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ORIGINAL ARTICLE

Radiation doses to normal tissues during craniospinal irradiation: Improvement of the dose to the eye and lens, dosimetric study

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KEYWORDS

Craniospinal irradiation;
Dose to the eyes and lenses;
Dosimetric study

Abstract *Introduction:* Craniospinal irradiation is a very important element in treating medulloblastoma. Every effort should be made to decrease the radiotherapy related side effects, especially with the currently available 3D conformal radiotherapy planning system.

Objective: This dosimetric study is aiming to report the results of the analysis of doses received by target volumes and organs outside the target volumes during the treatment of medulloblastoma patients. And also by comparing the doses reaching the eyes and the lens with the use of different shielding methods.

Methodology: Ten children with recent diagnosis of high risk medulloblastoma were included. They were subjected to MRI of the brain and spine together with CSF cytology 3 weeks after surgery. They were subjected to fixation, conventional simulation, followed by CT simulation. The scans will be transferred to the treatment planning system. The brain, spinal canal, and different normal tissue were outlined.

For the cranial fields, parallel opposed fields were used with the isocenter of the fields in the midplan in the center of the brain, and behind the eyes. Sensitive tissues close to the target volume were shielded using either MLCS or blocks.

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The dose prescribed was 36 Gy/20 fractions for cranial and spinal regions. The maximum, minimum, and mean doses to each anatomic structure were computed using dose volume histograms. All patients gave informed consent.

Results and conclusion: The dose of radiation received by the target volume and the organs at risk with the use of our new treatment planning system is nearly identical to other studies. The use of block shielding shows lower doses to eyes and lenses regardless of the position of the isocenter, on the other hand, with the use of MLCs for shielding, the isocenter should be behind the eye not in the center of the brain as this shows lower doses to eyes and lenses.

1. Introduction

Medulloblastoma constitutes 15–20% of all childhood central nervous system tumors. The median age at diagnosis is usually 6 years. The most common site of origin is the vermis and the 4th ventricle. The presence of a large residual tumor >1.5 cm or cerebro-spinal metastasis identifies high risk patients.[1]

Reduced-dose (23.4 Gy) craniospinal irradiation (CSI) in combination with weekly vincristine, followed by a boosting of the dose to the posterior fossa up to 55.8 Gy followed by adjuvant systemic chemotherapy in the form of vincristine, CCNU and cisplatin yield a progression-free survival of 79% at 5 years and is considered the state of the art for standard risk medulloblastoma patients.[2]

Higher radiotherapy dose to the CSI 36–39 Gy is usually considered for M0 cases (>1.5 cm residual without craniospinal metastasis).[2]

Craniospinal axis irradiation (CSI) is considered the corner stone in the treatment of medulloblastoma. It is a complex technique with very irregular clinical target volume (CTV). It is executed in two phases, the whole brain and the neuraxis are treated in the initial phase. The site of the primary tumor is boosted in the second phase.[3]

A number of techniques are applied to improve dose homogeneity across the junction between the cranial and the spinal fields; including either direct abutment of the fields or the introduction of a gap with or without a moving junction. Effort had been made to decrease the dose to the lens, thyroid, heart, gastrointestinal tract (GIT), and gonads and to decrease the possible late effects of radiotherapy in those long living patients.

Several new modalities and techniques are now available aiming at more precise coverage of the target volume (spinal canal and brain) and more sparing of the organs at risk, including the use of CT simulators, better immobilization facilities, the use of conformal radiotherapy and IMRT.[4]

Since the introduction of the linear accelerator (Elekta) with photon energies ranging between 4 and 6 MV and treatment planning system (Precise Elekta) with many software tools for displaying and evaluation 5 years ago in Alexandria Clinical Oncology department we became more able to give better radiotherapy to those patients.

2. Aim of this study

This dosimetric evaluation study is aiming at reporting the results of analysis of doses received by target volumes and organs at risk (OAR) during treatment of high risk medulloblastoma patients. Also we will compare the dose reaching to the eyes and lenses with the use of different shielding methods (multi-leaf collimators MLCs and block shielding).

3. Materials and methods

Ten children with recent diagnosis of high risk medulloblastoma (large residual >1.5 cm, M0) were included in the study after reviewing the pathology from March 2009 to November 2010. All of them were subjected to MRI of the brain and spine together with CSF cytology 3 weeks after surgery. All patients were planned to receive craniospinal irradiation (CSI) concomitant with weekly vincristine starting 4 weeks after surgery. The parents of all children gave informed consent that the children's plans will be studied and will be subjected to research.

All patients received craniospinal irradiation (CSI) with two lateral parallel opposed fields to the head and a matched posterior spine field, with the moving of the junction 1 cm every 7 fractions (The position of the lower cranial border and the upper spinal field were shifted).

The cranial fields were treated iso-centrically while the spinal field was treated at fixed SSD.

An immobilization mask was fabricated from the thermoplastic material for each patient. The patients were simulated from the top of the head to the mid-pelvis using CT scan. During simulation, patients were placed in prone position with neck extended so that the spinal field could exit below the mandible.

CT spacing was 3 mm for the brain and 5 mm for the spine. Patients were marked with sagittal and lateral laser lines during the verification, simulation and subsequent treatment.

The CT scans were then transferred to Precise Elekta treatment planning system where spinal canal and brain were contoured as the target volumes. Organs at risk were also contoured. They include lenses, eyes, optic nerves, heart, lungs, liver, and kidneys. Care was taken to include the cribriform plate in all cases. Then the treatment fields were designed for treatment.

The energies of the photon beams were 4 and 6 MV for the cranial and spinal fields, respectively.

For the cranium, parallel opposed fields were used with two isocenters for each patient one behind the eye and the other in the center of the brain. The cranial fields include whole brain and extended caudally as long as the shoulder permits with 1 cm above the shoulder to allow the moving junction. In order to generate the field aperture for the cranial fields, the multileaf collimator was automatically positioned with the inside corner of the aperture 0.5 cm from the contoured brain then multi-leaf collimators (MLCs) leaves were adjusted.

Because the inferior divergence of the cranial fields may overlap into the spinal cord, a couch rotation of 6°–8° was added to eliminate such divergence. Also a collimator rotation of 8°–10° on the lateral cranial fields was done to match the divergence of the superior spinal field edge.

So couch and collimator rotation in the lateral cranial fields were applied to effectively have all three field edges from both the lateral brain ports and the posterior spine port to meet at the cervical junction as a single plane. So the dose homogeneity at the craniospinal junction was achieved.

For the spinal field, a single posterior long thin spinal field was used. It should cover the whole spine. The posterior spine field was simulated; the superior border of the spinal field touches the inferior border of the cranial field. The full length was opened to treat the spine by asymmetric jaws. If the distance from the 2nd cervical vertebra to the base of the spine (2nd sacral vertebra) was more than 39 cm then the treatment was carried out at extended SSD. SSD was 100 cm in eight patients and 110 and 120 cm in two other patients.

For the cranial fields, the average field size was 20×20 cm. For the spinal field, the length ranged from 26 to 38 cm. The width of the spinal field ranged from 4 to 8 cm.

MLCs and or cerrobend shielding blocks were used to shield eyes, lenses (Fig. 1) and other sensitive tissues close to the target volume as kidneys and lungs. For each patient, four planes were created; plan 1, the isocenter of the cranial fields was placed in the center of the brain and MLCs were used to shield the eyes and lenses. In plan 2 the isocenter was behind the eyes and MLCs were used to shield the eyes and lenses. In plan 3 the isocenter was behind the eyes and the shielding block was used to shield the eyes and lenses. In plan 4 the isocenter was in the center of the brain and the shielding block was used to shield the eyes and lenses.

The dose prescribed was 36 Gy/20 fractions for cranium and spine regions. For cranial dose prescription, the dose was normalized to the center of the brain. For spinal cord dose prescription the dose was normalized to the center of the field at the anterior surface of the spinal cord to achieve good coverage (95%) as the dose is lower at the anterior surface of the spinal cord. The delivered MU of the spinal fields ranged from 190 to 300 and for the cranial field ranged from 95 to 108 Mu.

4. Statistical analysis

This study included 10 patients, for each patient four planes were done, two planes before and the other two after adding the shielding blocks, for each plane of each patient the added dose plan function was used to check the dose coverage of the combined cranial and spinal dose plans. Then the four plans for each patient were compared using visual inspection of the dose distribution, dose volume histogram and dose volume histogram parameters. These parameters were listed and analyzed statistically using excel sheet and SPSS (version 11). Comparison of the dosimetric parameters among the four plans for the 10 patients was done by Wilcoxon signed Rank test. A P value of less than 0.05 was taken as statistically significant.

5. Results

5.1. Radiation doses to target volumes and organs at risk during CSI (Tables 1 and 2)

By reviewing the treatment planning and dose volume histograms of all 10 patients, the following were the results as regards the dose distribution of the target volumes (brain and spinal canal) and organs at risk:

5.2. As regards the target volumes

Brain was covered in all the cases by 95% of the dose (Fig. 2). The minimum dose received by any of the treated patients was 34.2 Gy while the maximum dose received was 40.3 Gy (still within the brain tolerance).

The spinal cord was covered in all the cases by 95% of the dose (Fig. 2). The minimum dose received by the spinal cord in any of the treated patients was 34.2 Gy, while the maximum dose was 41.4 Gy (still within spinal cord tolerance).

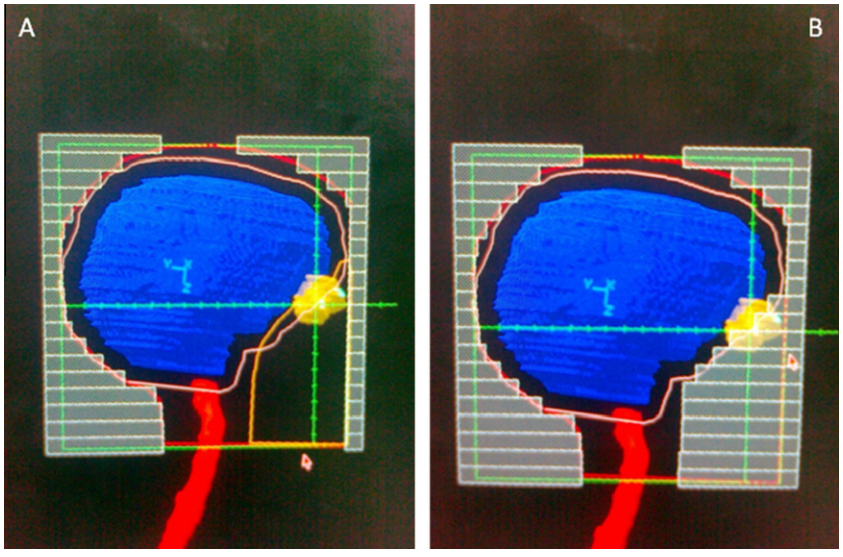

Figure 1 Beam eye view for right cranial field comparing shielding of eyes and lenses from radiation using a block (A) and MLC (B).

Table 1 Radiation doses in percentage for target volumes and organs at risk during CSI.

Patients	Brain min	Brain max	Cord min	Cord max	Liver mean	R. k. mean	L. k. mean	Heart max	Heart mean	Lung $D_{20\%}$	Optic max.	Body max.
1	96	107	95	115	16	5	5	97	51	10	99	124
2	95	109	96	113	18	5	10	92	54	10	99	115
3	96	106	97	115	17	8	7	95	50	8	101	117
4	95	110	96	111	14	9	7	95	55	8	101	117
5	95	111	95	110	20	4	4	92	39	15	100	113
6	95	112	95	113	16	3	5	95	49	8	95	119
7	95	112	95	115	22	14	2	93	51	5	95	125
8	95	109	95	110	23	11	13	95	54	12	104	112
9	95	106	98	113	17	14	17	97	56	15	97	119
10	95	110	96	109	15	8	8	94	50	9	97	118
Min	95	106	95	109	14	3	2	92	39	5	95	112
Max	96	112	98	115	23	14	17	97	56	15	104	125
Average	95.2	109.2	95.8	112.4	17.8	8.1	7.8	94.5	50.9	10	98.8	117.9
Median	95.5	109.5	96.5	111	17.5	8	7.5	94	50.5	9.5	99.5	117.5

Average = mean of the means.

Table 2 Radiation doses in cGy for target volumes and organs at risk during CSI.

Patients	Brain min	Brain max	Cord min	Cord max	Liver mean	R. k. mean	L. k. mean	Heart max	Heart mean	Lung $D_{20\%}$	Optic max.	Body max.
1	3456	3852	3420	4140	576	180	180	3492	1836	360	3564	4464
2	3420	3924	3456	4068	648	180	360	3312	1944	360	3564	4140
3	3456	3816	3492	4140	612	288	252	3420	1800	288	3636	4212
4	3420	3960	3456	3996	504	324	252	3420	1980	288	3636	4212
5	3420	3996	3420	3960	720	144	144	3312	1404	540	3600	4068
6	3420	4032	3420	4068	576	108	180	3420	1764	288	3420	4284
7	3420	4032	3420	4140	792	504	72	3348	1836	180	3420	4500
8	3420	3924	3420	3960	828	396	468	3420	1944	432	3744	4032
9	3420	3816	3528	4068	612	504	612	3492	2016	540	3492	4284
10	3420	3960	3456	3924	540	288	288	3384	1800	324	3492	4248
Min	3420	3816	3420	3924	504	108	72	3312	1404	180	3420	4032
Max	3456	4032	3528	4140	828	504	612	3492	2016	540	3744	4500
average	3427	3931	3448.8	4046	640.8	291.6	280.8	3402	1832	360	3556.8	4244
Median	3438	3942	3474	3996	630	288	270	3384	1818	342	3582	4230

Average = mean of the means.

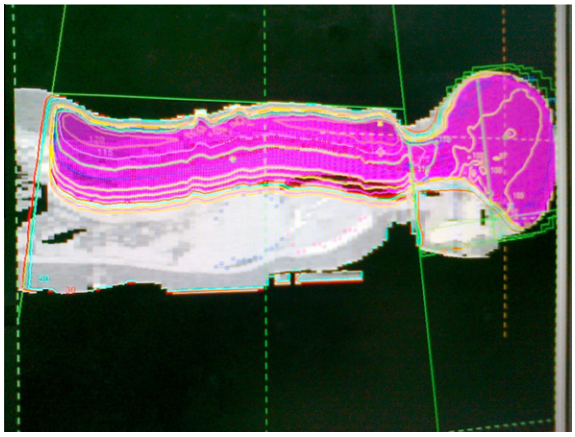

Figure 2 Isodose distributions in the sagittal plane in the patient's midline for CSI. It shows that brain and spinal cord is well covered by 95% of the dose (pink shadow).

5.3. As regards organs at risk (OARs)

The average of the mean dose received by the whole liver for all patients was 18% of the prescribed dose, i.e. 641 cGy, with a dose range of 504–828 cGy.

The average of the mean dose received by any of the kidneys was 8% of the prescribed dose, i.e. 280 cGy with a dose range of 72–612 cGy.

The average of the maximum dose received by the heart of the treated patients was 94.5% of the prescribed dose, i.e. 34 Gy, with the dose ranging from 33 to 34.9 cGy.

The average of the dose that 20% of the lungs received is 10% of the prescribed dose, i.e. 360 cGy with the dose ranging from 180 to 540 cGy.

The average of the maximum dose of the optic nerve was 98.5% of the prescribed dose, i.e. 36 Gy, with the dose ranging from 34 to 37 Gy. The maximum dose is still below the maximum point dose for the optic nerve.

The average of the body maximum dose was 118% of the prescribed dose, i.e 42 Gy, with the dose ranging from 40 to 45 Gy; this maximum point was in the back muscles (still within the tolerance of the muscle).

5.4. As regard eyes and lenses

The dose received by the eyes and lenses using two different shielding techniques and two different positioning for brain isocenters:

Four plans were carried out for every patient, they are:

Plan 1: Isocenter is in the center of the brain with MLC shielding.
Plan 2: Isocenter is behind the eyes with MLC shielding.
Plan 3: Isocenter is behind the eyes with block shielding.
Plan 4: Isocenter is in the center of the brain with block shielding.

The mean dose received by the right and left eyes and the maximum dose received by the right and left lens were listed and compared for the four plans. (Tables 3 and 4):

5.4.1. Plans 1 and 2

Plan 2 shows lower doses to eyes and lenses compared to plan 1. In plan 2, the average of the mean dose of the right and left eyes was 46% and 45% compared with 53% and 52% in plan 1 (Table 3). In plan 2 the average of the maximum dose of the right and left lens was 38% and 41% compared with 44% and 48% in plan 1 (Table 4). Using MLCs to shield the eyes and lenses, with putting the isocenter behind the eye, will lead to lower doses to the eyes and lenses than with putting the isocenter in the center of the brain. Although the difference was significant for both the eyes ($P = 0.007$ and 0.007), it was not significant for both the lenses ($P = 0.058$ and 0.066).

5.4.2. Plans 3 and 4

Plan 4 shows lower doses to eyes and lens compared to plan 3. In plan 3, the average of the mean dose of the right and left eyes was 32% and 31.5% compared with 30.5% and 30% in plan 4 (Table 3). The average of the maximum dose of the right

Table 3 Mean dose received by the eye in percent for four different plans using two different brain isocenters and different shielding methods.

Patients	Rt eye mean dose				Lt eye mean dose			
	Plan 1	Plan 2	Plan 3	Plan 4	Plan 1	Plan 2	Plan 3	Plan 4
1	31	31	12	12	33	23	12	13
2	70	56	36	32	57	41	21	19
3	77	68	46	48	60	55	32	35
4	46	41	30	24	50	42	36	30
5	65	64	50	49	51	47	34	30
6	33	32	17	18	24	26	15	11
7	38	20	18	11	37	27	19	13
8	62	57	46	49	75	72	59	60
9	43	38	29	25	61	52	37	40
10	65	55	37	37	74	61	50	47
Min%	31	20	12	11	24	23	12	11
Max%	77	68	50	49	75	72	59	60
Average	53	46.2	32.1	30.5	52.2	44.6	31.5	29.8
Median	46	41	30	25	54	44.5	33	32.5

Average = mean of the means.

Table 4 Mean dose received by the eye in cGy for four different plans using two different brain isocenters and different shielding methods.

Patients	Rt eye mean dose				Lt eye mean dose			
	Plan 1	Plan 2	Plan 3	Plan 4	Plan 1	Plan 2	Plan 3	Plan 4
1	1116	1116	432	432	1188	828	432	468
2	2520	2016	1296	1152	2052	1476	756	684
3	2772	2448	1656	1728	2160	1980	1152	1260
4	1656	1476	1080	864	1800	1512	1296	1080
5	2340	2304	1800	1764	1836	1692	1224	1080
6	1188	1152	612	648	864	936	540	396
7	1368	720	648	396	1332	972	684	468
8	2232	2052	1656	1764	2700	2592	2124	2160
9	1548	1368	1044	900	2196	1872	1332	1440
10	2340	1980	1332	1332	2664	2196	1800	1692
Min	1116	720	432	396	864	828	432	396
Max	2772	2448	1800	1764	2700	2592	2124	2160
Average	1908	1663.2	1155.6	1098	1879.2	1605.6	1134	1072.8
Median	1656	1476	1080	900	1944	1602	1188	1170

Average = mean of the means.

and left lens was 15.5% and 11% compared with 13% and 11% in plan 4 (Table 4). When we use blocks, not MLCs, to shield the eyes, there will be no significant difference if the isocenter was put in the center of the brain or behind the eyes. (both show low doses to eyes and lenses) (P = 0.183, 0.138 and 0.527, 0.546).

5.4.3. Plans 2 and 3

Plan 3 shows lower doses to eyes and lenses compared to plan 2. In plan 2, the average of the mean dose of the right and left eyes was 46% and 45% compared with 32% and 31.5% in plan 3 (Table 3). The average of the maximum dose of the right and left lens was 38% and 41% compared with 15.5% and 11% in plan 3 (Table 4). So placing the isocenter behind the eye while using block shielding will shows significant lower doses to the eyes and lenses than placing the isocenter in the same place while using MLCs for shielding. (P = 0.005, 0.005 and 0.007, 0.005) for both eyes and lenses.

5.4.4. Plans 1 and 3

Plan 3 shows lower doses to eyes and lenses compared to plan 1. In plan 1, the average of the mean dose of the right and left eyes was 53% and 52% compared with 32% and 31.5% in plan 3 (Table 3). In plan 1, the average of the maximum dose of the right and left lens was 44% and 48% compared with 15.5% and 11% in plan 3 (Tables 5 and 6). So putting the isocenter behind the eyes with block shielding shows significant lower doses than putting the isocenter in the center of the brain with using MLCs shielding (P = 0.005, 0.005 and 0.005, 0.008).

5.4.5. Plans 1 and 4

Plan 4 shows lower doses to eyes and lenses compared to plan 1. In plan 1, the average of the mean dose of the right and left eyes was 53% and 52% compared with 30.5% and 30% in plan 4 (Table 3). The average of the maximum dose of the right and left lens was 44% and 48% compared with 13% and 11%

Table 5 Maximum dose received by the lenses in percent for four different plans using two different isocenters and different shielding methods.

Patients	Rt lens max dose				Lt lens max dose			
	Plan 1	Plan 2	Plan 3	Plan 4	Plan 1	Plan 2	Plan 3	Plan 4
1	24	29	12	12	41	33	12	13
2	69	59	10	11	37	23	10	11
3	93	80	53	28	75	54	12	12
4	23	17	23	20	77	60	10	10
5	53	56	12	12	60	45	12	11
6	18	19	6	7	38	46	10	10
7	17	17	7	10	9	12	7	9
8	34	29	11	11	62	68	23	17
9	36	30	11	11	20	19	9	7
10	70	46	10	8	60	49	9	8
Min%	17	17	6	7	9	12	7	7
Max%	93	80	53	28	77	68	23	17
Average	43.7	38.2	15.5	13	47.9	40.9	11.4	10.8
Median	35	38	11	11	41	45.5	10	10.5

Average = mean of the means.

Table 6 Maximum dose received by the lenses in cGy for four different plans using two different isocenters and different shielding methods.

patients	Rt lens max. dose				Lt lens max dose			
	Plan 1	Plan 2	Plan 3	Plan 4	Plan 1	Plan 2	Plan 3	Plan 4
1	864	1044	432	432	1476	1188	432	468
2	2484	2124	360	396	1332	828	360	396
3	3348	2880	1908	1008	2700	1944	432	432
4	828	612	828	720	2772	2160	360	360
5	1908	2016	432	432	2160	1620	432	396
6	648	684	216	252	1368	1656	360	360
7	612	612	252	360	324	432	252	324
8	1224	1044	396	396	2232	2448	828	612
9	1296	1080	396	396	720	684	324	252
10	2520	1656	360	288	2160	1764	324	288
Min	612	612	216	252	324	432	252	252
Max	3348	2880	1908	1008	2772	2448	828	612
Average	1573.2	1375.2	558	468	1724.4	1472.4	410.4	388.8
Median	1260	1368	396	396	1476	1638	360	378

in plan 4 (Table 5). So putting the isocenter in the center of the brain with using block shielding shows significant lower doses than putting the isocenter in the center of the brain with using MLCs shielding ($P = 0.005$ for both eyes and lenses).

6. Discussion

This dosimetric study was conducted to report the results of the analysis of doses received by target volumes and organs at risk during treatment of 10 children with high risk medulloblastoma treated with craniospinal irradiation concomitant with chemotherapy at our department. Also we compared the dose reaching to the eyes and the lens with the use of two different shielding methods and two different positions for brain isocenter.

As regards the target volume; the minimum dose received by the brain in any of the treated patients was 34.2 Gy and the maximum dose received was 40.3 Gy. The median of the maximum dose received by the brain was 39.4 Gy while the median of the minimum dose received by the brain was 34.38 Gy.

The minimum dose received by the spinal cord by any of the treated patients was 34 Gy, and the maximum dose was 41.4 Gy, The median of the maximum dose received by the cord was 39.96 Gy while the median of the minimum dose received by the brain was 34.74 Gy.

These results are closely related to the results published by Darunee Tongwan in his dosimetric analysis of craniospinal irradiation in the supine position comparing four different techniques, where the median dose received by the brain was 36.91 Gy and the median dose received by the spine was 38.12 Gy.[5]

As regards organs at risk, starting with the liver, the median dose received by the whole liver for all patients was 17.5% of the prescribed dose, i.e. 630 cGy, with a dose ranges between 504 and 828 cGy. This was similar to Darunee's study in which the dose to the liver ranged from 533 to 698 cGy with a median dose of 576 cGy.

Considering the kidneys, the median dose received by the right and left kidneys was 8% and 7.5% of the prescribed dose, i.e. 288 and 270 cGy to the right and left kidney, respectively with a dose range between 72 and 612 cGy, which is nearly identical to the median dose received by the kidneys in Darunee's study.

In the present study, the maximum dose received by the heart in any of the treated patients was 34.9 Gy, with the mean dose ranged between 14.04 and 20.16 Gy. This is in agreement with the dose received by the heart in Darunee's study, which ranged from 14,00 to 19,00 Gy.

In Darunee's study, the lungs received a dose ranging from 413 to 565 cGy with a median dose of 476 cGy. This is nearly the same in our study where the dose received by 20% of the lungs ranged from 180 to 540 cGy with a median dose of 342 cGy.

In this study, the average of the mean dose received by the right and left eyes was 53% and 52% of the prescribed dose when using plan 1 (MLC and isocenter in the center of the brain), this was improved to 46% and 45% for both the right and left eyes when the isocenter was moved just behind the eyes and using MLCs for shielding (plan 2). On the other hand, using blocks for shielding was associated with the dramatic improvement in the mean dose reaching the eyes, i.e. 32%, 31.5% to right and left eyes, respectively when using (plan 3) and 30.5%, 30%, respectively when using (plan 4).

So, by using blocks for shielding instead of MLCs there was a dramatic decrease in the dose reaching the eyes. The mean dose to the eyes was reduced by 42%.

In the present study, the average of the maximum dose received by the right and left lens was 44% and 48% of the prescribed dose when using plan 1 (MLC used and the isocenter is in the center of the brain), this was improved to 38% and 41% for both right and left lens when the isocenter was moved to just behind the eyes with the use of MLCs for shielding (plan 2). On the other hand, using blocks for shielding was associated with dramatic improvement in the maximum dose reaching the lens, i.e. 15.5%, 11% to right and left lenses, respectively when using (plan 3) and 13%, 11%, respectively when using (plan 4). The maximum dose to the lens was reduced by 70% and 77% for the right and left lens, respectively.

Our results were similar to the results obtained by Kalapurakal et al.[6] in his study evaluating the adverse effect of the use of multi-leaf collimator on the dose received by the lens in

children with leukemia receiving cranial irradiation where the dose to the lens was increased by about 64% and 72% when using MLC without shielding blocks.

The fact that the use of MLCs was associated with an increase in the dose of the lens was also recognized by Vijay et al.[7] evaluating shielding of the whole brain by three different methods in 10 children receiving whole brain irradiation and reaching the conclusion that the use of conformal planning and shielding using MLCs will lead to better coverage of the PTV by the 95% isodose curves but higher dose to the eyes and lenses.

The dose to the lens was also evaluated in the study done by Cochran et al.[8] evaluating the dose to the lens during craniospinal irradiation using protons and showing that angling the cranial proton beam 15°–20° posteriorly will lead to substantial decrease in the dose received by the lens by nearly 50%.

But still our results were away from the results shown by Pakisch et al.[9] who showed that the dose to the lens was reduced to only 4% from the described midplan dose with the use of combination of angulation of the couch, placement of additional eye blocks close to the surface, and the angulation of the gantry during prophylactic cranial irradiation and with the use of 8 MV photon beams.

7. Conclusion

From the above mentioned study we can conclude that, the dose of radiation received by the target volume and the organs at risk during craniospinal irradiation of children with high risk medulloblastoma with the use of our new linear accelerator and treatment planning system Elekta and Precise Elekta is nearly identical to other studies and is reaching its target (OARs are within normal tissue tolerance).

As regards the dose to the lenses, using block shielding shows lower doses to eyes and lenses regardless to the position of isocenter, on the other hand, with the use of MLCs for shielding, the isocenter should be behind the eye not in the center of the brain as this shows lower doses to the eyes and lenses. If we use the isocenter in the brain we should use block.

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