A Shape-Based Dose Model for the Prediction of High Grade Radiation Induced Xerostomia for Head and Neck Cancer Patients

Pranav Lakshminarayanan[1], Todd McNutt[2], Russell Taylor[3], Scott Robertson[2], Xuan Hui[2], Zhi Cheng[2], Michael Bowers[2], Joseph Moore[2], Harry Quon[2]

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

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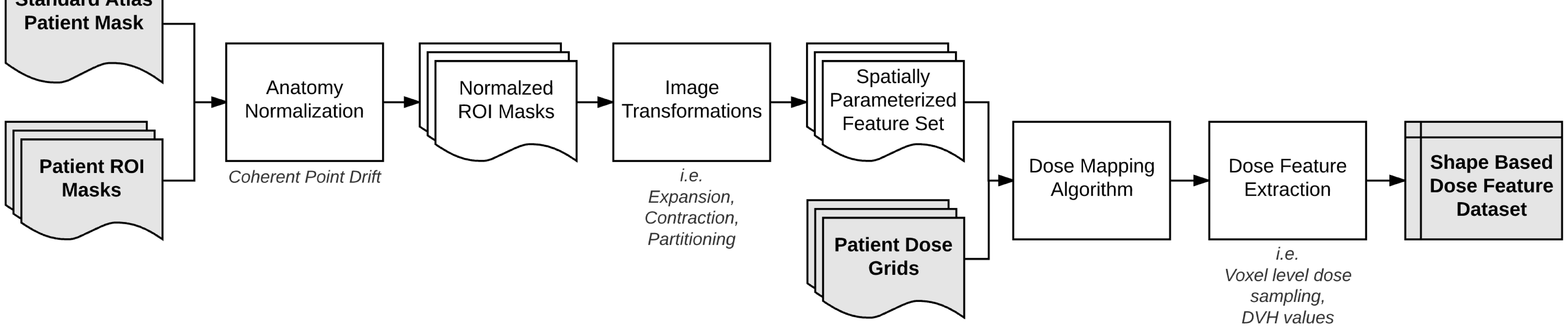
Purpose/Objectives

- Techniques to **predict and prevent** the occurrence of high grade toxicities following treatment are limited, often resulting in a decrease in quality of life of surviving patients.
- The goal of this study was to **identify regions in the parotid glands** of high importance when predicting the occurrence of high grade xerostomia.
- The use of **shape-based dose features** was proposed to parameterize relevant regions of interest (ROIs) and characterize the dose distribution at a higher resolution than organ-level dose-volume histograms (DVH).

Materials/Methods

- **Three-dimensional contoured masks** of the parotid glands, **dose grids**, and xerostomia **assessment data** from a cohort of 257 head-and-neck cancer patients treated from 2008-2015 at one institution were gathered from a **learning health system database**.
- The set of selected ROI's were normalized by **registration to a common anatomy** using a **coherent point drift (CPD)** deformable registration algorithm. CPD provides a robust registration method of patient anatomy in the form of binary masks without the need for landmarks.
- **Shape transformations** were applied to the normalized anatomy to create substructures. Transformations include geometric expansions, contractions, and partitioning into smaller regions. These transformations are composed to break down a single ROI into several smaller regions.
- For each derived structure, a patient's dose grid was mapped onto the anatomy to **extract dose characteristics**, (DVH values, voxel sampling).
- Using the dose data and baseline xerostomia grade as features, a **random forest classifier** with 10-fold cross validation was applied to predict the occurrence of a worsening of xerostomia between 6 months to 1 year post-treatment.

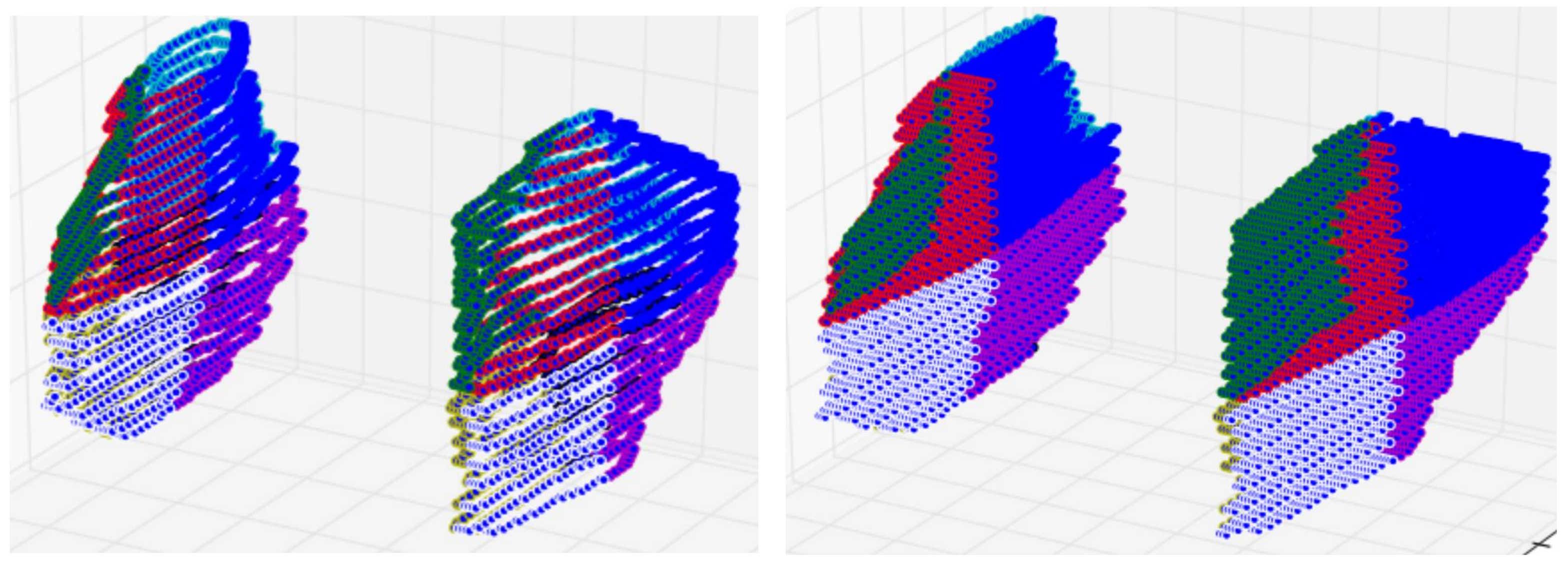
Figure 1: Shape Based Dose Feature Generation Pipeline



Results

Partitioning into Shells and Octants

For each parotid gland, shells were created with outer bounds defined by, 2 mm expansion, no expansion, and 5 mm contraction. Then, shells were partitioned into octants defined by x, y, and z axes, creating 24 substructures per gland (48 per patient). D90 and D20 were computed for each derived structure



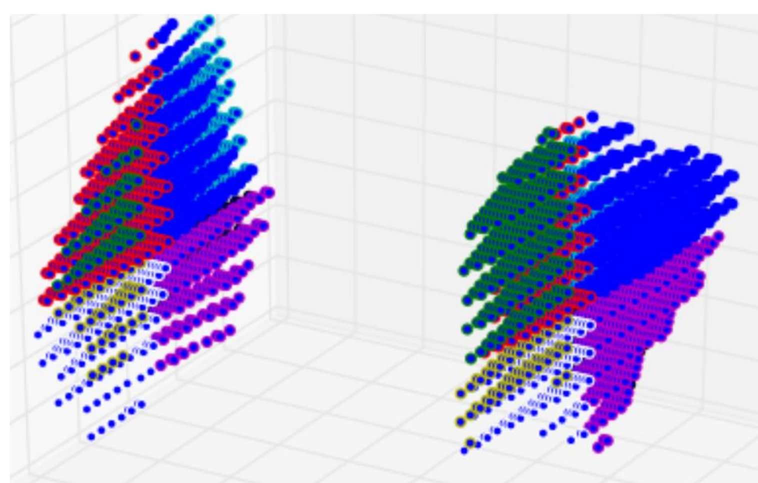


Figure 2: Visualizations of parotids partitioned into shells and octants.

Shells are bounded by:
(top left) 2 mm expansion
(above) original surface of parotid
(left) 5 mm contraction

Extract Ductal Region of Parotids

For each parotid gland, the ductal region, found on inferior medial face, was derived. DVH values from D10 to D90, in increments on 10% volume were computed.

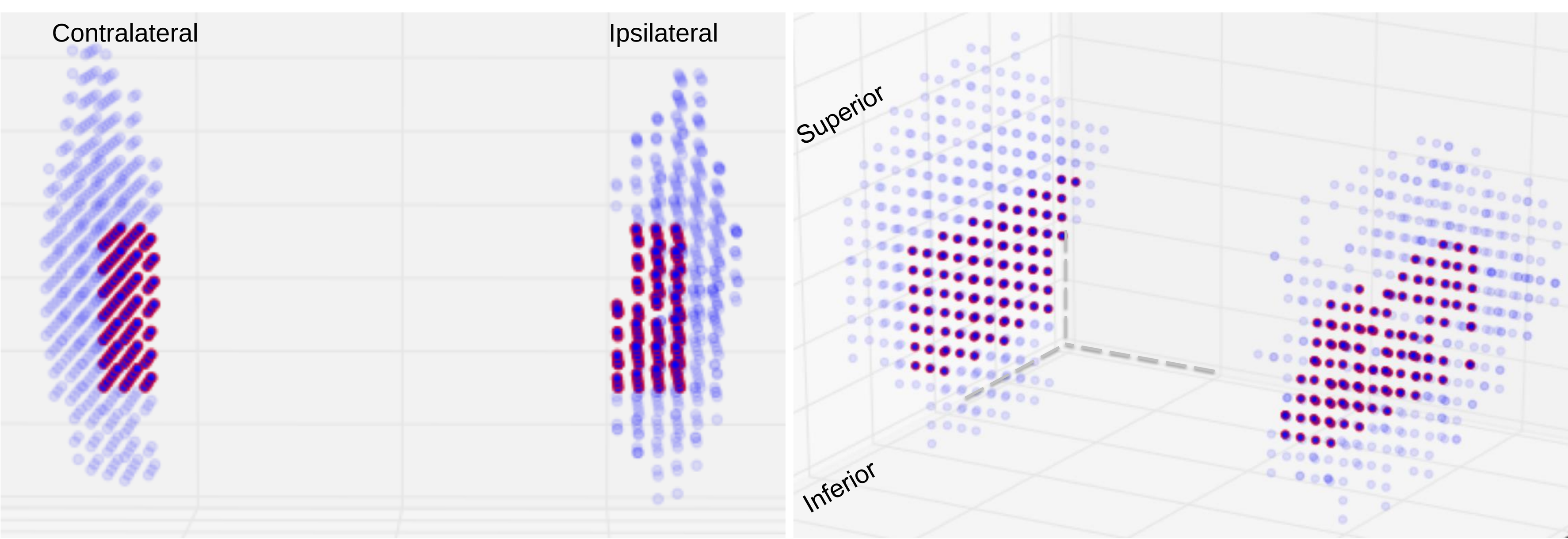


Figure 3: Visualizations of segmented ductal region on atlas patient anatomy. Coronal view (left) and 3-D view (right)

Prediction Results

A control group of organ level DVH features was tested, using D10, D20, …, D90 for both parotids. The use of shape based dose features was able to improve predictive capability.

Table 1: Measures of Accuracy of Prediction using a Random Forest classifier (n=40)

Features	Accuracy	Sensitivity	Specificity
Organ level DVH	69.76 %	80.01 %	52.50 %
Shells and Octants	76.92 %	84.62 %	61.53 %
Ductal region	73.72 %	84.47 %	58.41 %

Conclusions

- The results of this experiment support the validity of **the use of shape-based models** to characterize dose to a patient's anatomy.
- Areas near the surface of the anterior-inferior region in the ipsilateral parotid that were exposed to a high dose were deemed to have the greatest effect on the development of high-grade post-treatment xerostomia.
- Beyond the scope of xerostomia, shape-based dose models provide an **effective method to reliably interact with patient anatomy**, derive features, and learn the relationship between delivered dose and patient toxicities at a more **anatomically conscious** level than organ-level dose volume histograms.