Original Investigation *doi: 10.5455/medscience. 2014.03.8218*

Dosimetric Evaluation of Tomotherapy, Non-coplanar and Coplanar IMRT Plannings for Total Scalp Irradiation

Songul Barlaz Us[1], Esil Kara[2], Asli Yazici[2], Bahar Dirican[3], Eda Kaya Pepele[4], Simay Gurocak[4]

[1] Department of Radiation Oncology, Mersin University Faculty of Medicine, Mersin, Turkey

[2] ONKO Ankara Oncology Center, Ankara, Turkey

[3] Department of Radiation Oncology, Gulhane Military Hospital, Ankara, Turkey

[4] Department of Radiation Oncology, Inonu University Faculty of Medicine, Malatya, Turkey

Abstract

In this study, the dosimetric effects of the Tomotherapy, noncoplanar and coplanar IMRT plannings were evaluated for the total scalp irradiation. Tomotherapy based and linac based IMRT plans were compared for 61 years old female patient with multipl myeloma. Two different linac based IMRT plans which are coplanar and noncoplanar were performed for total scalp irradiation. 20 Gy was given to the PTV volume. Firstly, homogeneity index and conformity index values were calculated for PTV. Secondly, the doses of organ at risk (OaR) which are lenses, brain, brainstem and parotid glands were dosimetrically evaluated. While, tomotherapy plan was more homogenous, noncoplanar plan was more conformal than the others. Our study figure out that the OaR doses can be decreased by using tomotherapy based IMRT. However, the treatment time was increased when the tomotherapy based IMRT used for treatment. Tomotherapy based IMRT can be used for total scalp irradiation with respect to OaR.

Keywords: IMRT, tomotherapy, coplanar, noncoplanar, OaR

(Rec.Date: Oct 02, 2014 Accept Date: Oct 30, 2014)

Corresponding Author*:* Songul Barlaz Us, Department of Radiation Oncology, Mersin University Faculty of Medicine, Mersin, Turkey
E-mail: barlaz@gmail.com

Introduction

There are many irradiation techniques for total scalp irradiation in the literature. The most important point is to provide homogenous dose distribution across the scalp and decrease the dose of critical organs in all treatment techniques. Different techniques can be used for total scalp irradiation. 3D-CRT (parallel opposed photon/electron junctions), IMRT, HDR, helical tomotherapy, electron arcs and abutting electron fields have been used in the practice [1-4].

Different irradiation techniques can be choosing depending on which aspect we are handling the issue. In the electron technique, brain dose is low but the scattering of electrons on oblique surfaces can create unusual dose distributions and the effect of laterally scattered and backscattered electrons from the skull must be understood [5,6]. Dose-volume histogram is acceptable and coverage of the target volume is adequate but incidence of beam angle and field matching are the problem for combination of electron and photon technique [7]. Target dose homogeneity and critical organs doses are suitable in HDR brachytherapy. However, HDR brachytherapy technique requires more preparation and planning time than standard ones [8].

Linac-based IMRT is well-suited for total scalp irradiation however dose of critical organs, such as brain, eyes etc., increase with IMRT [2]. The ability of helical tomotherapy to produce concave dose distributions makes it potentially for complicated target shape in total scalp irradiation for extensive lesion of the total scalp. Helical tomotherapy also avoid problems associated with field matching and use of more than one modality. Additionally, tomotherapy allows correction of intrafraction setup errors [7].

In this study, 61 year-old female patient who is diagnosed Multiple myeloma was studied. Total scalp irradiation was performed by used helical tomotherapy, non-coplanar IMRT and coplanar IMRT and results were compared.

Materials and Methods

Before starting the IMRT planning, patient was immobilized in supine position with thermoplastic head mask. Treatment planning CT scan was obtained with 3 mm slice thickness (Siemens, Biograph mCT 20 Excel). The target volume and organs at risk (OaRs) were defined by the same physician. The entire scalp were contoured as PTV and brain, brainstem, lenses, optical nerves, parotid glands were delinated as OaRs using by velocity software.

All planning have 10 fractions defined for delivery of 20 Gy. %95 of the PTV volume was received at least 20 Gy for all plan. Tomotherapy-based IMRT plan were optimized by using Tomotherapy planning station. Directional bloc was drawn that 5 mm distance from inside of PTV for improving dose distribution. For the dose optimization, parameters of tomotherapy planning were as follow; field width was 2.5 cm, pitch was 0.4 planning modulation factor was 3.00, plan calculation grid was the fine (0.305x0.305 cm). Linac-based IMRT plans were optimized by using Prowess Panther DAQ planning system. Step and shoot technique was used for linac based IMRT plans. Non-coplanar planning was performed by using 10 fields beam arrangement with 7 couch angles not equal to 00 (3300, 900). 84 was the total segment number of the non-coplanar IMRT planning. Coplanar plan was performed by using 9 fields with 900 couch angle for each beam and total number of the segments was 72.

OARs doses were evaluated by using RTOG (Radiation Therapy Oncology Group) protocols and quality of PTV was evaluated with parameters of homogeneity index (HI) and the conformity index (CI) [9]. CI was calculated by using the following formula for PTV:

$$CI = \frac{TV_{RI}}{TV}$$

Where is target volume covered by the reference isodose and is target volume. Conformity index ranges from 0 (All of the target volume is situated outside of the prescription isodose) to 1 (All of the target volume is irradiated at the prescribed dose) [10, 11]:

The used HI formula was following: $HI = \frac{D_5 - D_{95}}{D_p}$

where and represent the doses received by the 5% and 95% volumes of PTV respectively and is the prescribed dose [12]. Ideal value is zero (0) for homogeneity index.

Results

Coronal, sagittal and transverse isodose distributions of the three treatment plans are showed in Figure 1. %95 of the PTV volume is received at least 20 Gy, so %95 (19 Gy) and %100 (20 Gy) isodose lines of prescription dose are represented in the dose distributions. As can be seen in Table 1., maximum, minimum and median doses of PTV are respectively 22.42 Gy, 12.42 Gy and 20.08 Gy for coplanar planning, 21.44 Gy, 15.45 Gy and 20.07 for non-coplanar planning and 22.17 Gy, 17.32 Gy and 20.31 Gy for tomotherapy planning. Maximum doses in all plans are almost same. Maximum has highest value and minimum dose has the lowest value in coplanar planning. Homogeneity index values are 0.084, 0.067 and 0.043 and conformity index values are 0.952, 0.974 and 0.949 for coplanar, noncoplanar and tomotherapy planning respectively. Treatment times of the coplanar, non-coplanar and tomotherapy are following 360.78 MU, 322.4 MU and 581.2 MU. As can be seem tomotherapy treatment time is higher than other planning techniques.

Dose volume histograms (DVH) including of PTV and critical organs (brain, brain stem, lenses, optical nerves, parotid glands) are presented Figure 2.

Critical organs maximum, minimum and median doses are showed in Table 2. As it is seen from Table 2, maximum doses to brain are almost same (approximate value is 21.6 Gy) but minimum dose for tomotherapy is quite low (2.32 Gy). Depending on minimum dose, the median dose is low for tomotherapy planning (14.38 Gy). Brainstem doses resemble the brain doses. Maximum dose to right lens is too high in coplanar planning (10.28 Gy) and this is the lowest in tomotherapy planning (6.04 Gy). Maximum dose to left lense are similar in coplanar and non-coplanar plannings (9.06 Gy and 9.03 Gy respectively) and is the lowest in tomotherapy (5.18 Gy). Dose to optic nerves are almost same in all planning modalities. Due to optic nerves are adjacent to the PTV, maximum dose values for optic nerves are close to the doses to PTV. Similarly parotid glands are close by the PTV in consequence of maximum parotid glands doses are about 20 Gy and median parotid glands doses is the lowest in the tomotherapy planning (right is 5.88 Gy and left is 5.42 Gy).

Table 1. Homogenity and conformity indexes, minimum, maximum and median doses of PTV and treatment time values for tomotherapy, coplanar and noncoplanar IMRT planning.

	HI	CI	PTV D_{max}	PTV D_{min}	PTV D_{median}	Treatment Time (MU)
Tomotherapy	0.043	0.949	22.17	17.32	20.31	581.2
Coplanar	0.084	0.952	22.42	12.42	20.08	360.78
Noncoplanar	0.067	0.974	21.44	15.45	20.07	322.4

Table 2. Maximum, minimum and median values of critical organs for all treatment planning (T: tomotherapy, CP: coplanar and NCP: non-coplanar)

Organs	Maximum Doses (Gy)			Minimum Doses (Gy)			Median Doses (Gy)		
	T	CP	NCP	T	CP	NCP	T	CP	NCP
Brain	21.39	22.32	21.09	2.32	15.87	14.67	14.38	18.79	18.21
Brain stem	21.47	20.63	20.56	2.32	16.45	15.23	10.81	19.00	19.03
Lens (right)	6.04	10.28	6.52	2.42	5.50	1.40	3.29	6.54	2.68
Lens (left)	5.18	9.06	9.30	2.37	5.56	2.88	3.10	6.54	4.23
Optic nerve (right)	20.48	20.11	20.05	17.43	16.65	16.01	20.04	19.92	19.74
Optic nerve (left)	20.73	20.38	20.24	17.44	17.27	17.30	20.11	19.96	19.93
Parotid glands (right)	21.11	19.85	20.56	0.87	2.76	13.45	5.88	11.15	18.89
Parotid glands (left)	20.11	19.88	19.76	0.85	3.91	9.53	5.42	10.62	7.59

 doi: 10.5455/medscience. 2014.03.8218

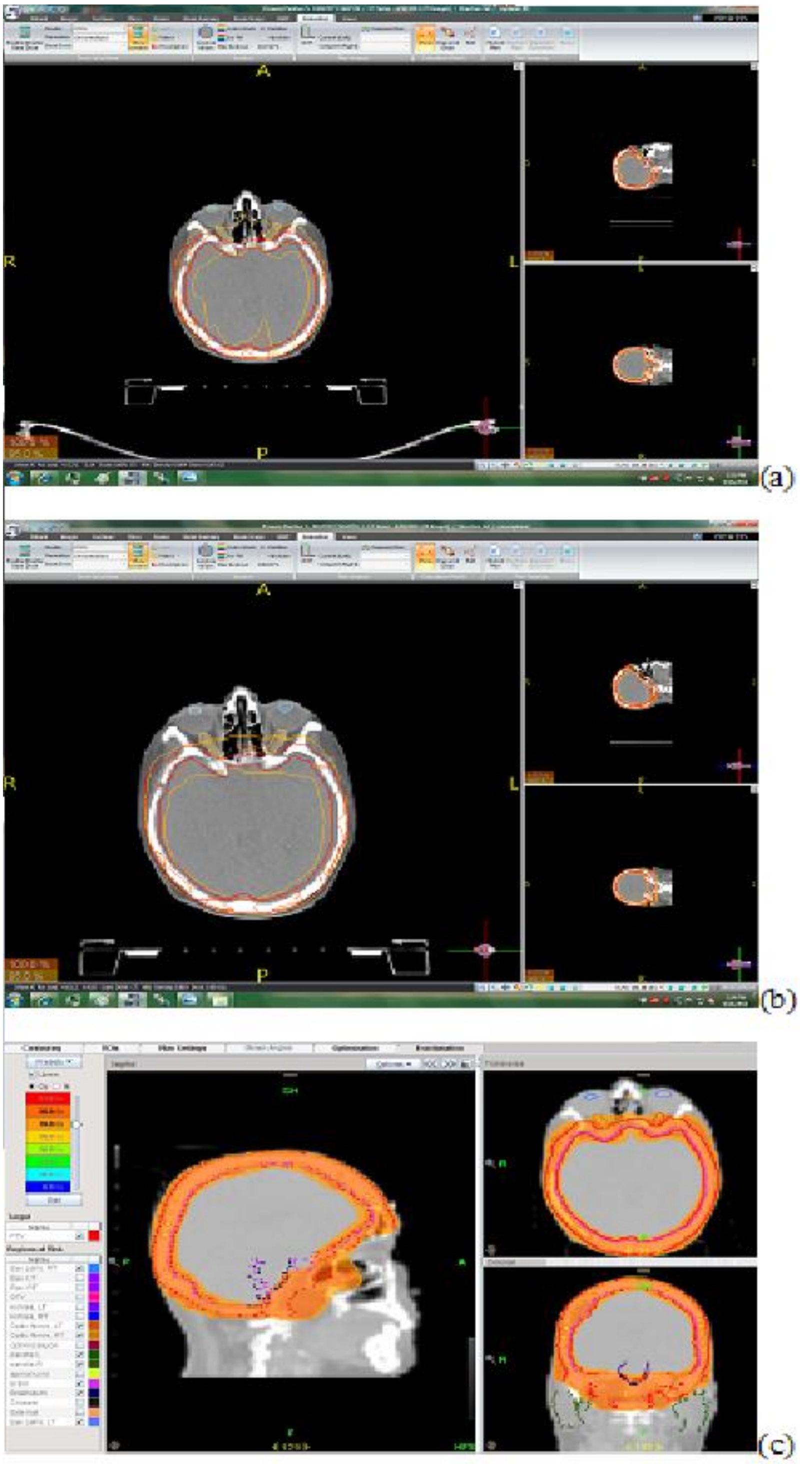

Figure 1. Isodose distribution for coronal, sagital and transverse planes (Dark Oranges colour: 20 Gy and light oranges colour: 19 Gy). a) Coplanar planning b) Non-coplanar planning c) Tomotherapy planning

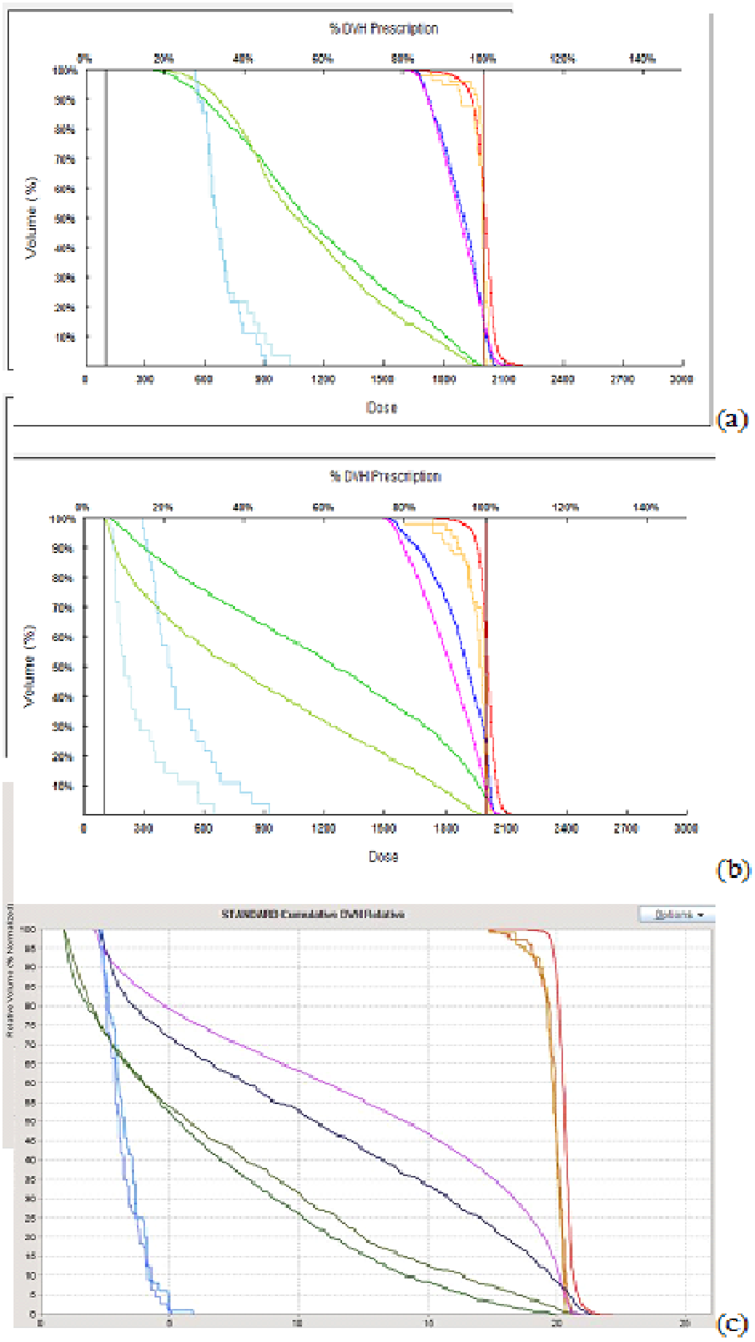

Figure 2. DVH for target volume and critical organs (red: PTV, light blues: right and left lens, greens: right and left parotid glands, dark blue: brainstem, light plum: brain, oranges: right and left optic nerve) Coplanar planning b) Non-coplanar planning c) Tomotherapy planning

Discussion

The main purpose of the treatment planning for total scalp irradiation is to get homogen dose distribution on PTV and to reduce the dose of critical organs as much as possible. Reducing the dose of the critical organs that are near the PTV is difficult in total scalp irradiation. Different techniques used in total scalp irradiation have superiority to each other. Locke et.al obtained by using IMRT technique that critical structure doses are more uniform than the conventional treatment plan [13]. Similarly in the Wojcicka et al's study, IMRT produced brain sparing and the best target dose homogeneity and coverage and delivery clinically acceptable doses to normal structure [2]. Also IMRT plans, non-coplanar and coplanar, were compared and it was showed that dose homogeneity PTV coverage increased and optic chiasm doses reduced in non-coplanar planning in the work of Ostheimer et al [14]. The other study was practiced by Kelly et.al. In this case, static IMRT and Volumetric Arc Therapy (VMAT) were examined and they were showed that VMAT plan can also be a good option for total scalp irradiation. [15]. Likewise, Orton et al carried out tomotherapy and arc therapy and they were observed that helical tomotherapy was well-suited for scalp irradiation because the tomotherapy plan was more uniform dose to the scalp and lower dose to the brain in high-dose regions than state of the arc treatments [7]. As for that VMAT, helical tomotherapy and LPE was compared in Song's et al. study. According to Song's et al, helical tomotherapy planning was the best target coverage and conformity and low doses to the brain. The VMAT plan was showed acceptable OaR sparing and better conformity compared with the LPE plan and they were decided that helical tomotherapy is the best modality for total scalp irradiation [16].

In our study, homogeneity index of the tomotherapy planning was better than non-coplanar planning and coplanar planning. But non-coplanar planning was the most conformal planning according to others. Maximum dose to optic nerves could not be decreased anymore and these dose values are same in all plans. Lens doses are over limits according to RTOG protocol for linac-based IMRT but they are low in the tomotherapy planning. Median doses to parotid glands are the lowest in tomotherapy planning. Maximum doses to brain and brainstem are same in three planning. Also the minimum dose is quite decreased and low-dose volumes are declined in the tomotherapy. But tomotherapy treatment time is higher than other planning techniques.

Conclusion

Tomotherapy has the ability to deliver a beam that is tangential to the scalp at all points in tomotherapy and has got capability of rapid dose decrease in short distance which is useful to reduce the OaR doses. Three treatment techniques are well-suited for scalp irradiation even though tomotherapy based IMRT treatment planning has more advantage than coplanar and non-coplanar planning. It was decided to get the treatment done with tomotherapy.

References

1. Nakamura R, Harada S, Obara T, Ehara S, Yoshida A, Akasaka T, Shozushima M. Iridium-192 brachytherapy for hemorrhagic angiosarcoma of the scalp: a case report. Jpn J Clin Oncol. 2003;33(4):198-201.
2. Wojcicka JB, Lasher DE, McAfee SS, Fortier GA. Dosimetric comparison of three different treatment techniques in extensive scalp lesion irradiation. Radiother Oncol. 2009;91(2):255-60.
3. Samant RS, Fox GW, Gerig LH, Montgomery LA, Allan DS. Total scalp radiation using image-guided IMRT for progressive cutaneous T cell lymphoma. Br J Radiol. 2009;82(978):e122-5.
4. Ozyar E, Gurdalli S. Mold brachytherapy can be an optional technique for total scalp irradiation. S.Int J Radiat Oncol Biol Phys. 2002;54(4):1286.
5. Able CM, Mills MD, McNeese MD, Hogstrom KR. Evaluation of a total scalp electron irradiation technique. Int J Radiat Oncol Biol Phys. 1991;21(4):1063-72.
6. Yaparpalvi R, Fontella DP, Beitler, JJ. Improved dose homogeneity in scalp irradiation using a single set-up point and different energy electron beams. Br J Radiol. 2002;75(896):670-7.

7. Orton N, Jaradat H, Welsh J, Tomé W. Total scalp irradiation using helical tomotherapy. Med Dosim. 2005;30(3):162-8.
8. Liebmann A, Pohlmann S, Heinicke F, Hildebrandt G. Helmet Mold-Based Surface Brachytherapy for Homogeneous Scalp Treatment: a Case Report. Strahlenther Onkol. 2007;183(4):211-4.
9. Kataria T, Sharma K, Subramani V, Karrthick KP, Shyam Bisht S. Homogeneity Index: An objective tool for assessment of conformal radiation treatments. J Med Phys. 2012;37(4):207-13.
10. ICRU 50 Prescribing recording and reporting photon beam therapy. http://www.icru.org/home/reports/prescribing-recording-and-reporting-photon-beam-therapy-report-50 access date 20.09.2014
11. Feuvret L, Noël G, Mazeron JJ, Bey P. Conformity Index: A Review. Int J Radiation Oncology Biol Phys. 2006;64(2):333-42.
12. Pathak P, Vashisht S. A quantitative analysis of intensity-modulated radiation therapy plans and comparison of homogeneity indices for the treatment of gynecological cancers. J Med Phys. 2013;38(2):67-73.
13. 13. Locke J, Low DA, Grigireit T, Chao KS. Potential of tomotherapy for total scalp treatment. Int J Radiation Oncology Biol Phys. 2002;52(2):553-9.
14. Ostheimer C, Janich M, Hübsch P, Gerlach R, Vordermark D. The treatment of extensive scalp lesions using coplanar and non-coplanar photon IMRT: a single institution experience. Radiat Oncol. 2014;9:82.
15. Kelly PJ, Mannarino E, Lewis JH, Baldini EH, Hacker FL. Total dural irradiation: RapidArc versus static-field IMRT: a case study. Med Dosim. 2012;37(2):175-81.
16. Song JH, Jung JY, Park HW, Lee GW, Chae SM, Kay CS and Son SH. Dosimetric comparison of three different treatment modalities for total scalp irradiation: the conventional lateral photon–electron technique, helical tomotherapy, and volumetric-modulated arc therapy. J Radiat Res. 2014 Jun 13. pii: rru049. [Epub ahead of print]