# Radio-morphology:
# Parametric Shape-Based Features for Outcome Prediction in Radiotherapy


Pranav Lakshminarayanan[1], Wei Jiang[2], Scott Robertson[1], Zhi Cheng[1], Peijin Han[1], Michael Bowers[1], Joseph Moore[1], Junghoon Lee[1], Harry Quon[1], Russell Taylor[3], and Todd McNutt[1]

1. Johns Hopkins Medicine, Department of Radiation Oncology and Molecular Radiation Sciences
2. Johns Hopkins University, Department of Civil Engineering
3. Johns Hopkins University, Department of Computer Science

JOHNS HOPKINS MEDICINE
RADIATION ONCOLOGY & MOLECULAR RADIATION SCIENCES
ONCOSPACE


## Purpose and Objectives

- Current methods of characterizing dose distributions do not provide a spatially aware description of dose.
- **Radio-morphology** (or "dosomics") was proposed as a method to parameterize regions of interest (ROIs) and produce consistently defined, shape-based dose features, that encode the **spatial distribution of dose** at a higher resolution than organ-level dose-volume histograms (DVHs)

## Materials and Methods

The **Oncospace database** was queried for:

- Anatomical contours, as 3D binary masks
- Dose grids
- Clinical assessments and patient characteristics

The feature generation pipeline (see *Figure 1*) consists of the following steps:

**Anatomy normalization:**

- ROI masks were registered to a set of reference anatomy using a **deformable registration** algorithm.
- For binary masks, **coherent point drift (CPD)** was used for a landmark-less registration

**Geometric transformations:**

- **Scaling** transformations were used to expand or contract structures, producing shells.
- **Partitioning** transformations were used to break down structures into sub-volumes, such as slices, octants, or radial sectors.
- **Cascades of transformations** were applied to parametrically produce more complex sub-structures that encapsulate different regions of the anatomy.

**Dose feature extraction:**

- Dose grids were mapped onto the derived substructures
- Characteristics of the dose were derived, including voxel-level sampling and DVH values

Machine learning methods were applied, using the spatial-dose feature sets, to predict post-treatment clinical outcomes and **identify high importance regions** of the anatomy.

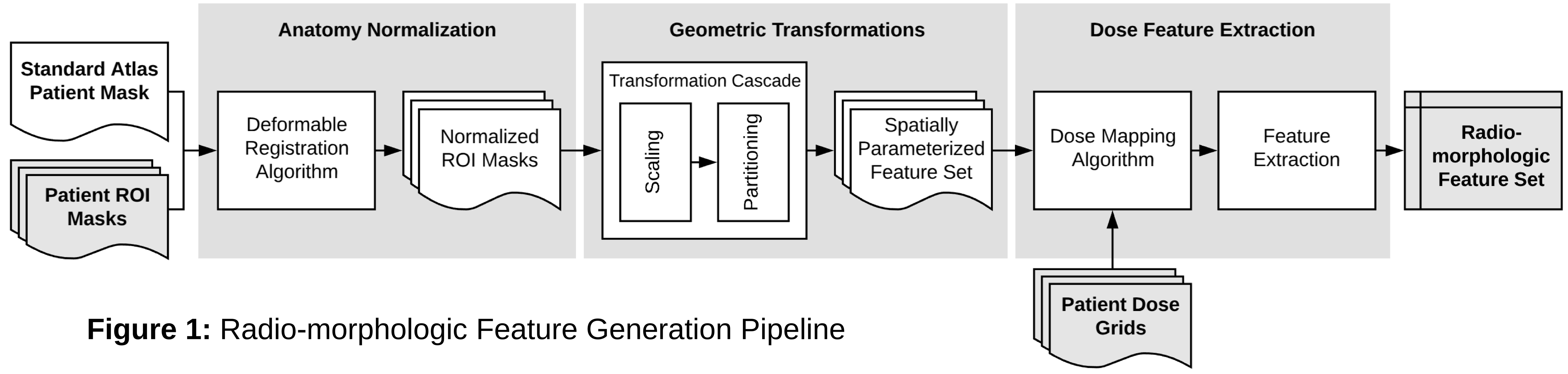



**Figure 1:** Radio-morphologic Feature Generation Pipeline

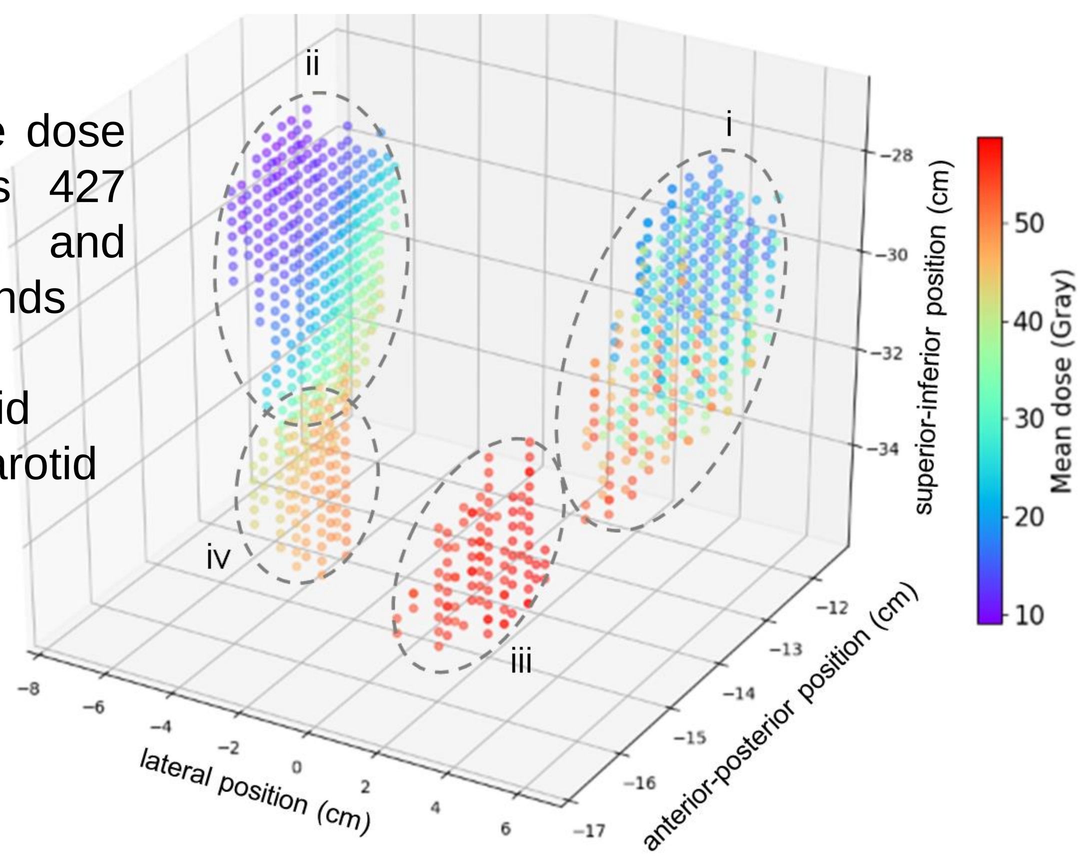
## Results

### Voxel-Based Analysis of Salivary Glands for Xerostomia

Anatomy normalization makes it possible to produce **population-level, spatial dose statistics** from spatial dose distributions, normalized across patient anatomy and tumor laterality.

**Figure 2:** Average dose distribution across 427 patients' parotid and submandibular glands

(i) Ipsilateral parotid
(ii) Contralateral parotid
(iii) Ipsilateral submandibular
(i) Contralateral submandibular




The **Ridge logistic regression** algorithm was applied to the dose-voxel data and clinical covariates to **identify influential regions** for predicting xerostomia at 3-6 months, post treatment.

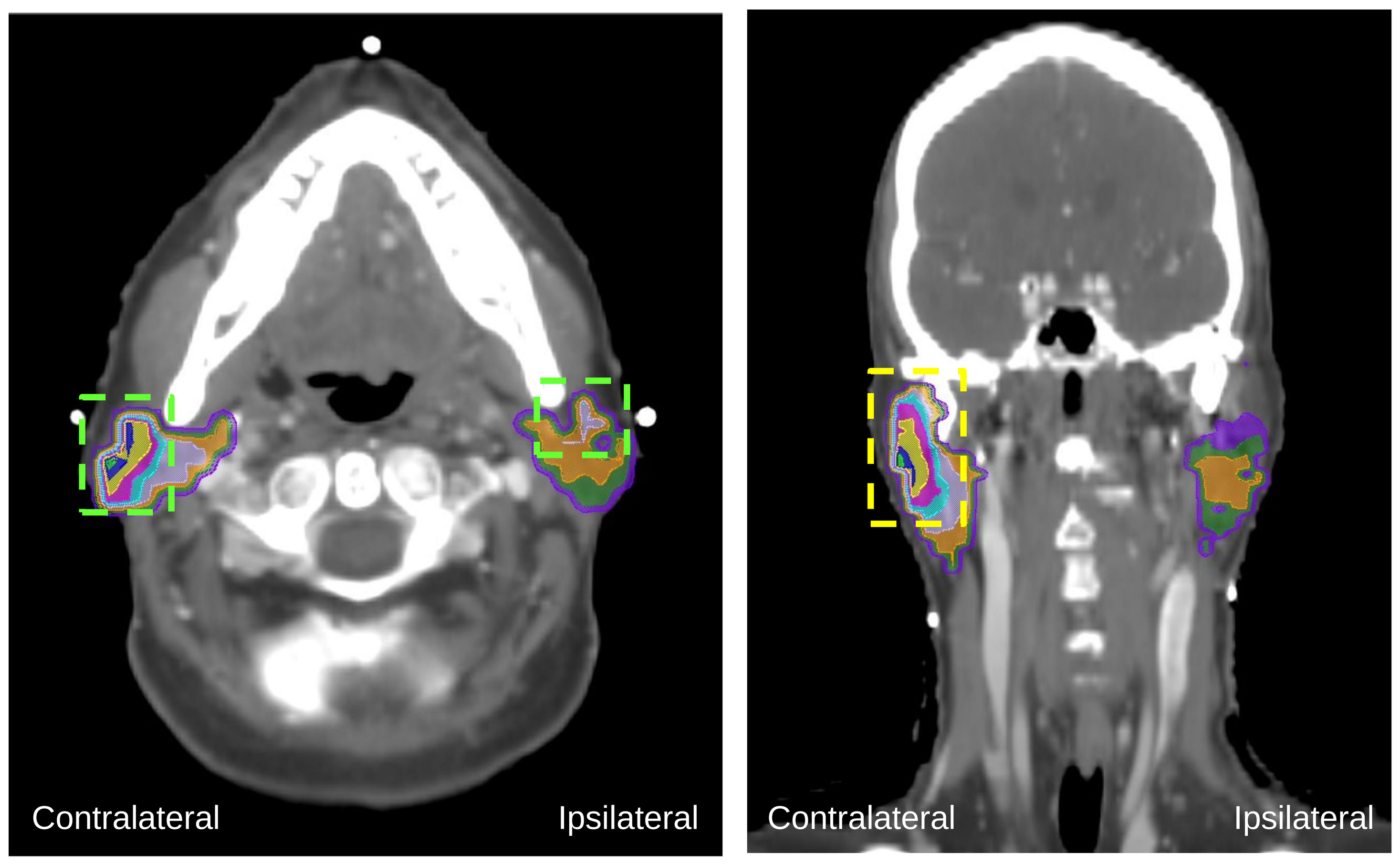
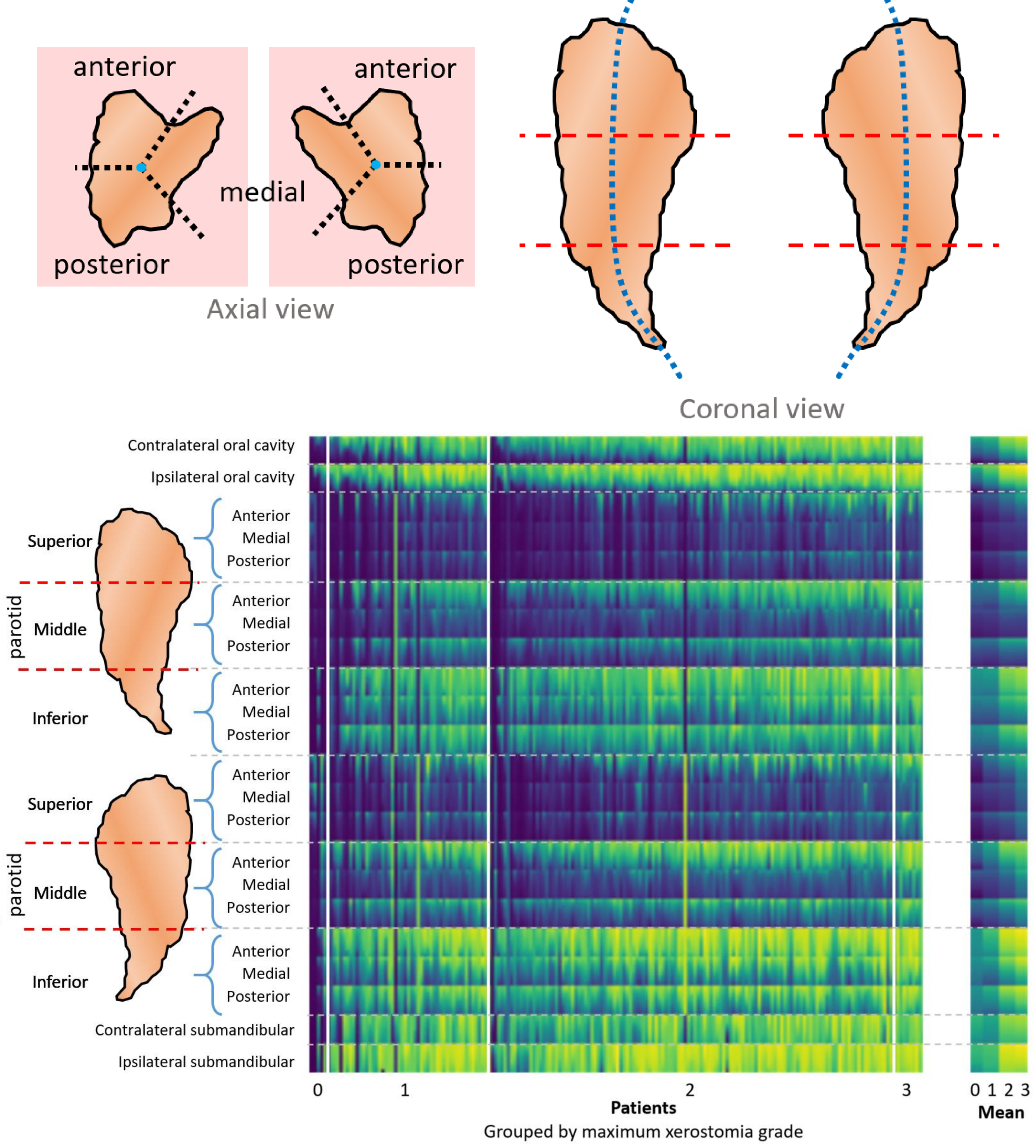



**Figure 3:** Regions of influence for prediction of high-grade xerostomia (CTCAE grade > 1) at 3-6 months post treatment, visualized on reference anatomy. Highly predictive regions were found on the contralateral parotid gland and near the ductal region of the parotids.

### High-Volume Parametric Feature Extraction

Applying a series of geometric transformations transformed a set of ROIs into a large number of **parametrically defined** and **normalized** substructures.

**Figure 4:** Geometric transformations and dosimetric features extracted from parotid glands, compared against severity of xerostomia.




## Conclusions

- The radio-morphologic feature generation pipeline provides a method to consistently and efficiently derive a large volume of **spatially descriptive dosimetric features**.
- Large scale data analysis makes it possible to further investigate the physiological effects of radiotherapy and fine tune future treatment.