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A quantitative assessment of volumetric and anatomic changes of the parotid gland during intensity-modulated radiotherapy for head and neck cancer using serial computed tomography

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ABSTRACT

To evaluate the change in volume and movement of the parotid gland measured by serial contrast-enhanced computed tomography scans in patients with head and neck cancer treated with parotid-sparing intensity-modulated radiotherapy (IMRT). A prospective study was performed on 13 patients with head and neck cancer undergoing dose-painted IMRT to 69.96 Gy in 33 fractions. Serial computed tomography scans were performed at baseline, weeks 2, 4, and 6 of radiotherapy (RT), and at 6 weeks post-RT. The parotid volume was contoured at each scan, and the movement of the medial and lateral borders was measured. The patient's body weight was recorded at each corresponding week during RT. Regression analyses were performed to ascertain the rate of change during treatment as a percent change per fraction in parotid volume and distance relative to baseline. The mean parotid volume decreased by 37.3% from baseline to week 6 of RT. The overall rate of change in parotid volume during RT was − 1.30% per fraction (− 1.67% and − 0.91% per fraction in ≥ 31 Gy and < 31 Gy mean planned parotid dose groups, respectively, $p = 0.0004$). The movement of parotid borders was greater in the ≥ 31 Gy mean parotid dose group compared with the < 31 Gy group (0.22% per fraction and 0.14% per fraction for the lateral border and 0.19% per fraction and 0.06% per fraction for the medial border, respectively). The median change in body weight was − 7.4% (range, 0.75% to − 17.5%) during RT. A positive correlation was noted between change in body weight and parotid volume during the course of RT (Spearman correlation coefficient, $r = 0.66$, $p < 0.01$). Head and neck IMRT results in a volume loss of the parotid gland, which is related to the planned parotid dose, and the patient's weight loss during RT.

Introduction

Xerostomia is one of the most common side effects affecting the patient's dentition, mastication, taste, sleep, and overall quality of life after radiotherapy (RT) for head and neck cancer (HNC).[1] Parotid-sparing intensity-modulated radiotherapy (IMRT) aims to reduce xerostomia after head and neck RT by reducing the mean parotid dose. Randomized data comparing 3-dimensional conformational radiotherapy (3DCRT) with parotid-sparing IMRT for HNC have shown reduced xerostomia rates and severity, and improvement in quality of life endpoints using IMRT.[2] Previous studies have reported that patients with HNC experience anatomic changes throughout RT including weight loss and primary tumor volume loss.[3] In addition, anatomic changes within the normal tissues and organs at risk, such as the parotid gland, may affect the real-time dosimetry, which in turn can influence toxicity outcomes.[4,5] We conducted a prospective study of serial computed tomography (CT) scans in treatment position to evaluate volumetric and anatomic changes in the parotid gland during a course of definitive IMRT for HNC and their relationship to the planned parotid dose.

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Table 1
Patient, tumor, and treatment characteristics

Age (y)	Gender	Primary site	T	N	Overall stage	No. of CT scans	Mean planned parotid dose (Gy)		Change in parotid gland volume during treatment (%)		CCRT
							Left	Right	Left	Right	
46	M	Base of tongue	2	2c	IVa	4	34.38	34.00	39.0	37.1	Cisplatin
54	M	L tonsil	2	2c	IVa	5	37.72	35.23	42.9	34.5	Cetuximab
59	F	Base of tongue	4a	2b	IVa	2	26.41	27.82	18.8	33.6	Cisplatin
63	M	Nasopharynx	2	2	III	3	33.56	28.94	16.3	21.7	Cisplatin
65	M	Larynx	2	0	II	5	27.49	27.55	13.0	25.2	None
63	M	Larynx	4a	2c	IVa	5	32.97	39.01	44.3	57.2	Cisplatin
45	M	Nasopharynx	4	1	IVa	5	30.80	35.86	57.6	49.7	Cisplatin
48	F	L tonsil	2	2b	IVa	5	76.93	27.39	37.6	8.1	Cisplatin
46	M	Hypopharynx	3	2c	IVa	5	28.85	29.32	20.6	36.2	Cisplatin
57	M	R tonsil	2	2c	IVa	4	29.05	39.94	43.2	29.5	Cisplatin
55	F	Larynx	3	0	III	4	26.25	21.67	6.6	24.7	Cisplatin
61	M	L hypopharynx	3	0	III	5	26.86	25.24	16.2	14.2	Cisplatin
50	M	Unknown primary	x	2b	IVa	5	32.12	35.77	8.6	10.5	Cisplatin

CCRT = concurrent chemoradiation treatment; F = female; L = left; M = male; R = right; T =tumor category; N = nodal category.

Methods and Materials

Patient population

The study was conducted as a prospective, single-arm study, with approval from the institutional review board. Written informed consent was obtained from each patient before entering the study. Thirteen patients with HNC underwent treatment with curative-intent parotid-sparing IMRT between 2007 and 2008 to a total median dose of 69.96 Gy to the target volume in 33 fractions. Twelve patients received concurrent chemotherapy with weekly cisplatin ($n = 11$) or cetuximab ($n = 1$). Twelve patients were treated with full-length IMRT fields, and 1 patient was treated with IMRT fields matched to a low anterior neck field. Patient, tumor, and treatment characteristics are described in Table 1. Additionally, the patient's body weight was measured weekly during treatment.

CT imaging

Patients underwent CT simulation (Brilliance CT Big Bore, Philips Medical Systems, Cleveland, OH) in the supine position immobilized with a custom thermoplastic mask. Treatment planning was performed using Philips Pinnacle[3] (version 6.0 to 8.0 m, Philips Medical Systems, Fitchburg, WI). IMRT plans were designed with 7 to 9 6-MV photon beams, using an inverse optimization algorithm with normalization such that 95% of the planning target volume (PTV) was covered with the prescription dose (66 to 69.96 Gy), with the aim of no more than 1% of PTV receiving less than 93% of the prescription dose, and no more than 1% or 1 cc of the tissue outside the PTV receiving more than 110% of the prescription dose. The bilateral parotid gland dose volume objective was to keep the mean dose below 26 Gy or keep the parotid's volume receiving 30 Gy below 50%, without compromising tumor coverage.

Serial CT scans were performed at clinical baseline, weeks 2, 4, and 6 during RT corresponding to doses of 12.72, 33.92, and 55.12 Gy, respectively, and at 6 weeks after completion of RT. All CT studies were obtained by a 64-multidetector-row CT (Lightspeed VCT; GE Healthcare, Milwaukee, WI) using 2.5-mm slice thickness. All 13 patients completed the baseline and week 2 CT scan. Eleven of 13 patients completed CT scan at week 4 during RT, and 9 of 13 patients completed the scan at week 6 of RT. Finally, 11 of 15 patients completed the CT scan at 6 weeks post-RT. Over the course of the protocol, a total of 5 patients could not complete all CT scans owing to the following reasons: difficult intravenous access ($n = 2$), contrast injection failure ($n = 1$), and development of renal insufficiency during chemo-radiotherapy ($n = 2$). A total of 57 CT scans were performed over the study period. All patients were treated by a single board-certified radiation oncologist.

Measurement of parotid gland volume

Twenty-six parotid glands were studied for change in volume over the course of RT. The parotid glands were contoured by a single operator in all CT scans. A total of 114 parotid glands were contoured over the course of a study period. Gland volumes were provided by the Pinnacle[3] planning software (version 6.0 to 8.0 m, Philips Medical Systems, Fitchburg, WI).

Measurement of parotid borders and relationship to the bony landmark

On each of the 57 CT scans, an arbitrary bony landmark was chosen at the anteriormost part of the C1 vertebra (Fig. 1). First, the plane located midway between the superior and inferior limits of the parotid glands was determined using z-coordinate provided by the Pinnacle[3] planning software. In that plane, the medial and lateral edges of each parotid gland were marked on each CT scan. The lateral distances between the C1 bony landmark and parotid borders were determined as differences in their x-coordinates. Based on these lateral distances, we calculated the movement of the medial and lateral borders relative to the C1 landmark. The distance between the medial and lateral borders of the parotid gland was also recorded at each CT scan.

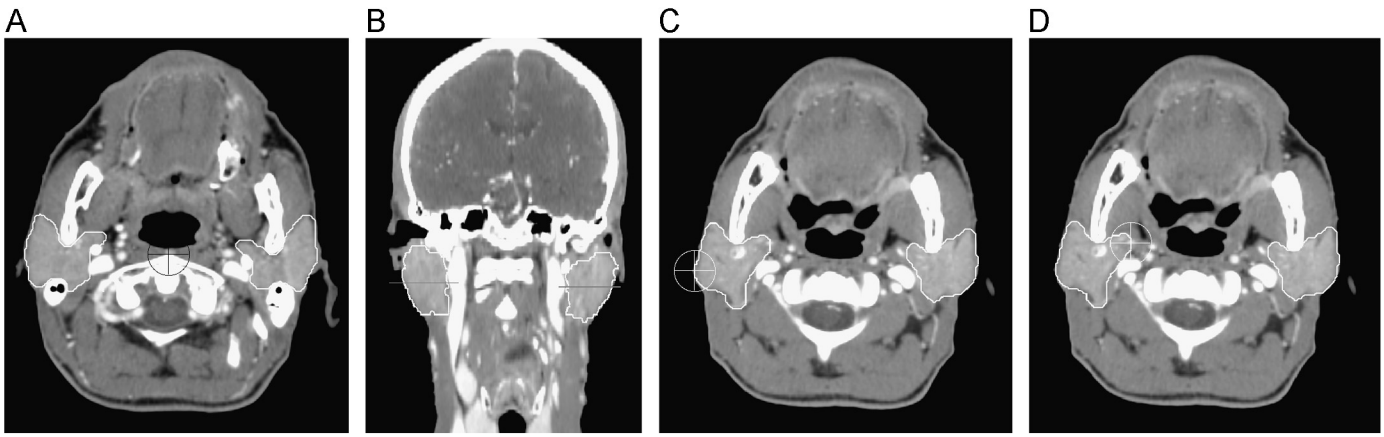

Fig. 1. Measurements of medial and lateral borders of the parotid. (A) Most anterior aspect of C1 vertebra chosen as a bony landmark for reference measurement; (B) measurements of the parotid gland are taken in a plane located midway between the superior and inferior limits of the gland; (C) x-coordinate of the most medial edge of each parotid was compared to the x-coordinate of bony landmark chosen in step (A); (D) x-coordinate of the most lateral edge of each parotid was compared to the x-coordinate of the C1 bony landmark chosen in step (A).