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Particle therapy of children

Preparation of pediatric patients for treatment with proton beam therapy

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ABSTRACT

Purpose: Anesthesia is often used in proton beam therapy (PBT) for pediatric patients and this may prolong the treatment time. The aim of the study was to examine preparation of pediatric patients to allow smooth performance of PBT.

Material and methods: Preparation was initiated 1–2 days before treatment planning CT and continued for 10 days. The patient first visited the facility to become familiar with the treatment room and staff. As the second step, the patient stayed in the treatment bed for a certain time with their mother, and then stayed on the treatment bed alone. Special fixtures painted with characters, music, and gifts were also prepared.

Results: From 2010 to 2014, 111 pediatric patients underwent PBT. These patients were divided into 3 groups: 40 who could follow instructions well (group A, median age: 13.6 years old), 60 who could communicate, but found it difficult to stay alone for a long time (group B, median age: 4.6 years old), and 11 who could not follow instructions (group C, median age: 1.6 years old). Preparation was used for patients in group B. The mean treatment times in groups A, B and C were 13.6, 17.1, and 15.6 min, respectively, on PBT treatment days 2–6, and 11.8, 13.0, and 16.9 min, respectively, for the last 5 days of PBT treatment. The time reduction was significant in group B ($p = 0.003$).

Conclusion: Preparation is useful for pediatric patients who can communicate. This approach allows PBT to be conducted more smoothly over a shorter treatment time.

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Radiotherapy is frequently used for pediatric tumors to improve disease control. However, many pediatric patients cannot remain still on the treatment bed during radiotherapy, and these patients often require sedatives or general anesthesia [1,2]. Proton beam therapy (PBT) is widely used in pediatric patients to reduce toxicities [3–5], but the treatment time for PBT can be longer than that for photon radiotherapy and similar sedatives or anesthesia are required. Buchsbaum et al. showed that anesthesia is safe and efficient in pediatric patients receiving PBT [6] and Owusu-Agyemang et al. showed that non-invasive anesthesia is effective and safe for pediatric patients, with a seizure/laryngospasm/bronchospasm rate of 0.05% [7]. However, daily sedation or anesthesia has several difficulties, including the need for specialized staff and an extension of the treatment time.

In our hospital, anesthesiologists are unavailable on a regular basis and there is no room to perform anesthesia near the PBT treatment room. A pediatric physician induces anesthesia or administers sedatives, accompanies the patient to the treatment room, observes the PBT, and remains with the patient on transfer back to the ward. Pediatric patients also receive PBT in the same treatment room as adult patients; therefore, we have to minimize anesthesia and shorten the occupancy time in the treatment room. It would be advantageous if the need for sedation could be reduced in pediatric patients who cannot remain still, but can communicate, and we have developed a preparation process for these patients that allow PBT to be conducted smoothly and rapidly. In this report, we retrospectively investigated the effect of this process on performance of PBT for pediatric patients.

Methods and materials

Patients

A total of 111 pediatric patients received PBT at our hospital from April 2010 to April 2014. Prior written informed consent was obtained from the parents of all patients. The patients

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comprised 55 boys and 56 girls, and had a median age of 6.2 years old (range: 0.7–19.6 years old). The sites of irradiation were the brain (n = 40), head and neck (n = 33), and body (n = 38). The diagnoses were rhabdomyosarcoma (n = 23), neuroblastoma (n = 16), Ewing sarcoma (n = 13), pons glioma (n = 10), ependymoma (n = 8), germ cell tumor (n = 7), retinoblastoma (n = 4), glioma (n = 4), arteriovenous malformation (n = 3), chordoma (n = 3), yolk sac tumor (n = 3), and other tumors (n = 17). The patient and tumor characteristics are shown in Table 1.

Patient groups

Of the 111 patients, 40 could follow instructions and did not require preparation for PBT (group A; median age 13.6 (range 7.1–19.6) years old); 60 had difficulty staying in the treatment bed for a long time, but could communicate (group B; median age 4.6 (range 2.0–12.6) years old); and 11 could not follow instructions and required anesthesia (group C; median age 1.6 (range 0.7–3.0) years old). The preparation process described below was performed for patients in group B. The number of preparation sessions was limited to 10.

Proton beam therapy

Computed tomography (CT) images were taken at 2- to 5-mm intervals for brain or head and neck tumors, and at 5-mm intervals for body trunk tumors. A respiratory gating system (Anzai Medical Co., Tokyo, Japan) was used as required [8]. The clinical target volume was defined based on the tumor diagnosis. An additional margin of 5–10 mm was added to cover the entire CTV by enlarging the multileaf collimator and adjusting the range shifter. Proton beams from 155 to 250 MeV generated through a linear accelerator and synchrotron were spread out and shaped with ridge filters, double-scattering sheets, multicollimators, and a custom-made bolus to ensure that the beams conformed to the treatment planning data. During each treatment session, the patient position was monitored using an orthogonal fluoroscopy unit attached to the treatment unit under direct vision. On the first treatment day, a therapeutic radiologist and a radiotherapy technologist both checked the fluoroscopy images, while in routine treatment only a radiotherapy technologist checked these images. The relative biological effectiveness (RBE) of the PBT was assumed to be 1.1 [9].

Table 1
Characteristics of patients.

Characteristics	Number	%
Age (years)	0.7–19.6	6.2 (median)
Gender		
Boy	55	50
Girl	56	50
Irradiated site		
Brain	40	36
Head and neck	33	30
Body	38	34
Diagnosis		
Rhabdomyosarcoma	23	21
Neuroblastoma	16	14
Ewing sarcoma	13	12
Pons glioma	10	9
Ependymoma	8	7
Germ cell tumor	7	6
Retinoblastoma	4	4
Glioma	4	4
Arteriovenous malformation	3	3
Chordoma	3	3
Yolk sac tumor	3	3
Others	17	15

Preparation

The purpose of the preparation process was to allow the patient to remain still while alone in the treatment bed during PBT. Preparation was scheduled and performed by a radiation technologist and a nurse who were in charge of the actual treatment. Preparation was performed using a step-by-step schedule (see Supplementary File-1). The first step was to become familiar with the treatment room and staff. This step mainly consisted of visiting the PBT facility and playing with the radiation technologist and nurse. The second step was to stay still in the treatment bed for a period of time with a well-known person (mother in most cases). The final step was to remain still on the treatment bed for the required treatment time while alone (see Supplementary File-2). An immobilization bed and mask (those actually used during PBT) were utilized during preparation to allow the patient to become used to fixation. A picture book was usually used from the first visit as an aid to preparation. In this book, well-known characters provide a simple explanation of PBT. To reduce anxiety, a special treatment area was prepared for pediatric patients. Favorite characters were painted on the treatment mask and the body fixture was decorated as the patient wished (Fig. 1). A favorite video or music CD was played during position adjustment and irradiation, and a sticker was placed on the treatment calendar on every treatment day as a gift.

Treatment planning CT was performed about 1 week before the first day of PBT and preparation was initiated on this day or 1–2 days earlier. The average time of preparation was about 15 min per day and was limited to a maximum of 30 min. Preparation was performed about 5–6 times before PBT. Some patients who could not remain still on the treatment bed alone on the first treatment day continued preparation during the treatment period up to a total of 10 times overall.

Statistical analysis

Two measurements were used to evaluate the efficacy of the preparation process: the daily occupancy time of the treatment room, and the number of patients who needed anesthesia during PBT. The occupancy time was defined as the time from patient entry into the treatment room until completion of irradiation. One-way analysis of variance (ANOVA) was performed to compare occupancy times among groups A, B and C. The numbers of patients who needed anesthesia during PBT were recorded for treatment planning CT, on the first day of PBT, and on the last day of PBT.

Results

Of the 60 patients who underwent the preparation process (group B), 36 needed anesthesia for treatment planning CT (essentially prior to preparation), 31 needed anesthesia on the first day of PBT (after the preparation process was initiated), and 17 needed anesthesia within the first 5 treatment days (after preparation was complete). The dose of anesthetic agent also decreased in 9 of these 17 patients. Changes in the number of patients who needed anesthesia in group B are shown in Fig. 2a.

In all 111 patients, 47 needed anesthesia for treatment planning CT (median age 3.4, range 0.7–8.7), 41 needed anesthesia on the first day of PBT (median age 3.0, range 0.7–8.7), and 27 needed anesthesia on the last day of PBT (median 2.5, range: 0.7–8.7). The dose of anesthetic agent was decreased in 9 of these 27 patients. Anesthesia was required in 41% of all patients for treatment planning CT (100%, 93%, 70% and 56% in 2-, 3-, 4-, and 5-year old patients, respectively), but only in 24% after preparation (75%, 57%, 10% and 0% in the respective age groups). Changes in the num-