

# A Novel Three Dimensional Conformal Radiation Therapy Technique to Decrease the Mean Parotid Gland Dose in Whole Brain Radiation Therapy

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## Abstract

**Purpose:** Whole brain radiation therapy remains standard for patients with multiple brain metastases not amenable to stereotactic irradiation. Incidental irradiation of the parotid glands can result in xerostomia. A novel technique (NT) using 3D conformal radiotherapy was used to decrease the radiation dose to the parotid glands and hence the risk of xerostomia.

**Methods:** CT simulations of 20 de-identified patients were randomly selected. For each patient, 3 different WBRT plans were generated. The first using the standard opposed laterals fields with the inferior border at C2, the second with the inferior border at C1 and the third using a NT. In the NT, we placed the isocenter 0.5-1 cm superior to the contoured parotid glands. Superior to the isocenter, two lateral fields were designed similar to the standard opposed laterals. Inferior to the isocenter, 2 oblique fields were used, conformal to the contoured brain, with a 1 cm collimation to the edge of the MLC. Prescription dose was 30 Gy in 10 fractions for all plans. Brain coverage and the means of the right, left and bilateral parotids were compared in each of the plans.

**Results:** In all three techniques of WBRT, brain coverage was adequate with 95% of the dose covering more than 95% of the brain volume. The average of the mean right parotid dose using C2, C1, and the NT were 17.7 Gy  $\pm$  4.4, 12.3 Gy  $\pm$  3.3, and 5.6 Gy  $\pm$  2.1. The average of the mean left parotid dose using C2, C1, and the NT were 18.3 Gy  $\pm$  4.2, 13.0 Gy  $\pm$  3.1, and 6.2 Gy  $\pm$  1.5. The average of the mean bilateral parotids dose using C2, C1, and the NT were 18.0 Gy  $\pm$  4.0, 12.6 Gy  $\pm$  2.8, and 5.8 Gy  $\pm$  1.8.

**Conclusion:** Our simple new 3DCRT technique for WBRT significantly reduces mean parotid gland dose compared to the standard techniques.

**Keywords:** 3DCRT; Radiation therapy; Parotid gland; Brain

## Introduction

Brain metastases account for more than 50% of all intracranial tumors and they affect 10%-40% of patients with cancer [1]. Radiation treatment of brain metastasis has evolved with time and currently includes stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT). However, whole brain radiation therapy (WBRT) remains the standard for patients with high tumor burden, not amenable to SRS or SRT. WBRT is also used for prophylactic cranial irradiation in patients with small cell lung cancer (SCLC) [2].

Side effects of WBRT including xerostomia were not frequently studied in the past and WBRT fields were designed using opposed lateral beams with two-dimensional imaging. Currently, with computed tomography (CT) based planning, it has been noted that the salivary glands, specifically the parotid glands, receive significant amounts of radiation using the standard opposed laterals technique that is still used nowadays [3]. In a study by Noh et al, the average mean parotid dose was 17.5 Gy (range, 10.5-26.2) for both glands in CT-based WBRT fields. Mean parotid doses of 20 and 25 Gy were observed in 34.4% and 6.3% of 64 individual glands [3]. This is a

relatively high dose, considering that even at lower mean doses of 10-15 Gy, around 50% of patients have significant loss of salivary excretion [4].

Several techniques have been suggested to decrease mean parotid dose. One strategy is using C1 instead of C2 as the inferior border of WBRT fields [5]. Another proposed technique is using the multileaf collimator (MLC) to decrease the dose to the parotid [6]. Also, some centers have tried more sophisticated planning using volumetric modulated Arc therapy (VMAT) [7] to reduce parotid glands doses. Since the interest in protecting the parotids in WBRT is relatively recent, there isn't yet an established 3DCRT WBRT technique that can replace the standard opposed laterals fields.

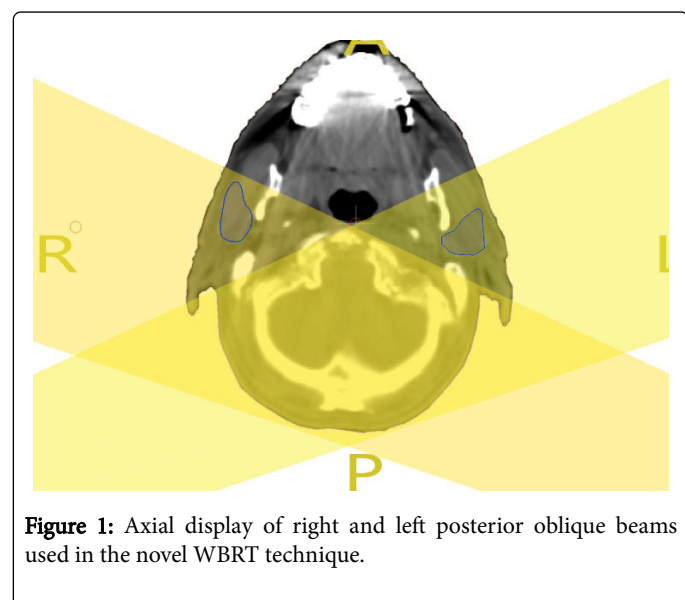
We present a study that explores the dosimetric outcomes utilizing a novel technique using 3D conformal radiotherapy (3DCRT) to decrease the radiation dose to the parotid glands and hence the risk of xerostomia.

## Material and Methods

We conducted a dosimetric study that included 20 randomly selected patients from a de-identified list of patients who received

WBRT from 2015 to 2017 at the department of Radiation Oncology at our institution. The simulation CT scans and treatment plans, already performed as part of clinical care, of the included patients were retrieved from the treatment planning system (Panther, Prowess, Concord, CA, USA).

After we contoured the brain and the parotids, three different WBRT plans were generated for each patient. The first using the standard opposed laterals fields with the inferior border at C2, the second using opposed laterals with the inferior border at C1 and the third using a novel proposed technique. In the new technique, we placed the isocenter 0.5-1 cm superior to the contoured parotid glands. Above the isocenter, two upper half-blocked lateral fields were designed similar to the standard opposed laterals. Inferior to the isocenter, two half-blocked lower fields were used, conformal to the contoured brain, with a 1 cm collimation to the edge of the MLC. The lower beams used were a left posterior oblique (angle: 115 degrees) and a right posterior oblique (angle: 245 degrees) such that each beam completely spares one ipsilateral parotid gland (Figure 1). Prescription dose was 30 Gy in 10 fractions for all plans.



**Figure 1:** Axial display of right and left posterior oblique beams used in the novel WBRT technique.

Dose volume histogram (DVH) data were generated for each of the three plans for every patient. Brain coverage and the mean doses of the right parotid, left parotid and bilateral parotids were compared in each of the three WBRT plans. Using IBM SPSS version 23, we investigated whether there's a statistically significant difference between the means of each of the above-mentioned variables among the three WBRT techniques using dependent samples t-test. Statistical significance was set at a cut-off point of  $\alpha = 0.05$ .

## Results

In all three techniques of WBRT, brain coverage was adequate with 95% of the dose covering more than 95% of the brain volume. The average of the mean right parotid dose using C2, C1, and the new technique were  $17.7 \text{ Gy} \pm 4.4$ ,  $12.3 \text{ Gy} \pm 3.3$ , and  $5.6 \text{ Gy} \pm 2.1$  respectively. The average of the mean left parotid dose using C2, C1, and the new technique were  $18.3 \text{ Gy} \pm 4.2$ ,  $13.0 \text{ Gy} \pm 3.1$ , and  $6.2 \text{ Gy} \pm 1.5$ . The average of the mean bilateral parotids dose using C2, C1, and the new technique were  $18.0 \text{ Gy} \pm 4.0$ ,  $12.6 \text{ Gy} \pm 2.8$ , and  $5.8 \text{ Gy} \pm 1.8$  (Table 1). There was a statistically significant decrease in the mean

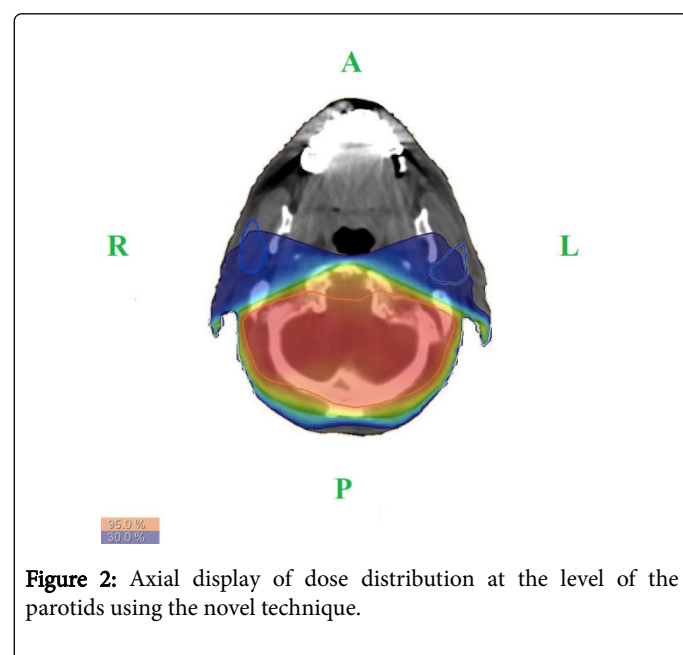
dose to the parotids, by at least two thirds, using our new technique versus the standard WBRT with the inferior border at C2 (p-value  $<0.0001$ ) and by at about a third using the inferior border at C1 (p-value  $<0.0001$ ).

	Average Mean Dose (Gy)		
	C2 Border	C1 Border	Novel Technique
Right Parotid	$17.7 \pm 4.4$	$12.3 \pm 3.3$	$5.6 \pm 2.1$
Left Parotid	$18.3 \pm 4.2$	$13.0 \pm 3.1$	$6.2 \pm 1.5$
Bilateral Parotid	$18 \pm 4.0$	$12.6 \pm 2.8$	$5.8 \pm 1.8$

**Table 1:** Average of the mean parotids dose using the three different WBRT techniques for twenty patients.

## Discussion

Our new 3DCRT technique for WBRT significantly reduces mean parotid gland dose compared to the standard C2 WBRT fields and compared to the C1 reduced fields as well. This was achieved without compromising the whole brain coverage (Figure 2).



**Figure 2:** Axial display of dose distribution at the level of the parotids using the novel technique.

Xerostomia can be quite detrimental to the patient's quality of life, and hence the interest in evaluating and subsequently limiting the dose to the parotid glands when delivering WBRT. In a prospective study by Chao et al. sparing of the parotid glands translated into objective (as measured by salivary flow) and subjective (measured by Quality of Life questionnaire) improvement of xerostomia in patients with head-and-neck cancers receiving radiation therapy [8].

When the mean dose to both parotids is limited to less than 25 Gy, it has been estimated that salivary flow will return to baseline by 12 months [9]. However, lower mean doses of 10-15 Gy can affect salivary flow [4]. This sheds light on the sensitivity of the salivary glands to radiation therapy. Flow reduction can begin within 1 or 2 weeks of radiotherapy [10] and usually persists for 6-12 months until the time of recovery from radiation damage [11]. The greatest reduction is

reported to be at around 1-3 months after radiation followed by gradual recovery [12]. This is relevant especially in context of the short life expectancy of most patients who require WBRT [13].

In a study by Orton et al. using C1 instead of C2 as the inferior border of WBRT fields, mean parotid dose was decreased from 18.3 Gy to 14.3 Gy ( $p < 0.01$ ) for a typical WBRT 30 Gy in 10 fractions plan [5]. In another study, using the multileaf collimator to shape the fields and spare the parotids, the mean parotid dose was lowered to 9.63 Gy [6]. Cho et al. reported on 53 patients, where averages of mean parotid dose using conventional opposed laterals fields versus modified fields conformal to the brain parenchyma were 17.4 Gy versus 8.7 Gy, respectively ( $p < 0.001$ ). Mean parotid dose of both glands  $\geq 20$  Gy were observed in 28.3% for conventional fields and in 0.0% for the modified fields [14]. Our study shows similar reduction in mean parotid dose with C1 versus C2 as the Orton et al. study. However, our new technique was able to decrease the mean parotid dose even further (5.8 Gy) compared to these different techniques mentioned above. Incremental dose reduction in parotid mean dose has been linked to better salivary flow. Modeling results from a study by Chao et al. suggest an exponential relationship between salivary flow reduction and mean parotid dose. The stimulated salivary flow at 6 months after treatment is reduced at a rate of approximately 4% per each additional Gray of mean parotid dose [8].

Some centers have tried more sophisticated planning using volumetric modulated Arc therapy (VMAT) [7] to reduce parotid glands mean and maximum doses. In their study on 10 patients, Sood et al. reported on reduction of the parotid glands mean and maximum doses from  $12.8 \pm 4.9$  Gy and  $30.6 \pm 0.5$  Gy using non-conformal WBRT to  $4.4 \pm 1.9$  Gy and  $15.7 \pm 5.0$  Gy using VMAT, respectively. Another similar study by Pokhrel et al. also re-planned WBRT of 10 patients using Intensity Modulated Arc Therapy (IMAT) with dose reduction of mean and maximum parotid glands dose of 65% and 50%, respectively, compared to conventional non-conformal WBRT fields [15].

Those Intensity modulated radiation therapy (IMRT) studies show the closest values to the currently reported technique. However, it's worth noting that IMRT, as a costly and sophisticated treatment modality, is not readily available in all countries, and when available, not always covered/reimbursed by insurance companies.

A minor disadvantage of our new technique compared to the conventional WBRT fields is the mild increase in planning and treatment time, given the use of four instead of two fields.

## Conclusion

Our new 3DCRT technique for WBRT significantly reduces mean parotid gland dose compared to the standard WBRT fields and can potentially decrease the risk of xerostomia and thus improve patients' quality of life. This simple technique can be practically used even in the setting of limited resources.

## Conflict of Interest

The authors declare that they had read the article and there are no competing interests.

## Funding Statement

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