DOSE EVALUATION IN CRANIAL-SPINAL JUNCTION AND SURROUNDING ORGANS IN MEDULLOBLASTOMA THERAPY

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ABSTRACT

Improved radiotherapy techniques in craniospinal radiotherapy (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. 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. Using an anthropomorphic phantom, this work aim to measure the delivered dose to the cranial-spinal junction and surrounding critical organs at medulloblastoma therapy in radiotherapy clinical in Recife, Brazil. For this, the adult anthropomorphic phantom ALDERSON was planned on half-beam block technique and it was irradiated 5 times, allowing results to be average. Thermoluminescent detectors (TLDs) were used to perform dosimetric measurements during treatment with 6 MV photon fields. There was complete phantom dismantling, TLD replacement and phantom repositioning after each exposure. The results showed that, using standard LiF:Mg,Ti TLD chips, the delivered dose, as percentage of isocentre measured dose, to cervical spinal cord, thyroid gland, mandible, pharynx and larynx were 112%, 61%, 11%, 71% and 77%, respectively. No excess radiation dose was measured at the junction of the three fields.

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 measure the delivered dose to the
cranial-spinal junction and surrounding critical organs at medulloblastoma therapy in a
radiotherapy clinical in Recife, Brazil.

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 (ºC/sec)</th>
<th>Temp (ºC)</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

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 18x30cm$^2$ 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 40x5cm$^2$ and 17x5cm$^2$, 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.

2.3. Treatment

Phantom treatment was performed in a Varian 600C linear accelerator with 6MV photons containing independent collimators (Fig. 2). 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 1.07±0.03 Gy that correspond to 71.3% of prescribed dose. The doses received by each exposure for different organs within the radiation fields are shown in Table 2. A summary of mean doses of various tissues, along with the standard deviation, is also shown.
The results show that the dose to the cervical spinal cord was, on average, 12.1% higher than the measured dose in midplane brain (80% of prescribed dose for the cranial fields). 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, 60.7% of isocentre dose (mid brain) and it was compatible with Narayana study for low cranial-spinal junction (56.7%) [1]. Hood et al [4] observed measured dose of 85% of prescribed dose, but 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

Table 2. Mean dose (Gy) to various organs from cranial-spinal irradiation for medulloblastoma therapy

<table>
<thead>
<tr>
<th>Organ</th>
<th>Irradiation number</th>
<th>Mean Dose (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cord</td>
<td>1.22</td>
<td>1.22</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>Mandible</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>Larynx</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pharynx</td>
<td>0.72</td>
<td>0.69</td>
</tr>
<tr>
<td>Junction</td>
<td>1.19</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Figure 2. Irradiation of the adult anthropomorphic phantom with a lateral field to simulate medulloblastoma radiotherapy.
was from just one daily fraction applied on patients. The total dose would reach 13 Gy that is more than the half-value of radiation dose required to cause thyroid dysfunction (25 Gy) [6]. It should be noticed that some institutes used a boost to the posterior fossa, increasing the total dose.

Dose to the mandible, larynx, and pharynx were, respectively, 7.6%, 54.7% and 50.7% of prescribed dose to the tumor and 10.7%, 76.6% and 71.0% of measured dose in mid brain. 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 33% of total prescribed dose (cranial and spinal fields) and it was similar to the percentage found by Hood et al (32%) [4]. It was observed that the standard deviation of measured dose for 5 different exposures is low in most of cases (<5%). However, the standard deviation at the plane of the junction is much greater (20%), indicating the junction may be 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 this dose irreproducibility in this region or compensate the over and under dose in this plane.

4. CONCLUSIONS

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.

ACKNOWLEDGMENTS

The authors are thankful to the participating institution.

REFERENCES


