Three Dimensional Conformal Radiotherapy (3DCRT) for parotid gland cancer: Dose to cochlea, oral cavity and contralateral parotid

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Introduction

Parotid gland tumors constitute about 80% of all salivary gland tumors. About 80% of the tumors are located in the superficial lobe, and most of these tumors have an infra-auricular location. Postoperative radiation therapy is highly efficacious in decreasing the local recurrence in high risk patients.

Adjuvant radiotherapy is commonly achieved with a pair of wedged oblique beams. However the beams may irradiate the surrounding organs at risk (OARs), in particular the cochlea, oral cavity, contralateral parotid, spinal cord and brain stem causing significant increase in the risk of oral mucositis, xerostomia, dry ear, ear infections, and hearing deficits on the irradiated side. So, proper selection of the beam direction to spare the OARs from receiving doses exceeding their tolerance values is considered an important factor when treating such patients.

Aim of work

This study is aiming at reporting the results of doses received by target volumes and surrounding organs at risk (OARs) during postoperative 3DCRT treatment of parotid gland cancer using ipsilateral 2 oblique wedged and direct lateral fields.

Methods

This study included ten patients diagnosed as having parotid cancer, underwent superficial parotidectomy and referred to Alexandria Clinical Oncology Department (ACOD), during the period from January 2011 to March 2012 for postoperative radiotherapy to the parotid bed. All the patients had at least one indication for post-operative radiotherapy. All patients had computed tomography (CT) simulation (3 mm slice thickness) during which they were immobilized. The CT data transferred to treatment planning system (Precise Elekta).

All required structures were contoured including GTV, PTV, contralateral parotid, oral cavity, ipsilateral & contralateral cochlea, spinal cord, brain stem, eyes, lenses and optic nerves.

All CT scans were planned, calculated and treated with 6 MV photon beams on a Precise Elekta linear accelerator. The dose of 60Gy was prescribed to the center of the PTV. For two cases as the spinal cord maximum dose was high so the dose was reduced in a way that the dose to spinal cord did not exceed its tolerance.

For all plans, isodose distributions and dose volume histogram (DVH) were generated. The coverage of PTV was evaluated using the minimum and maximum dose. Dose inhomogeneity within PTV was calculated for all patients. Sparing of OARs was assessed using the mean dose for parotid & cochlea and oral cavity and the maximum point dose of spinal cord, brain stem, lenses, and optic nerves.

Results

Regarding PTV dose coverage; the average of minimum dose to PTV was 57 Gy and the average of maximum dose was 66 Gy and the percentage of the dose inhomogeneity within PTV was 15%. Regarding PTV dose conformity; 95% isodose wash closely matched the shape of PTV. Regarding OARs sparing, the average of the mean dose to contralateral parotid, oral cavity, ipsilateral, contralateral cochlea and both eyes was 8Gy, 36Gy, 15Gy, 4Gy and 120cGy respectively. The average of the maximum point dose to spinal cord, brain stem, both lenses and right and left optic nerve is 32Gy, 21Gy, 180cGy, 180cGy & 120cGy respectively. All values were far less than the corresponding organ tolerance.

Conclusion

Post-operative 3DCRT radiotherapy for parotid gland tumors using two oblique wedged and one direct lateral fields maintained OARs sparing without compromising dose coverage or conformity of PTV. So this technique may be considered as a class solution for the treatment of parotid gland tumors without the need to a complex technique as IMRT especially in radiotherapy centers lacking IMRT.

Introduction

Malignant salivary gland neoplasms accounts for 3-5% of all head and neck cancers. The parotid glands are one of the major salivary glands, with only 20% of its tumors being malignant. Mucoepidermoid carcinoma is the most common malignant histology affecting the parotids [1].

Surgery is the main line of treatment for operable parotid carcinomas, but local failure after surgery alone remains high [2]. Postoperative radiotherapy (usually 60 Gy at 1.8-2 Gy/f) is indicated to decrease local recurrence rate in patients with high-grade histology, inadequate surgical margin, perineural invasion and nodal disease [3].

Postoperative tumor volume includes the operative bed with at least 2cm margin. Elective neck irradiation is indicated in certain clinical situations [4, 5].

Various radiotherapy techniques have been described; the most commonly used is the wedged pair technique with photons which produces a low radiation dose to the contra-lateral parotid gland, but have a high exit dose through the oral cavity, brain-stem, spinal cord, and the cochlea[4,5].

The second most common radiotherapy technique is the mixed photon electron beam technique, which uses high energy electron beam 12-20 MEV and low energy photon beam 6MV, this technique is usually associated with high dose to the contra-lateral parotid gland, skin and mandible, and a more inhomogeneous tumor dose distribution[4,5].

Although postoperative radiation therapy following surgery is effective in controlling malignant tumors of the parotid gland, the beams may irradiate the surrounding organs at risk (OARs), in particular the cochlea, oral cavity, contralateral parotid, spinal cord and brain stem. This causes a significantly increased risk of oral mucositis, xerostomia, infections, and sensorineural hearing loss on irradiated side [6]

So to avoid occurrence of xerostomia, the mean dose to contralateral parotid should not exceed 24-26Gy and the mean dose to oral cavity also should be around 35 Gy[7]

To avoid sensorineural hearing loss, which may lead to significant cognitive impairment, depression and a reduction in quality of life, the mean cochlear dose should not exceeds 40 Gy[8,9].

For the spinal cord and brain stem, the maximum point dose should be kept within their tolerance levels of 45Gy.

So, optimum plan, which produces conformal dose distributions to the target volume while reducing the radiation dose to OAR, should be carried out to reduce the side-effects of radiotherapy at same time improve local tumor control.

This plan should be also, a standardized treatment planning procedure using the same set of treatment planning parameters such as beam arrangement for all patients within a group for specific tumor site as a starting point. Then the adjustments on patient-by-patient basis include field size and the beam weights (class solution). Using a class solution for every patient reduces the time needed to plan individual patients. It also makes the planning process more efficient, encourage consistency between plans produced for individual patients by different planning staff and so decrease the risk of errors in planning and delivery. [5, 10]

Aim of work

This study is aiming at reporting the results of doses received by target volumes and surrounding organs at risk (OARs) during postoperative 3DCRT treatment of parotid gland cancer using ipsilateral two oblique wedged and a direct lateral fields.

Methods

This study included ten patients diagnosed as having parotid cancer, underwent superficial parotidectomy and referred to Alexandria Clinical Oncology Department (ACOD), during the period from January 2011 to March 2012 for postoperative radiotherapy to the parotid bed. All the patients had at least one indication for post-operative radiotherapy (high-grade histology, inadequate surgical margin, presence of perineural invasion and nodal disease) [3]. All patients had computed tomography (CT) simulation (3 mm slice thickness) during which they were immobilized using individual thermoplastic head masks with thermoplastic shoulder fixation. The CT data transferred to treatment planning system (Precise Elekta).

All required structures were contoured, surgical bed and PTV contoured by clinical oncologists in accordance with ICRU50 [11]. OARs including contralateral parotid, oral cavity, ipsilateral, contralateral cochlea, spinal cord, brain stem, eyes, lenses and optic nerves were contoured by consultant radiologist.

At the start of this work, three different techniques were carried out for six patients to find out the optimum technique. The first technique is ipsilateral mixed photon electron beam, the second is ipsilateral two oblique wedged photon fields, and the third one is ipsilateral two oblique wedged and direct lateral photon fields. We decided to complete the work using the third technique.

For each patient, optimum plan was carried out using ipsilateral two wedged anterior and posterior oblique and direct lateral photon fields (figure 1). A dose of 60 Gy was prescribed to the center of the PTV according to ICRU [11]. For two out of the ten cases, the total dose was reduced as the spinal cord maximum dose was high.

For each patient, the field size was adjusted using beam eye view to improve dose coverage of PTV. MLCs were used to shape the PTV and to shield the close OAR as possible. Gantry angle, wedge angle, and beam weighting were also adjusted. A wedge angle of 60^0 was mostly used for oblique fields. In some patients a wedge was added to the lateral field with thick end inferior to compensate for hot spot produced by air gap at inferior part of the field (caudal). For lateral field, beam weight was about 50-70%. No collimation or couch rotation was used. Because of the superficial position of parotid bed, a bolus of 1-1.5cm thickness was used in all fields to improve target coverage in build up region.

For all plans, isodose distributions and dose volume histograms (DVH) were generated. Plan evaluation depends on dose coverage of PTV, its conformity, dose homogeneity within PTV and the sparing of OARs. The coverage of PTV evaluated using the minimum and maximum dose. Dose inhomogeneity percentage within PTV was calculated for all patients by subtracting the minimum from the maximum dose of the PTV. Sparing of OARs was assessed using the mean dose for contralateral parotid, cochlea & oral cavity & the maximum point dose of spinal cord, brain stem, lenses, and optic nerves.

Statistical analysis: For all patients, these dose volume parameters were recorded and analyzed statistically using excel sheet 2003 (table 1).

Fig 1: Left ipsilateral wedged pair & lateral beam arrangement used to generate 3DCRT.

Results

The average of the volume of PTV was 121cc (ranges=42-160cc) and the average of the contralateral parotid was 22cc (ranges7-35cc) and the average of the volume of cochlea was 0.4cc (ranges 0.2-1cc).

The three techniques were compared regarding target coverage, conformity, dose homogeneity within PTV and OARs sparing. The first technique showed underdose of PTV, unaccepted dose inhomogeneity within the PTV (mean=40%) and high doses to OARs. Although the dose to OARs with the second technique was lower compared to other techniques but the plan was not conformal with unaccepted dose inhomogeneity within the PTV (mean=18%).

Regarding the third technique, it showed the best dose homogeneity (15%) and conformity compared to other two techniques, although the dose to OARs was higher compared to the second technique but it was far lower than OARs tolerance. Typical dose distribution for 3DCRT plan using the third technique is shown in figure 2, it shows that PTV dose coverage & conformity is excellent as 95% of the dose completely covers the PTV and closely match its shape.

Revision of table1, confirm that 3DCRT plans of the present study produced excellent target coverage while keeping the dose to both cochlea, contralateral parotid, oral cavity, brain stem and spinal cord within acceptable levels

Summary for the dose distribution in ten cases of parotid gland cancer

For planning target volume (PTV)

Regarding PTV dose coverage; the average of minimum dose to PTV is 57 Gy and the average of maximum dose is 66 Gy but the percentage of the dose inhomogeneity within PTV is 15%. Regarding PTV dose conformity; 95% isodose wash closely match the shape of PTV.

For organs at risk (OAR)

The average of the mean dose to contralateral parotid, oral cavity, ipsilateral, contralateral cochlea and both eyes is 8Gy, 36Gy, 15Gy, 4Gy and 120cGy respectively. The average of the maximum point dose to spinal cord, brain stem, both lenses and right and left optic nerve is 32Gy, 21Gy, 180cGy, 180cGy & 120cGy respectively. All values are far less than their tolerance. This is confirmed by DVH of one case shown in figure 3. As the dose to eyes, lenses and optic nerves are comparable for all patients so we did not list it in the table we just mentioned the average.

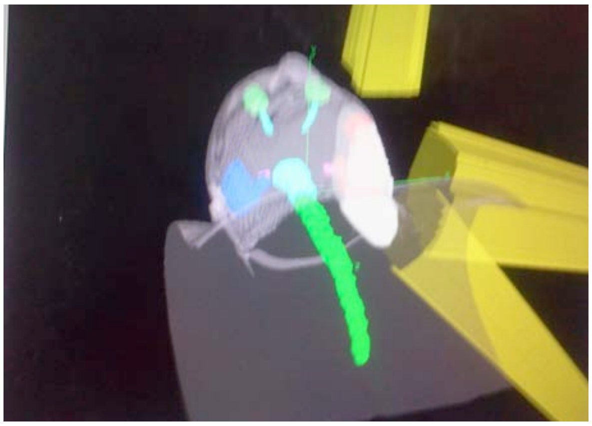

Fig 2: 95% isodose wash (white) match the PTV (red). It also shows both cochlea in pink, parotid in blue, spinal cord in green and eyes and optic nerves in light green

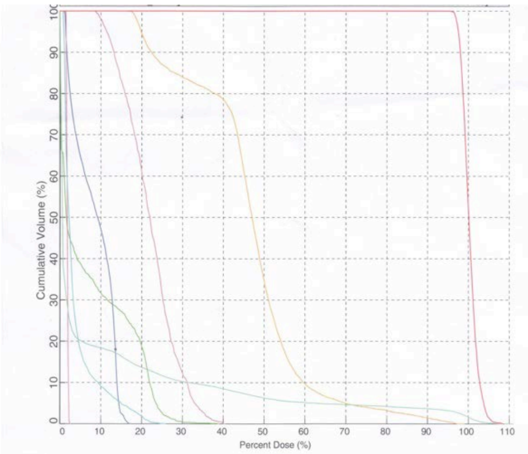

Fig 3: Dose volume histograms for different OARs for a case with parotid cancer planned by 3DCRT. PTV is shown in red, oral cavity in yellow, brain stem in light blue, spinal cord in dark green, contralateral parotid in blue & right and left cochlea in pink and body max dose in light green. The dose is in percentage.

Table 1: 3DCRT dose statistics in Gy for PTV & different OARs for postoperative parotid radiotherapy. PTV dose inhomogeneity in percentage is also shown. Dose prescribed is 60Gy

Pt No	PTV min dose	PTV max dose	Inhomgenity %	Spinal cord max dose	Brain stem max dose	contralateral Parotid mean dose	Oral cavity mean dose	Contral. cochlea mean dose	Ipsil, cochlea mean dose
1	57	67.20	17	16.8	15.6	6	43.8	1.8	8.4
2	57	66.60	16	19.8	21	7.8	30.6	1.2	12.6
3	57	67.20	17	**57***	41.4	8.4	51.6	2.4	7.2
4	57	63	9	18.6	15	7.2	33	1.8	16.8
5	57	66	15	**58.2***	14.4	12.6	45	3.6	3
6	57	64.20	12	16.8	18	10.2	15	12	40.8
7	57	67.20	17	36.6	31.8	8.4	31.8	3.6	16.8
8	57	67.20	17	34.8	22.2	10.2	31.2	12.6	27
9	57	67.20	17	40.2	19.2	7.8	54.6	1.8	8.4
10	57.60	64.80	12	23.4	15.6	4.8	27.6	1.2	13.2
Min	57	63	10	16.8	14.4	4.8	15	1.2	3
Max	57.60	67.20	16	58.2	41.4	12.6	54.6	12.6	40.8
Average	57	66	15	32	21	8	36	4	15

*Patients number 3 &5 were treated with lower doses to avoid the very high dose to the spinal cord where the prescribed dose was reduced to 50Gy (the spinal cord dose was 47.5 and 48.5 respectively)

Discussion

Post-operative radiotherapy to the parotid bed is an integral part of the optimum management of parotid gland carcinoma. Although it reduces local recurrence rate, radiation to the organs adherent to the surgical bed or in the exit of the irradiating beams may cause serious long standing problems [5]. So, optimum radiotherapy technique should ensure good target coverage and dose conformity while maintaining the dose to OARs within their tolerance levels. This can be achieved by adjusting beam direction and other beam parameters (as done in the present study) by using two ipsilateral wedged oblique and direct lateral fields.

Regarding PTV dose coverage; in our study, the average of minimum dose to PTV was 57 Gy (95%) and the average of maximum dose was 66 Gy (110%). Nutting et al [5] in his study comparing different radiotherapy techniques to the parotid gland found that (when using 3DCRT), the min dose to the PTV was 55Gy (91%) and the maximum dose was 62.8 Gy (105%). Also he found that the percentage of the dose inhomogeneity was 13% compared to 15% in our work. The dose heterogeneity within PTV in the study done by Yirmibesoglu et al [12] was greater and unaccepted with the use of wedged pair (about 30%), compared to 15% with 4 fields IMRT and 11% with 7 fields IMRT.

In the present work, the average of the mean dose to oral cavity was 36Gy, which is much higher than the mean dose to the oral cavity in the study done by Nutting et al[5]

Also in our study, the mean dose to contralateral parotid was 8 Gy compared to 1.6±0.7 in the study done by Nutting et al. Eda Yirmibesoglu et al [12] compared 2 wedged technique with 7 & 4 fields IMRT and achieved a mean dose to contralateral parotid of 2.4 Gy, 18.6 Gy & 1.1 Gy.

In spite of the higher radiation dose to the oral cavity and the contralateral parotid gland in our study, our results were still below the tolerance dose that causes xerostomia, which was determined by Eisbruch et al[13, 14] to be 24-26 Gy to the contralateral parotid gland, and it agrees with G Studer et al [7], who concluded that a mean dose of 35 Gy is enough to spare oral mucosa.

The mean dose to ipsilateral & contralateral cochlea in the present study, were 15Gy & 4Gy respectively. Both values were under the threshold to cause sensorineural hearing loss which ranges between 30 and 70 Gy [15,16].

Nutting et al [5] who carried out 3DCRT plan using two wedged ipsilateral oblique fields to irradiate the parotid, reported the mean dose to the cochlea to be 42.3Gy, which is much higher than we achieved. The mean dose of cotnralateral cochlea in the study done by Yirmibesoglu et al [12] was 4.8 Gy, 22.5 Gy & 1.6 Gy for 2 wedged technique, 7 & 4 fields IMRT respectively.

In the present work the maximum point dose to the brain stem was 21 Gy compared to 27.4Gy in the study done by Nutting et al [5].

The doses to the brain stem and cochlea achieved in our study were even better than doses achieved by IMRT in the study done by Nutting et al [5].

So, although we achieved higher dose to oral cavity and contralateral parotids (compared to other 3DCRT techniques) because we used lateral direct photon field, our values still less than the tolerance values of these organs, with better doses to the brain stem, ipsilateral and contralateral cochlea and without compromise the homogeneity and the conformity of the PTV.

Conclusion

Post operative 3DCRT radiotherapy for parotid gland tumors using two oblique wedged and direct lateral fields maintained OARs sparing without compromising dose coverage or conformity of PTV. So this technique may be considered as a class solution for the treatment of parotid gland tumors without the need to a complex technique as IMRT especially in radiotherapy centers lacking IMRT.

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