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ORIGINAL ARTICLE

Do collimator angle setup errors cause dose inhomogeneity at the junction zone during craniospinal irradiation? A phantom study

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Summary

Purpose: *Craniospinal irradiation (CSI) has some geometric uncertainties, especially at the junction zone. In this study we tried to evaluate how possible random setup errors of the collimator angle may contribute to these uncertainties.*

Materials and methods: *Cranial and spinal fields were drawn on RW3 solid water phantom in accordance with the divergence matching technique (DMT). Field dimensions were 18×18 cm and 6×30 cm, respectively. We placed light-insulated Kodak X-Omat V films at the junction zone, then we irradiated the films with different collimator angles with both Co-60 and 4 MV conditions, and determined how the junction zone was affected from random setup errors in DMT.*

Results: *10.6 degrees collimator angle was proper for 30 cm upper spinal field. For Co-60 machine the dose homogeneity of this angle was +4.5%. For the angles of 8, 9, 11 and 12 degrees the homogeneities were –13%, –11%, +5% and +10 %, respectively. For 4 MV photon the dose homogeneity of the 10.6 degrees collimator angle was +3%. For the angles of 8, 9, 11 and 12 degrees the homogeneities were -17%, -14%, +6 % and +13%, respectively.*

Conclusion: *As the CSI has some geometric uncertainties, serious dose inhomogeneities may occur at the junction zone. The collimator angle is of great importance and any random setup errors may not be tolerated.*

Key words: collimator angle, craniospinal irradiation, random setup errors

Introduction

Some of the central nervous system (CNS) malignancies (i.e. medulloblastoma, ependymoblastoma etc.) have the ability to spread via the cerebrospinal fluid (CSF) making thus CSI an indicated therapeutic method in these malignancies [1-3]. CSI was introduced by Paterson and Farr in 1953 who used 250 kV X-rays.

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One of the main purposes during irradiation is covering the planning target volume (PTV) at maximum uniformity and protecting normal/sensitive tissues. In CSI two different treatment planes are used. Both the cranium and medulla spinalis have some geometric difficulties covering the PTV uniformly because of their anatomy. At the junction level two different perpendicular planes are irradiated i.e. for the cranium two opposed parallel fields at the sagital plane, and for the medulla spinalis a posterior field at the coronal plane alone. As different planes are used, many geometric and dosimetric problems may occur at the junction level. In addition, the medulla spinalis is too long to irradiate with one field, so two separate fields are used and additional dosimetric problems may occur at the lower spinal junction zone [2,4-6]. The most practical treatment technique must be chosen to minimize daily setup errors (i.e. random errors). Random setup errors may occur especially at the junction zone between cranial and upper spinal field [2,4,7-10].

In this study we tried to find out whether cranial field collimator angle setup errors may cause dose inhomogeneity at the junction zone during CSI with the DMT.

Materials and methods

Divergence matching technique

This technique is frequently used in CSI. The opposed parallel cranial fields are rotated to match with the upper spinal field divergence [2,9,11,12]. The treatment fields are shown in Figure 1. Both cranium and the first two vertebrae (i.e. C1-C2) are irradiated in the same field. The face, eyes and anterior neck structures are protected with individual blocks or multi-leaf collimator.

The collimator angle of the cranial field is calculated by the formula [4,12]:

$$\theta = \tan^{-1} \frac{(\text{spinal field length} \times 0.5)}{\text{SSD}}$$

where θ =collimator angle and SSD = skin source distance

The changes of the collimator angle with field lengths are shown in Table 1.

Alcyon-II Co-60 and Orion 4 MV machines were used and the measurements were done with films located at the medulla depth (4.5 cm) of the junction zone.

The following procedure was used:

1. The calibration films were irradiated with Co-60 and 4 MV machines to make the film dosimetry and to calculate the absorbed dose from the optic densities of the irradiated films. The calibration films were given 25, 50, 75, 100, 125, 150 and 175 cGy doses, respectively, at the 10×10 cm open field in the 2 cm depth of the solid water phantom. The films were developed in an automatic bath machine and the calibration curve was drawn (Figure 2).

2. The 18×18 cm cranial field with 80 cm skin source distance (SSD) (for 4 MV the SSD was 100 cm) and 30×6 cm upper spinal field with the same SSD were drawn at the solid water phantom (Figure 3). The light-insulated films located at the junction zone were irradiated using 8, 9, 10.6, 11 and 12 degrees collimator angles, respectively. The cranial fields were given 75 cGy at the 8 cm depth and the spinal field was given 75 cGy at the 4.5 cm.

3. The films were developed under the same conditions with the calibration films and the optic densities of the junction zone in medulla spinalis depth (4.5 cm) were read with Macbeth TD 931 Optic Densitometry with 2 mm steps. Optic densities were

Table 1. The collimator angles match with spinal fields lengths

Upper spinal field length	*SSD=80 cm collimator angle*	*SSD=90 cm collimator angle*	*SSD=100 cm collimator angle*
4	1.4	1.27	1.14
6	2.15	1.91	1.72
8	2.86	2.54	2.29
10	3.57	3.18	2.86
12	4.29	3.81	3.43
14	5.00	4.44	4.00
16	5.71	5.08	4.57
18	6.42	5.71	5.14
20	7.12	6.34	5.71
22	7.83	6.97	6.28
24	8.53	7.59	6.84
26	9.23	8.22	7.41
28	9.93	8.84	7.97
30	10.62	9.46	8.53

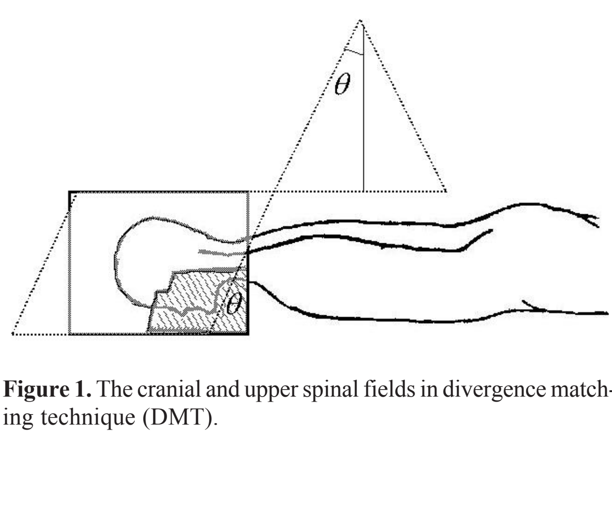

Figure 1. The cranial and upper spinal fields in divergence matching technique (DMT).

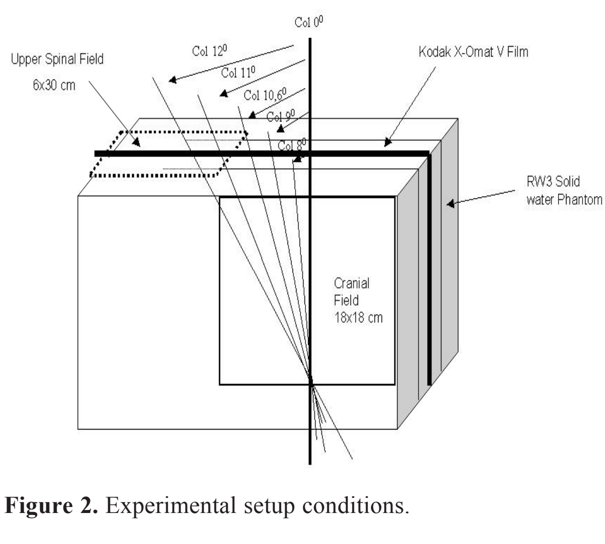

Figure 2. Experimental setup conditions.

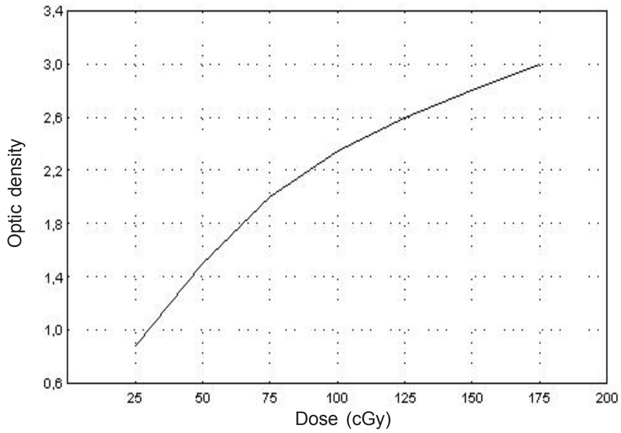

Figure 3. Calibration curve.

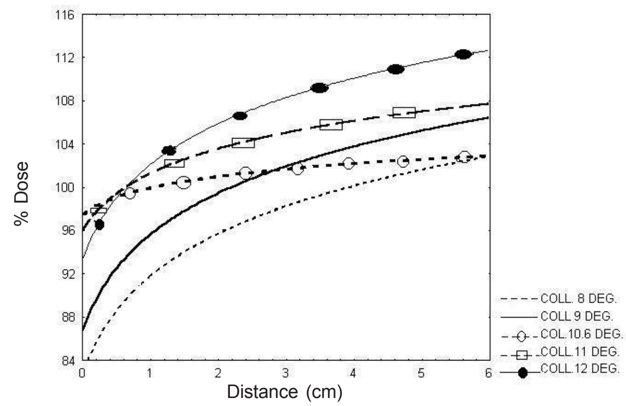

Figure 5. Changes of homogeneity with collimator angle for 4 MV.

transformed to absorbed doses by the calibration curve.

4. The given dose of the cranium was accepted as 100% and the other doses were normalized to the cranial dose. The homogeneity differences with changing collimator angles were drawn (Figures 4,5).

Results

As the upper spinal field length was 30 cm we determined the proper collimator angle as 10.6 degrees for DMT (Table 1). In the Co-60 situation the dose inhomogeneity at the junction zone was +4.5% for 10.6 degrees. For the other angles (8, 9, 11 and 12 degrees) the dose inhomogeneities were –13%, –11%, +5 % and +10%, respectively. Figures 4 and 5 show the changes of the homogeneities with different collimator angles. With 4 MV the dose inhomogeneity at the junction zone was +3% for 10.6 degrees. For the angles of 8, 9, 11 and 12 degrees the inhomogeneities were –17%, –14%, +6 % and +13%, respectively. With increasing angles the inhomogeneity beyond the medulla spinalis also increased. This may cause improper high dosage of the anterior neck structures.

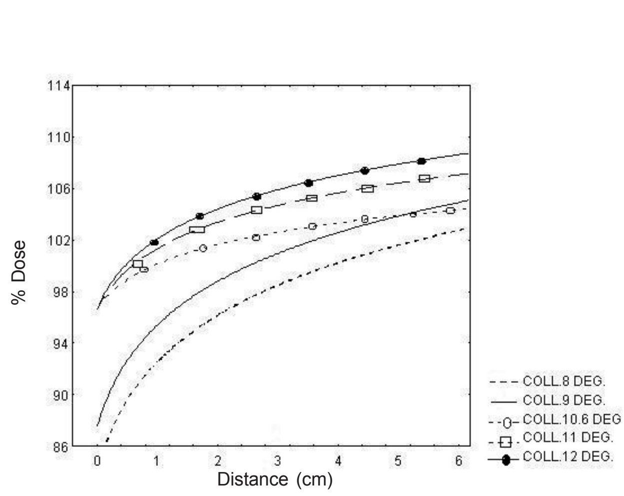

Figure 4. Changes of homogeneity with collimator angle for Co-60.

Discussion

Craniospinal irradiation should be practised with serious attention because of the anatomic and geometric difficulties of this area. The younger age distribution of the patients in need for CSI was a challenge for us to find out whether setup mistakes can be tolerated by this patient population. Maybe each technique has its own setup toleration limits. Because in our institution DMT is mostly used, we tried to find out whether random setup errors of the collimator angling can cause dose inhomogeneity at the junction zone. Field matching issues are of great interest and importance in the literature [4,5,7,12]. Wisser et al. used a special tool called "bonner box" for CSI. With this tool they were able to document the upper junction dose distribution for quality assurance [13]. Rades et al. developed a verification technique for all fields of the cervical junction in one single film [14].

According to ICRU 50, the dose uniformity across the target volume should be within the limits –5% and +7% [15]. Our results suggest that DMT can be safely put into practice with both Co-60 and 4 MV conditions. The dose distribution is homogeneous at the craniospinal junction zone at the medulla depth (4.5 cm) provided there is no collimator-angling mistake. The minor angling mistakes, even 1.6 degrees, cannot be tolerated and this can cause serious dose inhomogeneities (i.e. increasing/decreasing dose). With increasing angle the junction zone becomes expanded, so the dose to the thyroid, mandible, pharynx and larynx increases. Narayana et al. suggest using the low junction (i.e. lower border from C5-C7) to decrease the dose to the neck structures, although the dose to the medulla spinalis was greater than the high junction (i.e. the lower border below the C2) [16]. Another method to minimize the normal tissue doses is the use of electron energies for spinal fields. Chang et al. recently evaluated the treatment toxicities of 79 younger patients (≤18-year-old) who received CSI. Forty-six of them were treated with electrons. Although the hematologic toxicities were more common in the electron group, the authors concluded that there was no difference in the treatment interruptions [17]. With electron CSI the normal tissue doses decrease dramatically. Li et al. showed that the dose to the thyroid decreased from 73% to 7%, the heart dose from 59% to 6% and only the lung dose increased because of the lateral scatter [18].

Conclusion

Setup errors of the collimator angling cannot be tolerated during CSI with DMT. The technicians should be warned about the results of collimator angling mistakes. Care must be exercised in examining the changes of the patients' status during treatment. Weight loss due to esophagitis or loss of hair due to irradiation may affect patients' appearance. In such a situation the patients' thermoplastic masks should be changed and the collimator angle should be checked.

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