THE MEASUREMENT OF DOSE TO THE LENS FROM PROPHYLACTIC CRANIAL IRRADIATION IN ACUTE LYMPHOBLASTIC LEUKEMIA

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ABSTRACT

This study was performed to measure the radiation dose to lens by thermoluminescent dosimetry in the children with acute lymphoblastic leukemia treated by prophylactic cranial irradiation. Ten patients treated at Division of Radiation Oncology, Department of Radiology, Siriraj Faculty of Medicine from January 1999 to May 1999 were included. The dose measured by 5 degrees posterior angle of the opposed lateral beams was less than 2 % decreased compared to that without angling beams. The mean calculated doses to the lens in this study were in the range of 135 – 263 cGy for the whole course of treatment. The clinical effect on this organ need to be further followed -up.

INTRODUCTION

Acute lymphoblastic leukemia (ALL) is the most common malignancy in children comprising 2-3 % of all new patients treated each year at Siriraj hospital.[1] Prophylactic cranial irradiation (PCI) combined with intensive chemotherapy have effectively improved the disease-free survival in these patients by decreasing the incidence of overall primary isolated central nervous system relapse to 5-10% or less. However, the toxicity from the treatment mainly involving physical growth and cognitive development is still ongoing concern.[2-4] The radiation effects to other structures in ALL were sparsely reported in the literature compared to those of neuropsychological aspects. Due to the proximity to the margin of radiation field and inherent radiosensitivity of lens, the measurement of radiation to this structure by thermoluminescent dosimetry (TLD) were performed in the children with ALL treated with PCI.

METHODS & MATERIALS

The simulation of standardized helmet technique with 80 cm source-skin distance for PCI in 10 patients were performed in supine position with general anesthesia required in small children. The head was immobilized by tape strips fastened to the couch during the procedure.

The central axis of the parallel opposed lateral beams were placed on center of the cranium with the beams flash over the entire head on anterior, posterior and cephalad directions. The caudal margin were defined by including cribiform plate, posterior orbit, infratemporal area and the first 2 cervical cord region to encompass all cranial meninges and shaped by lead shielding block. The anterior margin of the beam at the level of tranverse plane of eye were at lateral orbital rim which were the critical short distance to lens. The simulation were also performed both without and with 5 degrees posterior angle of the beams to

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adjust for divergence of the beam and to reduce the dose to contralateral lens.

After the simulation, the patients were moved to cobalt –60 treatment machine room to perform the measurement of dose by LiF –100 TLD rod # (1x1x6 mm.[3]). The dosimeters were placed at the central axis of the beams, the outer and inner canthus of each eye. Each patient was totally measured 6 times, half without angling beams and half with angling beams. The radiation dose prescribed at the midline plane was 180 cGy per fraction, 5 fractions per week. The total dose was 1,800 and 2,160 cGy for age less and more than 10 year at diagnosis respectively.

RESULTS

The distribution of dose measured by TLD was presented as a percentage of the dose at midline central axis. The % relative dose and the calculated dose to central axis and outer and inner canthus of left and right eye in each patient were shown on Table 1 and 2 respectively.

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Table 1. The relative and calculated dose to left eye

Patient No.	% Relative dose (No angling beam)			% Relative dose (With angling beam)		
	Central axis	Outer canthus	Inner canthus	Central axis	Outer canthus	Inner canthus
I	87.7	13.4	8.5	85.0	12.5	7.4
II	86.5	13.2	8.9	86.0	13.0	8.4
III	81.3	11.0	6.4	82.0	11.2	7.0
IV	76.5	10.7	6.9	80.4	12.5	8.6
V	78.8	23.6	7.5	80.2	12.3	7.3
VI	84.1	13.2	8.4	73.1	10.9	6.0
VII	87.7	16.6	8.3	77.2	9.8	6.4
VIII	74.8	12.3	6.1	72.0	12.4	6.4
IX	87.9	15.5	9.4	88.2	14.7	8.9
X	74.0	10.1	6.5	88.9	15.6	9.0
Mean	81.9	14.0	7.7	81.3	12.5	7.5
Calculated dose (cGy)	147.4	25.2	13.9	146.3	22.5	13.5

Table 2. The relative and calculated dose to right eye

Patient No.	% Relative dose (No angling beam)			% Relative dose (With angling beam)		
	Central axis	Outer canthus	Inner canthus	Central axis	Outer canthus	Inner canthus
I	89.0	6.5	8.4	85.4	13.3	7.7
II	87.7	16.6	10.6	85.2	13.7	9.2
III	85.0	16.6	9.4	81.4	10.8	7.3
IV	77.7	13.5	7.8	80.5	12.1	8.1
V	76.5	10.1	7.0	81.0	13.7	7.4
VI	75.6	12.8	6.8	75.8	9.9	6.5
VII	78.3	11.2	6.8	75.0	10.6	7.2
VIII	76.0	14.9	6.4	74.0	13.5	6.6
IX	89.3	17.7	9.4	89.0	15.7	10.2
X	88.9	15.8	9.4	87.2	15.4	9.0
Mean	82.4	14.6	9.4	81.5	12.9	7.9
Calculated dose (cGy)	148.3	26.3	14.8	146.7	23.2	14.2

DISCUSSION

Normal epithelial cells of lens lie beneath the anterior capsule and equator only. The germinal layer is located at the equator and is the layer most susceptible to radiation effect. The lens of infants and children are more sensitive than those of adults due to decreasing number of mitotic cells with age. The morphology of radiation cataract has been well described with vacuole formation in equatorial region as the initial change. These opacities forming from degenerative fibers and cell debris slowly migrate to posterior subcapsular zone of lens. The cataract may remain stable at any stage of progression. The symptoms from this complication may vary from some degree of visual impairment to complete blindness.[5]

Due to anatomic location just behind the lens and the report from TLD measurement in rando phantom by Kline et al,[6] the outer and inner canthus were used as clinical measurement points in this study. The variation of doses measured at outer canthus were more considerable than that at inner canthus. This may be caused by the proximity of field margin.

The field size of PCI in ALL encompasses all potential intracranial subarachnoid involvement with opposed lateral fields down to the second cervical cord region called helmet technique. The cribiform plate and optic nerve must be included in radiation beam whereas the anterior part of eyes must be blocked. Divergence of the beam into the contralateral eye is always a problem. To minimize this dose, the beam can be angled posteriorly not more than 5 degrees depending on setup geometry. This study showed less than 2 % relative dose decreased with this technique which was much less than that from the report by Kline et al[6] but correlated with that from the report by Pakisch et al.[7]

The alternative way to minimize this divergence is placing the central axis on lateral orbital rim behind the lens and then shape the field by using the customized block. Woo SY et al reported dose to lens measured in Rando phantom which were 21, 10.6 and 9.9% of the midplane dose from the central axis at the thickest part of cranium without or with beam angled 5 degrees posteriorly and the central axis at lateral orbital rim respectively.[8]

The mean calculated doses to the inner canthus and outer canthus were in the range of 135 – 263 cGy. From the report of Kline et al which revealed that the dose to lens was in the range of those at outer and inner canthus, this can help to predict the radiation effect to this organ. The latency and frequency of lens opacities are a function of radiation dose and fractionation.[9] In most human studies, total fractionated doses under 500 cGy have not caused significantly opaque lens. Merrriam et al[10] reported minimum cataractogenic X-ray dose of 200, 400 and 550 cGy when radiation given in a single dose, fractionated dose in 3 weeks to 3 months and fractionated dose over 3 months respectively. The radiation effect obviously diminished with fractionation whereas the latent period became shorter as dose increased.

The radiation effect to other structures of eye were also sparsely in the literatures such as optic atrophy[11] and abnormal visual- evoked potentials.[12]

CONCLUSION

The radiation- induced cataracts are deterministic late effect. This means that there is threshold dose below which they do not occur and above which the severity of biological response is dosed related.[12] The lens is definitely more sensitive in very young children than in adults with shorter latent period and higher incidence of cataract development from a given dose, so the follow-up after treatment is necessary in all.

REFERENCES

1. Tumor Registry. Siriraj Cancer Center. Statistical Report 1998. Faculty of Medicine Siriraj Hospital.
2. Waber DP, Tarbell NJ. Toxicity of CNS prophylaxis for childhood leukemia. Oncology (Huntingt) 1997;11:259-64.
3. Birkebaek NH, Fisker S, Clausen N et al. Growth and endocrinological disorders up to 21 years after treatment for acute lymphoblastic leukemia in childhood. Med Pedistr Oncol 1998;30:351-56.
4. Halberg FE, Kramer JH, Moore IM et al. Prophylactic cranial irradiation dose effects on late cognitive function children treated for acute lymphoblastic leukemia. Int J Radiat Oncol Biol Phys 1992;22:13-6.
5. Moss WT. The Orbit. In: Moss WT, Cox JD, eds,6th ed. Radiation Oncology. Rationale, Technique, Results. C.V. Mosby, St.Louise 1989:173-83.
6. Kline RW, Gillin MT, Kun LE. Cranial irradiation in acute leukemia: dose estimate in the lens. Int J Radiat Oncol Biol Phys 1979;5:117-21.
7. Pakisch B, Stucklschweiger G, poier E. et al. Reduction of the dose to the lens in prophylactic cranial irradiation: A comparison of three different treatment techniques and two different beam qualities. Int J Radiat Oncol Biol Phys 1992;23:183-88.
8. Woo SY, Donaldson SS, Heck RJ. Minimizing and measuring lens dose when giving cranial radiation. Radiother Oncol 1989;16,183-88.
9. Gordon KB, Char DH, Sagerman RH. Late effects of radiation on the eye and ocular adnexa. Int J Radiat oncol biol phys 1995; 31:1123-40
10. Merriam GR, Focht EF. A clinical study of radiation cataracts and the relationship to dose. Am J Roentgenol 1957;77,759-85.
11. Fishman ML, Bean SC, Cogan DG. Optic atrophy following prophylactic chemotherapy and cranial radiation for acute lymphocytic leukemia. Am J Ophthalmol 1976;82:571-6.
12. Uberall MA, Hertzberg H, Meier W et al. Visual –evoked potentials in long-term survivors of acute lymphoblastic leukemia in childhood. The German Late Effects \Working Group. Neuropediatrics 1996; 27:194-6.
13. Hall E. Cataractogenesis. In: Hall EJ, ed, 4th ed. Radiobiology for the Radiologists J.B. Lippincott, Philadelphia, 1994 323-47.