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Volumetric Change of Selected Organs at Risk during IMRT for Oropharyngeal Cancer

The goal of our project is to create a user interface to allow oncologists and radiologists to easily segment and analyze dose-volume radiation therapy data. There is necessity for easy to use analysis tools slow, complicated process that is required to analyze data given the current tools available. The analysis process used in this investigation is an exemplar case of the limitations of current analysis methods, and because of these limitations, the insights derived from investigations like this one cannot be completed until years later.

Introduction

Radiotherapy is delivered using the assumption that the dose of radiation planned is equal to that delivered during the treatment. This assumption is not accurate in the majority of cases due to setup errors and changes in the patient's anatomy. In the case of head and neck cancers, these changes in anatomy are more likely because of the great variety of different tissues in close proximity. These changes in anatomy then increase the inaccuracies of dose delivery, delivering greater doses to the surrounding areas instead of the target. This project's aim was to quantify the dose and volume changes to various organs surrounding target oropharyngeal cancer sites.

Materials and Methods

Patients with oropharyngeal squamous cell carcinoma underwent weekly kilovolt CT scans for each week of radiation therapy in addition to their planning CT scan. A single person contoured the organs at risk for each of the CT scans for each patient. The organs observed were: the parotid glands, submandibular glands, thyroid glands, constrictor muscles, sternocleidomastoid muscles, masticatory muscles, and larynx.

The contours were made following directions from papers by specialists on head and neck anatomy. Each of the symmetrical organs at risk was labeled ipsilateral or contralateral with respect to the location of the tumor. In order to speed up the contouring, a tool from Phillips RadOnc Systems was used (after CT-CT registration based on bone landmarks) to transfer the preceding contour to the CT scan of the following week. Additionally, not all organs at risk were contoured for all patients. The organ had to be clearly identifiable in the initial scan and it had to be uninvolved in the cancer.

Depending on the clinical target volume, targets were either given a total dose of 70 Gy or 63 Gy over the course of a 7 week. Since the CT scans were not always done exactly one week apart from each other, the volume values were pooled into each week of treatment, and these were used to create a sort of histogram to depict how the volume of the organs at risk changed as the treatment went on. A second set of volumes were computed by the same observer re-contouring a random set of organs in 6 patients randomly, and blindly to the original contours, 2 months after the original contouring. Measurement error was then calculated as the absolute value of the difference between these two volume measurements, and percent measurement error was computed by dividing the absolute measurement error by the average of the two measurements for each organ at risk.

Results

Scans from 26 patients of ages 41 to 73 were compiled and then organs at risk were retroactively contoured for the study. The median weight loss of these patients during the course of the 7 week treatment was -11.2%. This is attributed to both the chemotherapy and the dysphagia caused by the radiation to the oropharyngeal area. All patients has a percutaneous endoscopic gastronomy (PEG) tube inserted either in response to reports of dysphagia or prophylactically before chemoradiotherapy. Roughly a year after treatment, 5 of the patients continue to be PEG tube dependent because of persisting or recurring treatment.

A total of 185 CT scans were taken and analyzed, from these, 26 were planning CTs and 159 were acquired during treatment. Across all the scans, there was a 1.6% mean measured error. This error seemed consistent regardless of the variability in the volume of the organs at risk and regardless of the timing of the CT scans.

The volumetric changes were the most significant part of the results. The parotid glands (PG) shrunk by the greatest volume (~10 mL), next the masticator and sternocleidomastoid muscles (MM and SCM respectively) shrank by and average of about 5 mL each. The submandibular and thyroid glands had very small reductions in volume. In contrast, the constrictor muscles (CM) and the larynx (L) had a notable increase in volume during treatment. When comparing the relative shrinkage as a percent of the total volume of the organ, both of the salivary glands (PG and SMG) had the greatest relative reduction in size, by about 30%. The thyroid gland, masticatory muscles, and sternocleidomastoid muscles shrunk by 5% -10%, and the constrictor muscles and larynx increased by an average of 15% - 20%. The changes in volume followed a roughly trend over the time of the therapy, with the only major deviation being the salivary glands' quick initial reduction, followed by a low slope linear decline. All of these volumetric changes appear to be progressive and irreversible, once an OAR's volume changed by a noticeable amount, this change was enhanced in the following weeks, never reversed.

Discussion

It cannot be determined with certainty whether or not the volumetric changes seen here are a result of the therapy or of some other factor. Similar relative and absolute volume changes were found by other studies, including one at the University of Texas M.D Anderson Cancer Center. However, the trend did seem to correlate with the cumulative dose given to the organs at risk and the volume change of the OARs. The organ that seemed to change in both absolute and relative volume as well as function the fastest is the parotid glands. This supports that doctors check the patients parotid glands on both sides as early as the second week of treatment. The explanation provided for why the larynx and the constrictor muscles increased in volume with treatment is a combination of inflammation, swelling and edema. Due to the proximity to the tumor site, the L and CM were often not spared from high doses of radiation treatment. The great swelling that ensued caused in a lot of patients severe dysphagia. It was suggested that further research be done on whether larynx and constrictor muscle sparing from radiotherapy results in a greater ability to swallow. To combat dysphagia and loss of muscle function in the affected area, patients were recommended to partake in prophylactic exercises. To combat weight loss despite dysphagia, patients were often treated with a PEG tube, but told to still attempt to ingest primarily orally so as to not lose more oral function. Finally, it was suggested that further studies are done to identify factors that predict the volumetric and physiological changes seen in these patients.

Overall Assessment

This paper provides an example of the limitations of manual volumetric analysis of the effects of radiation therapy. It was mentioned several times that their options were limited and that further work should be done to study whether reducing doses affects the organ function and patient outcomes. However, this paper did not suggest methods or tools that would improve the analysis options available to researchers and also speed up the analysis so that oncologists can analyze in depth radiotherapy's effects on the patient and maybe change the dose application if needed. Furthermore, this paper was inconclusive as to what the best course of action was to treat patients with dysphagia, it was suggested that they practice prophylactic speaking and swallowing exercises, but it was not specified how they could transition away from the PEG tube dependency.

Citation

Ricchetti F, Wu B, McNutt T, Wong J, Forastiere A, Marur S, Starmer H, Sanguineti G. "Volumetric change of selected organs at risk during IMRT for oropharyngeal cancer." Int J Radiat Oncol Biol Phys. 2011 May 1;80(1):161-8. doi: 10.1016/j.ijrobp.2010.01.071. Epub 2010 Nov 19.