Cranial-spinal Junction and Surrounding Organs in Medulloblastoma Therapy: a Dosimetric Assessment between Different Techniques

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Abstract. Usually, medulloblastoma is treated with two lateral opposed fields in the brain and a posterior field along the spinal cord and there are several techniques available for the administration of craniospinal radiotherapy (CSRT). A common criticism is that overlap may occur at the match-line junction of the three fields, resulting in an increased risk of late effects in surrounding critical organs. Improved radiotherapy techniques in CSRT strive to reduce risks of late morbidity. The aim of this study is evaluate the delivered dose to cervical spinal cord and surrounding critical organs from two different techniques for medulloblastoma therapy in a radiotherapy centre in Recife, Brazil. For this, the adult anthropomorphic phantom ALDERSON was planned on half-beam block and angled fields techniques and it was irradiated 5 times in each technique. Thermoluminescent detectors were used to perform dosimetric measurements during treatment with 6 MV photon fields. For an applied dose of 1.5Gy in the plane of the junction, the half-beam block technique produced a mean dose measured of 1.38Gy compared with 1.51Gy for angled fields’ technique. The average dose to the cervical spinal cord was about 100% of the prescribed dose with both techniques. In spite of, in each daily fraction, doses to the mandible, pharynx and larynx were increased by the use of the half-beam block technique, the differences were not significant. No excess radiation dose was observed at the junction of the three fields and doses values in surrounding critical organs likely may decrease with the implementation of little changes on the technical procedure. There are not important differences between the dosimetry of junction cranial-spinal and surrounding organs due these different techniques.

KEYWORDS: Medulloblastoma, Craniospinal irradiation, Dosimetry, Junction, Cervical spinal cord.

1. Introduction

Medulloblastoma accounts for approximately 20% of brain tumors in childhood [1]. In spite of this it is not frequent in adult patients, it can occur in 1% of such tumors [2]. Dissemination along the neuraxis through cerebrospinal fluid is relatively common, with a reported incidence of 16–46% [3]. As a result, cranial-spinal radiotherapy (CSRT) has been the mainstay of treatment for this kind of cancer [1].

Improved radiotherapy techniques in CSRT strive to reduce risks of late morbidity and in the therapy for medulloblastoma there are several techniques available for the administration of CSRT. Usually, medulloblastoma is treated with two lateral opposed fields in the brain and a posterior field along the spinal cord [1,4]. A common criticism is that overlap may occur at the match-line junction of the three fields, resulting in an increased risk of late effects in surrounding critical organs (overdose) or tumor recurrence (underdose) [5]. Then, cranial-spinal junction site has been a point that several research groups have studied trying to reduce the dose to organs such as the thyroid gland, mandible, pharynx, and larynx [1, 4, 5].

Using an anthropomorphic phantom, this work aim to evaluate the delivered dose to cervical spinal cord and surrounding critical organs from two different techniques for medulloblastoma therapy in a radiotherapy centre in Recife, Brazil.

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2. Materials and Methods

2.1 Dosimetry Method

Thermoluminescent detectors (TLDs) were used to perform dosimetric measurements during treatment. LiF:Mg,Ti chips (TLD-100, Harshaw) were used and were individually calibrated to obtain dose response factors for each TLD. TLD doses were determined using a regular procedure adopted in the laboratory of thermoluminescence of CRCN.

For the treatment dose evaluation, TLDs were accommodated in the phantom, allowing systematic measurements at anatomically relevant sites such as mid brain, cervical spinal cord, thyroid, mandible, larynx, pharynx and cranial-spinal junction.

TLDs were read in a Harshaw (Thermo Electron Corporation, USA) automatic TLD reader, 5500 model, and were annealed and read using profiles described in table 1. The preheat and anneal were did using an oven (PTW-TLDO, Bicron)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Temperature Rate (°C/sec)</th>
<th>Temp (°C)</th>
<th>Interval of time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preheat</td>
<td>-</td>
<td>100</td>
<td>3,600</td>
</tr>
<tr>
<td>Acquire/Read</td>
<td>15</td>
<td>300</td>
<td>26+2/3</td>
</tr>
<tr>
<td>Anneal</td>
<td>-</td>
<td>400</td>
<td>3,600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>10,800</td>
</tr>
</tbody>
</table>

2.2 Radiotherapy Planning

2.2.1. Half-beam block technique

For this, an adult anthropomorphic phantom ALDERSON (RANDON Laboratory) was planned and treated with two lateral opposed fields in the brain and two posterior fields along the spinal cord using half-beam block technique. It is one of the widely credited techniques in which the collimator is opened twice the treatment field while centre of the superior fields (cranial) is matched with border of inferior field (spinal) (Figure 1).

For cranial field, collimator was opened as 18x30cm² with a focus surface distance (FSD) of 1m and collimation was asymmetric (half-beam blocked) and rotated of 11.3° in order to match the divergent edge of spinal field. The cranial dose prescription was set at 1.5Gy to the norm point (mid brain) at 7.5cm depth as prescribed for patients.

For the spinal field, the collimator for superior and inferior fields was opened as 40x5cm² and 17x5cm², respectively, and the fields were separated with gap of 1cm. The prescription dose was 1.5Gy to the norm point of each field situated at 4cm depth.

Figure 1. A typical half-beam treatment fields for cranial-spinal irradiation [KHAN, 2003].
2.2.2. Angled fields’ technique

In this planning therapy, the same adult anthropomorphic phantom was planned and treated with two lateral opposed fields in the brain and two posterior fields along the spinal cord. For cranial field, collimator was opened as 18x30cm² with a focus surface distance (FSD) of 1m. Regarding the spinal field, the collimator for superior and inferior fields was opened as 40x5cm² and 17x5cm², respectively, and the fields were separated with gap of 1cm. The prescription doses were the same of the first planning therapy (1.5Gy to the mid brain at 7.5cm depth and 1.5Gy to the norm point of each field situated at 4cm depth on the spinal fields).

The difference is an angle applied to the treatment coach that was rotated to 4.3° to correct for divergence and theoretically reduce the risk of overdose in the junction plane (Fig.2).

Figure 2. A typical angled fields technique for cranial-spinal irradiation [KHAN, 2003].
2.3. Treatment

Phantom treatment was performed in a Varian 600C linear accelerator with 6MV photons containing independent collimators (Fig. 3). It was irradiated 5 times, allowing results to be averaged. There was complete phantom dismantling, TLD replacement and phantom repositioning after each exposure, enabling any systematic or random variations in patient set up to be detected.

3. Results and Discussion

Average measured dose to the mid brain was 1.55±0.01 Gy for the half-beam block technique and 1.51±0.05 Gy for angled fields’ technique that both correspond about 100% of prescribed dose. The mean doses for different organs within the radiation fields from both techniques are shown in Table 2.

Table 2. Mean dose (Gy) to various organs from cranial-spinal irradiation using half-beam block and angled fields techniques for medulloblastoma therapy

<table>
<thead>
<tr>
<th>Organ</th>
<th>Mean Dose (SD)</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Half-beam block technique</td>
<td>Angled field technique</td>
<td></td>
</tr>
<tr>
<td>Cord</td>
<td>1.57 (0.01)</td>
<td>1.51 (0.05)</td>
<td></td>
</tr>
<tr>
<td>Thyroid</td>
<td>1.26 (0.03)</td>
<td>1.28 (0.03)</td>
<td></td>
</tr>
<tr>
<td>Mandible</td>
<td>0.26 (0.02)</td>
<td>0.24 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Larynx</td>
<td>1.25 (0.04)</td>
<td>1.14 (0.04)</td>
<td></td>
</tr>
<tr>
<td>Pharynx</td>
<td>1.15 (0.09)</td>
<td>1.08 (0.05)</td>
<td></td>
</tr>
<tr>
<td>Junction</td>
<td>1.38 (0.05)</td>
<td>1.51 (0.11)</td>
<td></td>
</tr>
</tbody>
</table>

The results show that the doses to the cervical spinal cord were, on average, the same of measured doses in midplane brain. A few studies have estimated spinal cord dose resulting from cranial-spinal irradiation. Narayana et al [1] reported that this dose was 11.9% higher than the prescribed dose with
low junction (C5-C7), and was 6.7% higher than the prescribed dose for the high junction (C1-C2). Hood et al [4] observed similar percentage (6.5%) for superior spine. However, both of above studies have had differences with this study: in the first one the volume of this critical organ, as well as the dose using the cranial and spinal fields were outlined and calculated using a 3-dimensional treatment planning system; and in the second one the isocentre for the cranial treatment was located at the spinal junction, it was used a pediatric phantom for dose measurements and the measured dose of spinal cord was from spinal field only.

Thyroid dose measurements were, approximately, 85% of prescribed isocentre dose (mid brain) and it was a little higher than the value observed in Narayana study for high cranial-spinal junction (73.3%) [1], that is similar of the junction position in this study. Hood et al [4] observed measured dose of 85% of prescribed dose, also, in spite of brain radiotherapy during childhood may result in higher thyroid doses than those in adults due to the increased proximity of the thyroid gland to the isocentre spinal field.

This value of mean thyroid dose was from just one daily fraction applied on patients. The total dose would reach 15 Gy that is more than the half-value of radiation dose required to cause thyroid dysfunction (25 Gy) [6]. It should be notice that some institutes used a boost to the posterior fossa, increasing the total dose. It was observed that there was not difference between the techniques in this study, but it could decrease about 30% with a use of low cranial-spinal junction (C5-C7) [1].

Dose to the mandible, larynx, and pharynx were, respectively, 17.3%, 83.3% and 76.7% of prescribed dose to the tumor for half-beam block technique and 16.0%, 76.0% and 72.0% for angled fields technique. There is not an important difference between the measured doses in the surrounding organs due these different techniques. Comparing with data from Narayana’s study [1], these values can decrease with little changes on the technical procedure such as the position of cranial-spinal junction. It is important to emphasize that the mandible doses were from mandibular condyles. Molar regions are the most common sites of mandible bone complications, whereas a condyle makes part of temporal-mandibular articulations that may be affected by fibrosis and dysfunction after irradiation. Jereczek-Fossa et al [7] indeed the single dose is not sufficient to be used as a representative dose for the mandibular region.

Junction dose was a little better for the angled fields’ technique and the percentage from the both techniques were similar to the percentage found by Hood et al [4]. It was observed that the standard deviation of measured dose for 5 different exposures is low in most of cases (<5%), including at the plane of the junction, indicating the surrounding organs and junction may be not particularly sensitive to others negligible shifts in patient position. Some authors have suggested techniques [5], moving junction [8] or use of beams modifiers [9] to solve the dose irreproducibility in the junction region or compensate the over and under dose in this plane.

4. Conclusion

No excess radiation dose was observed at the junction of the three fields, however it is necessary to ensure the reduction setup errors so that it can leads to significant dosimetric errors to the dose in this region.

Doses values in surrounding critical organs likely may decrease with the implementation of little changes on the technical procedure.

There are not important differences between the dosimetry of junction cranial-spinal and surrounding organs due these different techniques.

Acknowledgements

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REFERENCES