On Presentation of Optimal Treatment Plan in Radiotherapy of Parotid Cancer: A Comparison of Nine Techniques in Three Dimensional Conformal Radiation Therapy (3DCRT)

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Abstract: Materials and Methods: CT of parotid patients during 2012 to 2014 is used. Twelve patients were evaluated by TPS Core plan, 3D dose distribution and using of dose-volume histogram (DVH), nine techniques were evaluated: a. 6MV photons, 3-fields AP (wedge), PA (wedge), lateral (open), b. unilateral 10 Mev electrons, c. unilateral 14 Mev electrons, d. Mixed beam technique using 6MV photon and 10 Mev electron (1:4 weighting), e. Mixed beam technique using 6MV photon and 14 Mev electron (1:4 weighting), f. unilateral 10 Mev electrons with bolus (0.5 cm bolus is used), g. unilateral 14 Mev electrons with bolus (0.5 cm bolus is used), h. Mixed beam technique using 6MV photon and 10 Mev electron (1:4 weighting) with Bolus (0.5 cm bolus is used), i. Mixed beam technique using 6MV photon and 14Mev electron (1:4 weighting) with Bolus (0.5 cm bolus is used) Results: Using of DVH to appraise, the dose to OARs are 0 for techniques 6MV photons, (3-fields), unilateral 10 Mev electrons with and without Bolus, unilateral 14 Mev electrons with & without Bolus. The highest conformal and homogeneity index and near to 1 were for 6MV photons, 3-fields, unilateral 14 Mev electrons with and without Bolus, mixed beam technique using 6MV photon and 14 Mev electron with and without Bolus.

Keywords: Bolus, Parotid Gland Cancer, Dose Volume Histogram,
Three Dimensional Conformal Radiation Therapy (3DCRT)

1. Introduction

Malignant salivary gland tumors compromise about 3 to 5% in the head and neck cancer [1-3]. Parotid tumors are the largest salivary gland tumors [1-3]. Today, radiotherapy combined with surgery in the treatment of parotid tumors widely are used specially for high grade parotid tumors [4-6].

One of concern and challenge issue of radiotherapy is that the treatment of these tumors with irregular surface due to the presence of external ear and region of different physical electron density (air cavities, dense bone, soft tissue) [7-10]. Existing of the heterogeneous tissues, internal inhomogeneity and also the diverse external contour yield an inhomogeneous dose distribution. Therefore some of the consequences of a heterogeneous treatment volume led to under dos of tumor (target volume) and over dose of critical structures [7-10].

Some of side-effects of radiotherapy to parotid tumors are osteoradionecrosis of the mandible, temporal lobe necrosis, Xerostomia, sensorineural hearing loss [3, 8, 9, 13, 28, 29].

Recent developments in three dimensional computerized radiation treatment planning (3D RTP) systems led to effective treatment with low side effects in organ at risks by using accurate calculation of dose distribution and optimal treatment has helped [8, 11, 12]. The information included a 3D dose distribution is condensed into dose-volume histograms (DVHs) which are essentially graphical demonstration of dose distributions exactly the target volume and organ at risk [8, 11, 12].

Two basic technique of radiotherapy such as a pair of angled wedged photon beams and mixed beam of photons

and electrons with different weighting are used [8]. The minimum treatment volume includes the ipsilateral parotid bed and the upper neck nodes [8, 13]. Using of bolus is other method which is used in radiotherapy of these tumors [14-18]. Bolus is a tissue-equivalent material that is widely used in electron and photon radiation therapy to move or shift the buildup region [19, 20].

According to the recommendations of AAPM Task Group 25 (American Association of Physicists in Medicine), bolus should designed in such a way that target Volume received at least 90 percent of prescribed doses but with internal inhomogeneity of tumor surface and non-uniformity of the dose with bolus observed that it would be the treatment of tumors of the parotid challengeable [15, 18, 19, 21-27].

Despite reports of many researchers who study mainly different treatment techniques and use of various radiation source (photons, electrons and a mixed beam) for this type of tumors, no unified study looking at impact of bolus in achieving an optimal treatment for parotid tumors [15, 18, 19, 21, 22, 24, 27, 30, 31].

Therefore offering an optimal treatment plan to the desired results in terms of dose distribution factors to adequate target coverage and protect critical structures surrounding OARs is so important.

This study aimed to achieve an optimal treatment plan using low-energy electrons, as well as different modes of electrons and photons will be considered. Also the effect of bolus to achieve the optimal treatment plan is performed.

2. Methods

The computed tomography (CT) scans of parotid patients were used in this study during 2012 to 2014. The prescription depth was 4.5 cm. These parameters were evaluated base on 12 patients who were referred to Omid hospital at Oncology Department in Urmia city. These patients previously treated postoperatively in Omid institution. All patients were treated using individual thermoplastic mask immobilization head and shoulder fixation and the CT images are taken by CT-simulator 2 slices. The CT data were transferred to CorePlan treatment planning system (ETAR). The included criterion in this study are uninvolved skin, any history about previously treated with radiotherapy and also there aren`t any extracapsular nodal spread.

Target volumes such as planning target volume (PTV) and gross tumor volume (GTV) and organs at risk (OARs) such as spinal cord, contralateral parotid gland and temporal mandibular joint (TMJ) were contoured on the CT images and dose prescription were performed according to the International Commission on Radiation Units (ICRU) 62 guidelines. For each patient, nine plans were done. The beam energies of each plan and field arrangements are listed in Table 1.

For each technique, the dose distribution was optimized to obtain uniform dose coverage to a prescription depth of 4.5 cm. A isodose distribution for a 6 MV wedge pair technique 1 is shown in figure 1. The dose volume histograms (DVH) were generated for target volume and OARS.
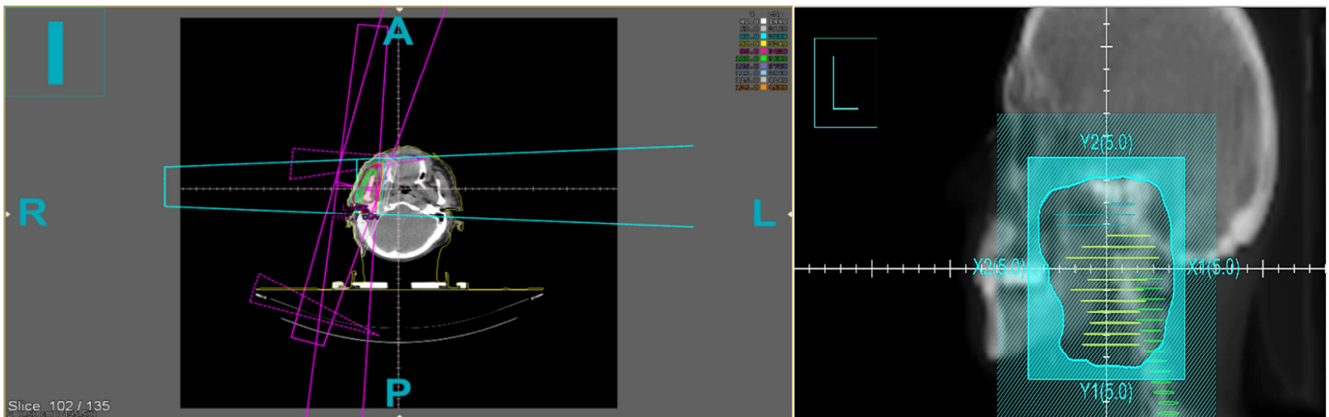

Fig. 1. (a). A isodose distribution for a plan 1, standard 6MV wedge pair technique. (b) DRR image.

The comparison of each plan depends on dose 5%, 95% coverage of PTV, sparing of OARS dose conformity index (CI), dose homogeneity within PTV by homogeneity index (HI). HI and CI were measured by using the equation 1, 2:

$$\frac{\text{Volume within 95\% isodose line}}{\text{Volume of PTV}} = CI \qquad (1)$$

$$\frac{D5\%}{D95\%} = HI \qquad (2)$$

HI measures the dose homogeneity across the PTV. Where D5% is the dose covered by 5% of the target volume, D95% is the dose covered by 95% of the target volume.

Sparing of OARs was assessed using the mean dose for contralateral parotid, spinal cord, TMJ (temporomandibular joint) and they also were compared.

***Table 1.** All of scenarios, treatment techniques considered for each patient in this study.*

Technique	Beam energies	Beam arrangement	Beam weights
1.	6MV Photon	AP/PA/Lat	AP (40%, 30°W), PA (40%, 30° W), Lat. (20%, open)
2.	10Mev Electron	Lateral	100%
3.	14Mev Electron	Lateral	100%
4.	6MV Photon+ 10 Mev Electron	AP/PA (Photon)+lateral (electron)	AP (40%, 30°W), PA (40%, 30° W), Lat. (20%, open)
5.	6MV Photon+ 14 Mev Electron	AP/PA (Photon)+lateral (electron)	AP (40%, 30°W), PA (40%, 30° W), Lat. (20%, open)
6.	10Mev Electron+ 0.5 cm Bolus	Lateral	100%
7.	14Mev Electron+ 0.5 cm Bolus	Lateral	100%
8.	6MV Photon+ 10 Mev Electron+ 0.5 cm Bolus	AP/PA (Photon)+lateral (electron)	AP (40%, 30°W), PA (40%, 30° W), Lat. (20%, open)
9.	6MV Photon+ 14 Mev Electron+ 0.5 cm Bolus	AP/PA (Photon)+lateral (electron)	AP (40%, 30°W), PA (40%, 30° W), Lat. (20%, open)
AP= antero-posterior; PA = postero-anterior; Lat = Lateral; W = wedge			

Statistical analysis

For all patients, HI and CI were calculated. When the CI was almost 1 indicates the plan is more conformal. HI value near to 1 number indicates a more homogenous dose distribution. Analyzed statistically using excel sheet 2016 and SPSS ANOVA and a post Hoc Tukey test was performed for individual comparison.

3. Result

The HI and CI were calculated for PTV for each technique (Table 2). Comparing of nine techniques help us to find an optimal technique.

Table 2 and 3 gives the statistical analysis for homogeneity and conformity of PTV according to Tukey test (table 2, 3. Figure 2). The results of HI divide to 4 groups and the results of each group are similar and different with other group. The number 1 for table of HI shown the highest homogeneity and also photon 6+ electron 14+ bolus, photon 6+ electron 14, electron 14, electron 14+ bolus, photon 6 are similar together with 95% confidence level (table 2). For CI, two groups are made and each group is different with other group. The number 2 for table 3 had that the highest conformity. The members of number 2 include electron 14+ bolus, photon 6+ electron 14, electron 14, photon 6, photon 6+ electron 14+ bolus and these members had similar conformity index.

***Table 2.** Homo index for nine plans.*

Plan	Subset for alpha = 0.05			
	1	2	3	4
photon 6+ electron 14+ bolus	1.0208			
photon 6+ electron 14	1.0283			
electron 14	1.0325			
electron 14+ bolus	1.0367			
photon 6	1.0375			
photon 6+ electron 10+ bolus		1.1875		
photon 6+ electron 10		1.2417	1.2417	
electron 10			1.2717	
electron 10+bolus			1.3050	1.3050
Sig.	1.000	.532	.151	.055
Means for groups in homogeneous subsets are displayed.				
a. Uses Harmonic Mean Sample Size = 12.000.				

***Table 3.** Conformity index for nine plans.*

| Conformity index for each plan, P value less than 0.001		
CI		
Tukey HSD[a]		
Plan	Subset for alpha = 0.05	
	1	2
electron 10+bolus	.7342	
photon 6+ electron 10+ bolus	.7442	
photon 6+ electron 10	.7467	
electron 10	.7492	
electron 14+ bolus		.9267
photon 6+ electron 14		.9508
electron 14		.9517
photon 6		.9558
photon 6+ electron 14+ bolus		.9617
Sig.	.996	.310
Means for groups in homogeneous subsets are displayed.		
a. Uses Harmonic Mean Sample Size = 12.000.		
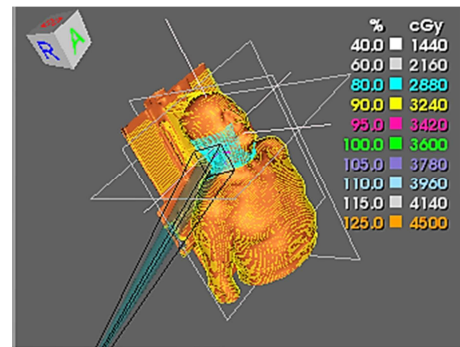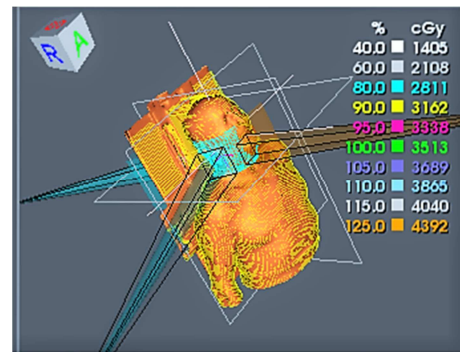
***Fig. 2.** Dose coverage of PTV by Bolus.*

A: for 8, 9 techniques, Mixed electron-photon beam with bolus, photon beam (1 technique).

B: for ipsilateral electron beam with bolus (6, 7 technique).

Based on DVH and comparing of each plan by this curve, it is clear that single 6MV photon with 3 fields significantly can better coverage the PTV and spare OARs (fig. 3). The conformity index is. 9558 and it is similar to electron 14 Mev with or without bolus and also the homogeneity index for single 6MV photon is 1.0375. For coverage of PTV using by homogeneity and conformity index, the techniques of 1, 3, 5, 7, 9 are similar and can obtain the best conformity and homogeneity at target volume, but by using the DVH, the 1, 3, 7 techniques can spare the OARs (fig. 3).
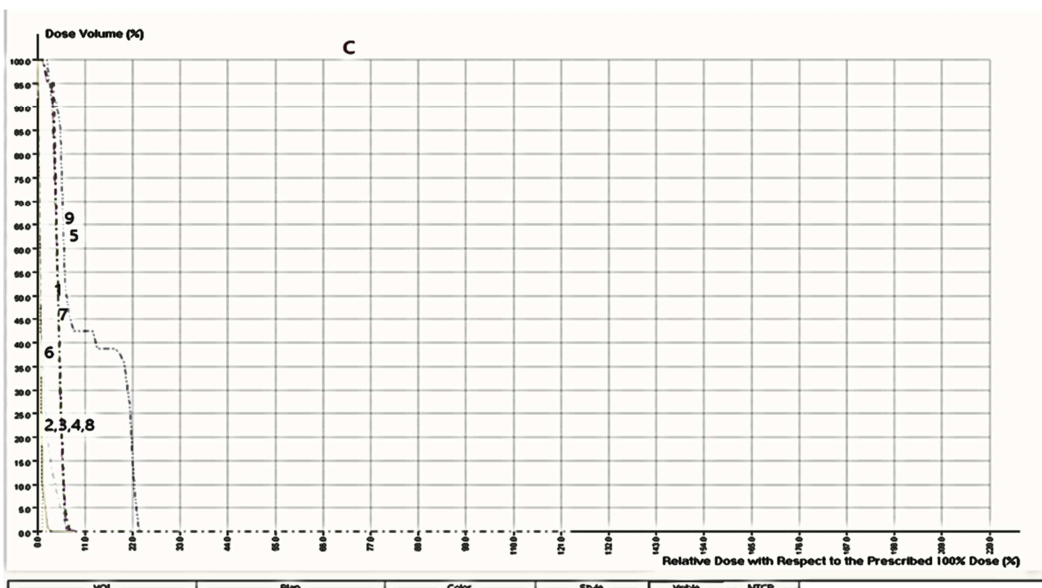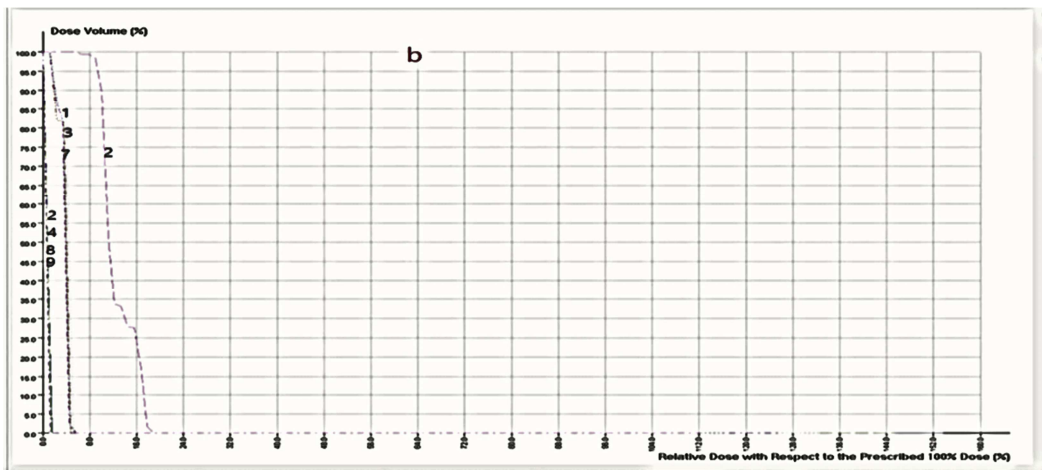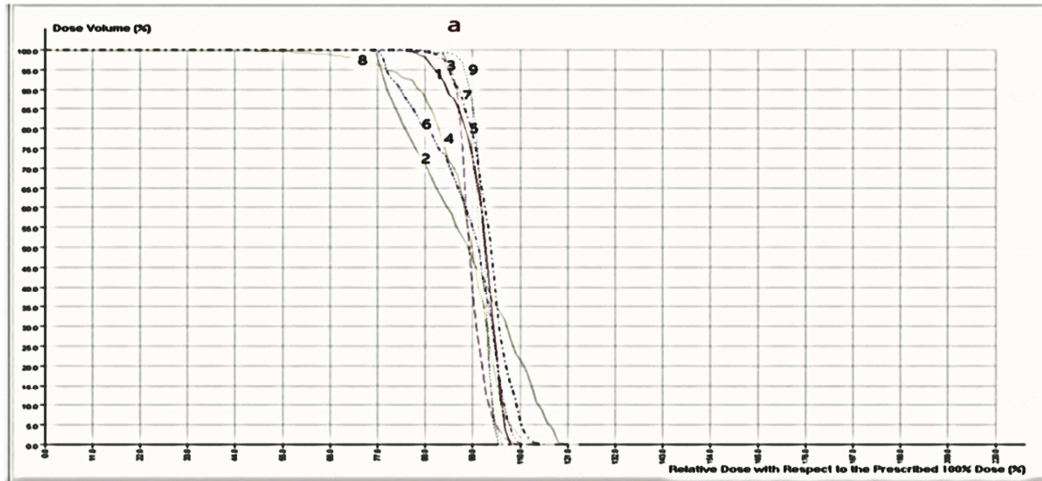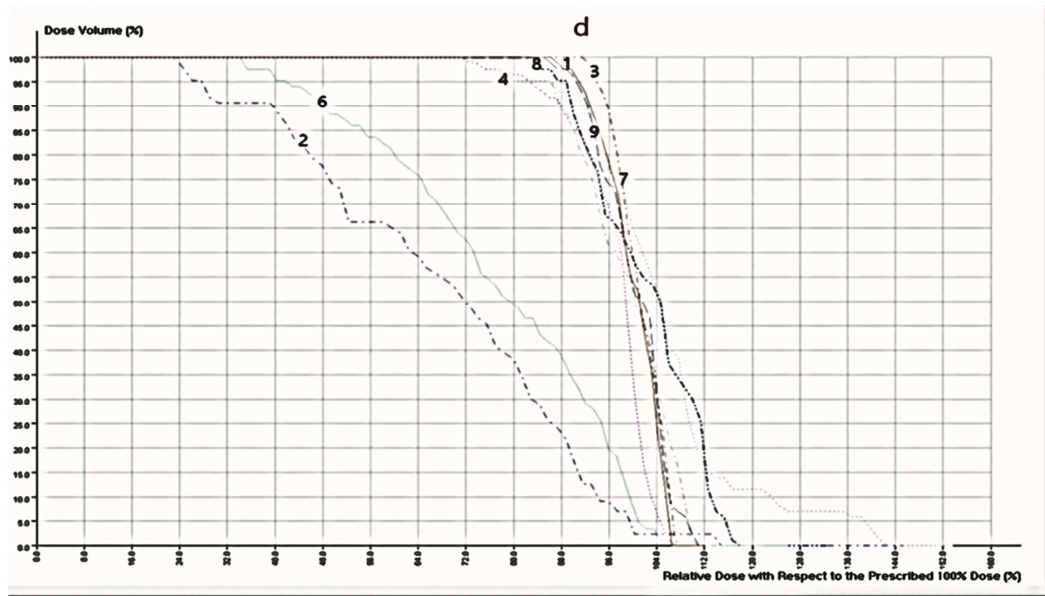
Fig. 3. Dose volume histogram for PTV (a), contralateral parotid (b), spinal cord (c), TM. Joint (d) for a patient with parotid cancer by nine different technique and dose is in percentage.

4. Discussion

Using of different techniques, beam energy could be used to achieve the optimal treatment plan. The characteristic of effective treatment planning are the good distribution dose, best coverage of PTV (planning target volume) and reducing dose to OARs organ [8, 32]. This provides the best control of tumor, sparing of the surrounding OARs and highest life quality for patient of parotid cancer. In the current study, nine techniques are compared and the resulting of isodose distribution of the plan and DVH curve showed different coverage of PTV and OARs, homogeneity, conformity. Plan of numbers 1, 3, 5, 7 and 9 had the highest CI & HI. They were achieved the good isodose distribution and coverage of PTV, but for sparing of OARs, the high energy electron was good (plan of 3,7) and also the 3-field photon was achieved best coverage of PTV and sparing of OARs (spinal cord, opposed parotid) expect temporal lobe (TM. Joint), the joint of temporal was necrosis due to excess dose to TMJ (higher than 45Gy). These results are in agreement with resulting of Yaparpalvi et al`s and Hela et al`s, but at their study the conformity index and homogeneity index did not achieved [8, 32]. At Hela et al`s study for photon technique, regarding OARs, contralateral parotid mean dose was 0.4 Gy which a little lower than mean dose in our study 0.6 Gy and also our resulting lower than the mean dose in study done by Nutting et al (1.6 Gy) (both used wedge pair technique, but at 2 field) [8, 32, 33], due to different beam weighting and difference at incidence beam or perhaps due to difference of depth prescription dose. Also for spinal cord mean dose, in three studies (Hela et al, Yaparpalvi et al, our study) for mixed beam electron-photon beam technique at three study were highest, but at our study for energy electron (1, 2, 3, 6, 7) were lower than other technique (the average is 2Gy) [8, 32, 33]. As same as resulting Yaparpalvi et al, temporal lobe and

temporomandibular joint necrosis is a side-effect of radiotherapy of parotid cancer patient using by all plan and it need to careful attention for treatment while using electron beam and electron-photon mixed beam [8]. All of DVH at figure 3 shown. At our study, the impact of bolus also are considered, but at previous study it just used for photon beam [8, 32, 33]. The resulting of comparison of technique 6, 7, 8, 9 showed that the CI was 0.9267 and the HI was approximately 1 for 14Mev electron, it showed that using of bolus for high energy electron is effective to providing an optimal treatment plan, but for other technique is not improve the treatment plan (table 2, 3). Our results shown that presence and absent of bolus are not significantly different, the results of them are significantly similar.

5. Conclusion

According to dose distribution, this paper offered using of 3-field photon with pair wedge technique and electron high energy with using of bolus to achieve optimal treatment plan of parotid cancer. It is noteworthy that when electron beam or mixed beam is used, it would not be good if they accompanied by bolus, because of existing of air gap and the problems of building, design and other problems that mentioned in previous study [27, 30, 31]. The techniques 2,6 are not good, because energy beam are low and they could not achieve an optimal treatment plan for parotid tumors. Also use of bolus is dependent to our facilities and would not affect the result.

Acknowledgments

Conflict of Interest

The authors declare no conflict of interest.

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