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Incorporating Parotid Gland Sub-Region Importance Data Into the Radiotherapy Treatment Planning Process

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Purpose

Present a proof-of-concept for incorporating model-derived importance data of spatial regions within parotid glands into head-and-neck radiotherapy treatment planning

Methods

1. Contralateral parotid gland structures for 5 head-and-neck patients were partitioned into 18 sub-regions of equivalent volume, and the relative importance of each region was determined using a previously derived model[3].
2. Artificial dose base plans were created for each patient, such that each sub-region contained a uniform dose in proportion to its relative importance.
3. The most important sub-region was given 20Gy (caudal-anterior, Fig. 1), while other sub-regions' dose was $20Gy \times I$, where I is the importance of said region normalized to the most important subregion.
4. Standard institutional protocols were followed (contralateral parotid whole mean < 20Gy) while treatment plans for all 5 patients were created retroactively using the Varian Eclipse™ treatment planning system.
5. New plans were then created after loading the artificial base plans into the optimizer, and imposing an additional upper-bound constraint on the contralateral parotid (max dose < 30-33Gy). This method creates a spatially-varying dose constraint, determined by regional importance.
6. Plans created with and without the base plans were then compared to assess whether dose to important regions can be significantly lowered while continuing to meet all other planning constraints.
7. Improvements were assessed using a predictive model[1] for stimulated salivary output loss at 1 year post-radiotherapy

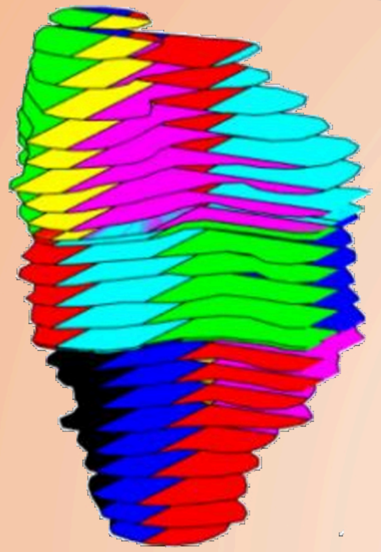
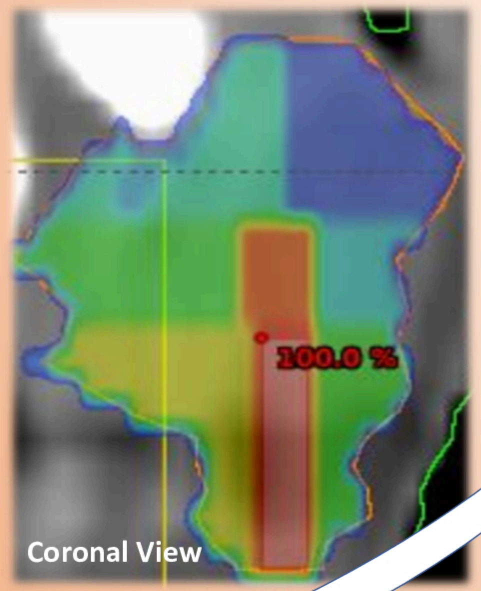
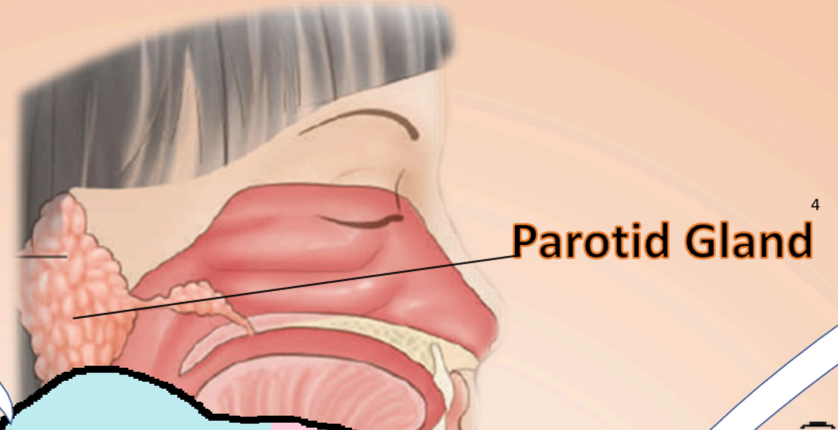


Figure 1: Contralateral parotids were spatially divided into 18 sub-regions of equivalent volume, and artificial base plans were created and loaded into Varian Eclipse™ (below), with subregions receiving uniform doses proportional to their relative importance.





Background

- Dose to the largest salivary glands, the parotid glands, during head-and-neck radiotherapy often results in damage to salivary function.
- This manifests itself as xerostomia (dry mouth), which hinders the ability of patients to swallow, speak, or taste, and causes pain, dental caries and other oral sequela.
- Volume-Modulated Arc Therapy (VMAT) allows dose to be sculpted around target volumes, avoiding organs at risk, such as the parotid gland.
- The current standard of care for minimizing the risk of Xerostomia during VMAT planning is to minimize the whole- mean dose delivered to each parotid gland.

We need to break up the parotid gland!

- Studies[1,2] have found the parotid gland to be inhomogeneous in response to dose.
  - This indicates that minimizing whole-mean dose may not be the optimal metric for preserving salivary function. The relative importance of different sub-regions within the parotid gland has recently been quantified[3]

The caudal-anterior, and middle-anterior regions have been found to be the most sensitive to radiation

- This regional-importance data can now be incorporated into the optimization of treatment plans.

Results

The whole-mean dose was lowered for each patient when plans were optimized using base plans. The dose to the most important subregion was generally found to decrease more than the whole-mean dose, or the dose to less important sub-regions.

This is shown in Figure 2 for the most and least important subregions, as well as the whole parotid.

The mean dose to the most important sub-region was found to significantly decrease using this technique (paired $t(8)=5.49$, $p<0.006$).

Improvements in salivary output retention of up to 20% of baseline were predicted, with an average improvement of 12%.

All clinical constraints were met with and without use of base plans.

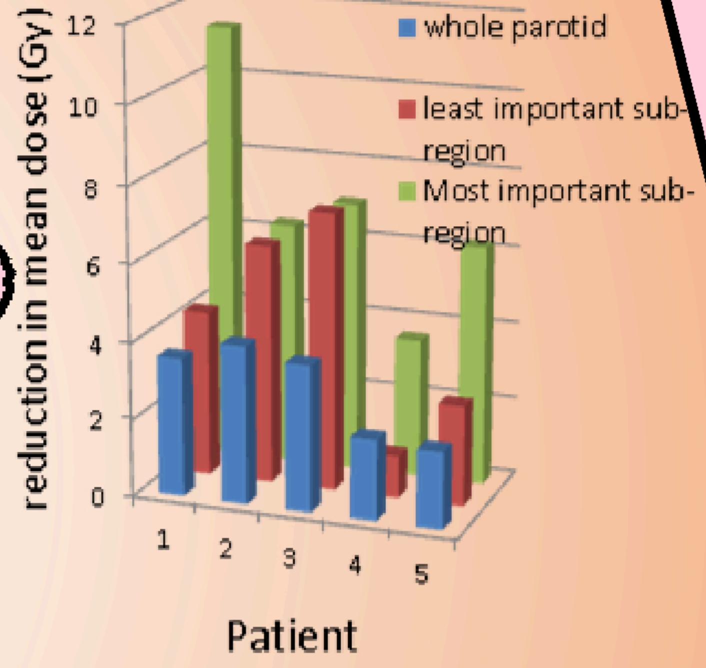


Figure 2: Planning with base plans showed a greater reduction in mean dose to the most important sub-region compared to the least important subregion or whole mean dose in 4/5 cases. Patients 2 and 3 had considerable overlap with the PTV, which may be why dose reduction is more uniform in these cases.

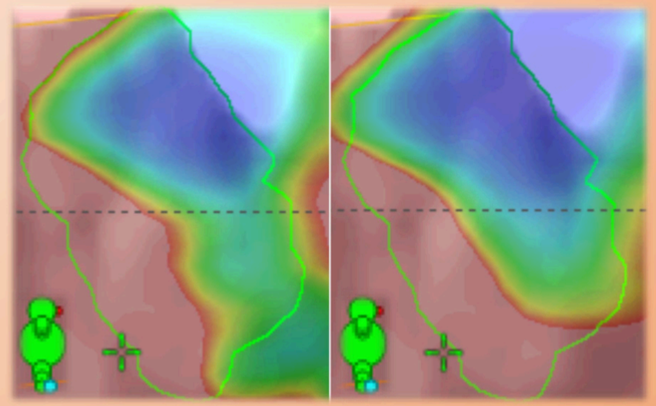


Figure 3: sagittal dose distribution for the parotid gland after planning with (left) and without (right) artificial base plans . A shift in dose away from the most important caudal – anterior region can be easily seen.

Conclusion

Minimizing the whole-mean dose to the parotid gland fails to account for the gland's spatially varying dose response.

- This study demonstrates a proof-of-concept for incorporating sub-regional importance data of the parotid glands into the treatment planning process.
- Preliminary results suggest that patient outcomes may be improved by accounting for sub-regional dose response within the parotid glands during treatment planning.
  - Moving forward, our goals include automatic incorporation of regional importance data during treatment planning without the need for base plans.

References:

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