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# DOSIMETRIC IMPACT OF INTRAFRACTIONAL PATIENT MOTION IN PEDIATRIC BRAIN TUMOR PATIENTS

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**Abstract—The purpose of this study was to determine the dosimetric consequences of intrafractional patient motion on the clinical target volume (CTV), spinal cord, and optic nerves for non-sedated pediatric brain tumor patients. The patients were immobilized for treatment using a customized thermoplastic full-face mask and bite-block attached to an array of reflectors. The array was optically tracked by infra-red cameras at a frequency of 10 Hz. Patients were localized based on skin/mask marks and weekly films were taken to ensure proper setup. Before each noncoplanar field was delivered, the deviation from baseline of the array was recorded. The systematic error (SE) and random error (RE) were calculated. Direct simulation of the intrafractional motion was used to quantify the dosimetric changes to the targets and critical structures. Nine patients utilizing the optical tracking system were evaluated. The patient cohort had a mean of 31 ± 1.5 treatment fractions; motion data were acquired for a mean of 26 ± 6.2 fractions. The mean age was 15.6 ± 4.1 years. The SE and RE were 0.4 and 1.1 mm in the posterior-anterior, 0.5 and 1.0 mm in left-right, and 0.6 and 1.3 mm in superior-inferior directions, respectively. The dosimetric effects of the motion on the CTV were negligible; however, the dose to the critical structures was increased. Patient motion during treatment does affect the dose to critical structures, therefore, planning risk volumes are needed to properly assess the dose to normal tissues. Because the motion did not affect the dose to the CTV, the 3-mm PTV margin used is sufficient to account for intrafractional motion, given the patient is properly localized at the start of treatment. © 2010 American Association of Medical Dosimetrists.**

*Key Words:* **Pediatric brain tumor, intra-fraction motion, target localization.**

## INTRODUCTION

Nearly one third of the 12,000 children diagnosed with cancer each year in the United States will receive external beam radiation therapy (EBRT) as part of their initial management. In modern pediatric treatment protocols, the volume targeted to receive the prescription dose is defined based on the specific diagnosis, location, extent of disease, relevant imaging studies, and clinical- and treatment-related factors including prior surgery, response to chemotherapy, and the risk of treatment-related side effects. Considering ICRU-50 and 62 definitions,[1,2] relevant imaging studies are required to define the gross tumor volume (GTV), which is expanded by an anatomically confined margin to form the clinical target volume (CTV). The CTV is meant to account for potential subclinical invasion of the tumor and defines the volume at risk. Ideally, the CTV would receive a tumoricidal dose of radiation, and no other tissue would be irradiated.

The concept of the planning target volume (PTV) is meant to account for temporal changes in the position, shape, and volume of the CTV, and variations in patient positioning and beam delivery that naturally occur with fractionated treatment. The former is accounted for by the internal margin (IM), while the variation in patient position is considered the setup margin (SM). The study of the IM for a given clinical scenario is amenable to weekly or daily volumetric imaging over the course of therapy. The study of the SM may be achieved by using a variety of localization tools. Improved knowledge of the components of the PTV would improve patient-specific targeting and localization, and identify opportunities to minimize target volume margins. Similar consideration should be given to the study of organs at risk (OR)[2] to develop precise definitions for planning risk volumes (PRV).[2]

The need to understand these margins for pediatric brain tumor patients has become critical, as high-dose conformal radiation therapy, including intensity modulated radiation therapy[3] (IMRT) and proton therapy[4] enter the pediatric mainstream. Given the importance and complexity of determining proper margins, numerous solutions have been proposed using population-based formulas for margin calculations[5–12] for the SM portion of the PTV. The SM required for various adult sites and localization techniques has received considerable attention. The sites that have been studied include head and neck,[13–16] brain,[17] liver,[18,19] prostate,[20–24] pelvic,[25] and lung.[26–28] However, there has only been one study published that focused on pediatric localization,[29] and it attempted to assess the interfraction margin for brain tumors based on weekly portal films.

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Table 1. The mean, standard error (SE), random error (RE), and geometric-based margin for the interbeam and intrabeam motion in each direction

| | Interbeam | | | Intrabeam | | |
|---|---|---|---|---|---|---|
| | PA | LR | SI | PA | LR | SI |
| Mean (mm) | −0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| SE (mm) | 0.4 | 0.5 | 0.6 | 0.1 | 0.1 | 0.1 |
| RE (mm) | 1.1 | 1.0 | 1.3 | 0.2 | 0.4 | 0.3 |
| Margin (mm) | 1.8 | 1.9 | 2.4 | 0.4 | 0.5 | 0.5 |

In this paper, we determine the intrafractional motion for non-sedated pediatric brain tumor patients using optical tracking localization.[30] In addition, the dosimetric consequences of patient motion on the PTV, CTV, spinal cord, and optic nerves were investigated.

## METHODS AND MATERIALS

*Patient cohort*

A cohort of non-sedated pediatric brain tumor patients was immobilized for treatment using a customized thermoplastic full-face mask and frameless bite-block attached to an array of infrared reflectors. The array was registered to the treatment planning CT and the linear accelerator coordinate system then optically tracked by 2 infra-red cameras that gave positional information at a frequency of 10 Hz (Varian Frameless Array, Varian Medical Systems, Palo Alto, CA). The patients were localized daily based on mask/skin marks, giving the baseline position. Weekly orthogonal films were taken to ensure proper setup. Immediately prior to the delivery of each treatment field, the deviations from baseline in the patient position as assessed from the array, was recorded.

*Intrafraction margin calculations*

All of the patients were treated with a noncoplanar beam arrangement, which prompts the need for a slight modification to traditional terminology. To describe the different components of the intrafraction patient motion, the terms interbeam and intrabeam were used. For each treatment field (which usually corresponded to a new table position) during a treatment fraction, the isocenter offset given by the optical system was manually recorded. These data were used to determine the interbeam motion. Because the optical system records data at a 10-Hz frequency with a corresponding time stamp, the isocenter offsets during treatment delivery were extracted and used to estimate the intrabeam motion. For example, the patient was localized via skin marks with the gantry and table at 0°, giving the baseline position of the array. The first field was then loaded and the table and gantry were moved to the proper location. The reading of the optical array was recorded, then the treatment for that field was delivered. That reading minus the baseline gave one data point for the interbeam motion. During offline analysis, the position data of that field during beam on was shifted by the interbeam amount, giving the intrabeam motion. This insured that the interbeam and intrabeam motions were decoupled.

Interbeam and intrabeam margins for each axis; posterior-anterior (PA), left-right (LR), and superior-inferior (SI); were calculated based on the geometric[11] methods described by van Herk. The geometric setup margin used was $2.5\Sigma + 0.7\sigma$, where $\Sigma$ is the systematic error (SE), given by the standard deviation of the means, and $\sigma$ is the random error (RE), given by the root mean square (RMS) of the standard deviations. Variation in size and shape of the target was not examined, as these are part of an internal margin.

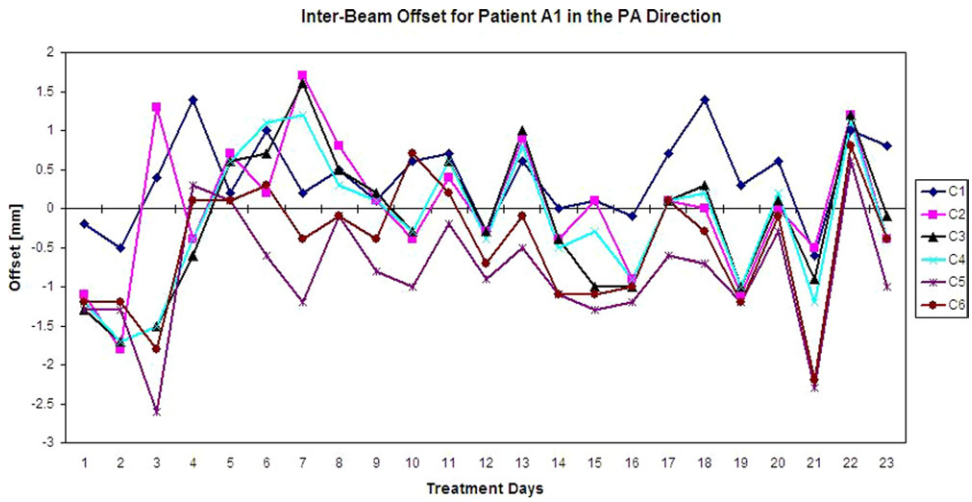


Fig. 1. The interbeam data points for patient A1 in the posterior-anterior (PA) direction are shown above. There were 23 fractions of position data. C1–C6 are the 6 different treatment fields (for this patient also the 6 treatment table position) per fraction.