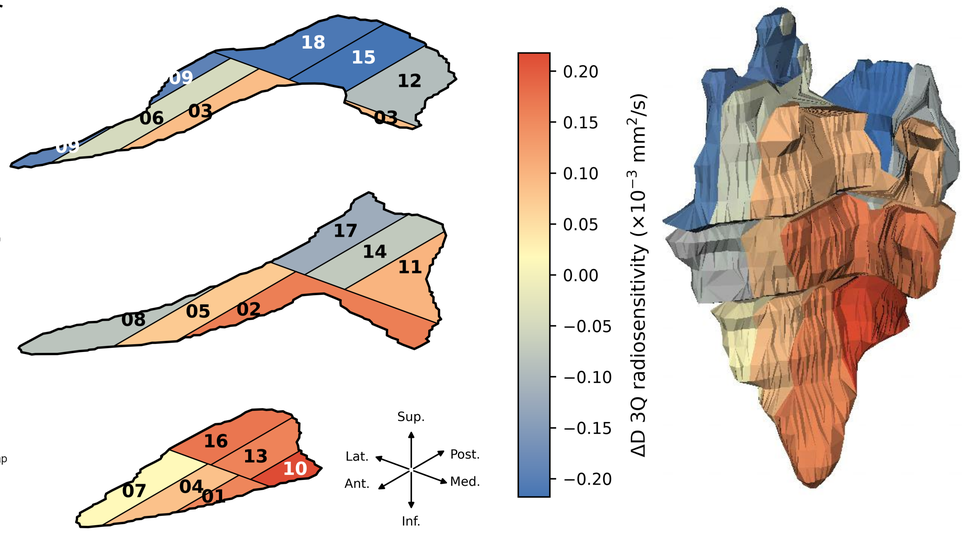


ΔD and ΔD* are dose-responsive biomarkers of radiation-induced parotid changes; Δf is not



Radiosensitivity is not uniform: caudal sub-segments respond most

Colours are the cohort's mean residuals across 12 patients and 24 glands.



The measured pattern broadly follows Clark's predicted importance

ρ = 0.41, n = 18 sub-segments.

Does not survive BH correction at this sample size.