

Clinical outcomes of pediatric intracranial ependymoma treated with proton beam therapy: a multi-institutional retrospective study

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I. Introduction

- Proton beam therapy (PBT)
- A preferred modality in pediatric brain tumors due to its dosimetric advantage (Bragg peaks)
- Although pencil beam scanning (PBS) has largely replaced passive scattering (PS) technique, data comparing their **long-term clinical outcomes remain limited**.

Purpose

To evaluate the **long-term clinical outcomes of pediatric patients with intracranial ependymoma treated with PBT at two tertiary institutions in Korea**

II. Materials and Methods

II-A. Patients

- Total 65 patients with intracranial ependymoma treated with PBT (2009–2024)

Table 1. Patient and tumor characteristics

	Total (N=65)
Disease status	Naive 59 (90.8%) Recurrent disease 6 (9.2%)
Sex	Male 37 (56.9%) Female 28 (43.1%)
Age at RT	<3 yr 12 (18.5%) ≥3 yr 53 (81.5%)
Tumor location	Supratentorial 19 (29.2%) Infratentorial 46 (70.8%)
WHO grade	Grade 1–2 21 (32.3%) Grade 3–4 44 (67.7%)
Pathology	Ependymoma 27 (41.5%) Anaplastic ependymoma 36 (55.4%) Subependymoma 1 (1.5%) Papillary ependymoma 1 (1.5%)
CSF seeding	Negative 63 (96.9%) Positive 1 (1.5%) Unknown 1 (1.5%)

Table 2. Treatment characteristics

	Total (N=65)
Surgery	GTR 39 (60.0%) NTR 12 (18.5%) STR 14 (21.5%)
Post-op MRI	No residual disease 42 (64.6%) Suspicious lesion 8 (12.3%) Definite residual disease 15 (23.1%)
Total RT dose	59.4 (Median)
RT field	Local RT 57 (87.7%) Whole brain RT 5 (7.7%) Craniospinal irradiation 3 (4.6%)
Proton technique	Scattering 19 (29.2%) Scanning 46 (70.8%)
Pre-RT chemotherapy	19 (29.2%)
Post-RT chemotherapy	14 (21.5%)

II-B. Treatment planning

- Different plan parameters between two institutions

Table 3. Planning characteristics

Institution	#N of fields	Main field directions	PTV	CTV - Postop. GTV	Distal margin	Aperture margin/ Robustness (mm)	Total dose (Gy)
National Cancer Center	PS 3 (2–4)	PA, RPO, LPO	CTV + 3 mm	7–10 mm	2 mm (1.0–6.0)	7.0 (5.0–12.0)	59.4 (50.4–66.6)
	PBS 3 (2–4)	RT/RPO, LT/LPO, PA/ASO	CTV + 3 mm	7–10 mm	3.5% + 2 mm (3.5% + 1–3 mm)	2.0 (1.0–3.0)	59.4 (45.0–63.0)
Samsung Medical Center	PBS 2 (1–3)	RPO, LPO	No PTV	-	3.5% (0.0–4.5)	0	54 (30.6–60.0)

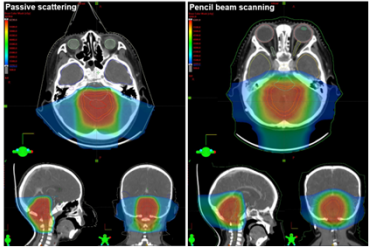


Figure 1. Examples of the proton therapy plans

II-C. Statistical analysis

- Survival curves using the Kaplan-Meier method
- Late toxicity

III. Results and Discussions

III-A. Survival outcomes

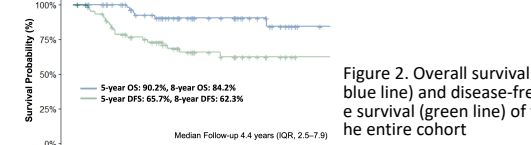


Figure 2. Overall survival (blue line) and disease-free survival (green line) of the entire cohort

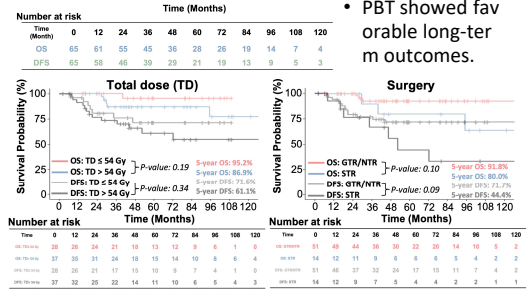


Figure 3. Survival curves for total dose (left) and surgery (right)

Table 4. Clinical outcomes

		5-year DFS	P-value	5-year OS	P-value
Age	<3 yr ≥3 yr	58.3% 67.4%	0.480	66.7% 97.3%	0.004
Sex	Male Female	67.3% 64.0%	0.640	88.5% 91.8%	0.980
Location	Supratentorial Infratentorial	75.3% 62.8%	0.980	91.7% 89.8%	0.680
Disease status	Naive Recurrent disease	68.3% 50.0%	0.570	93.4% 66.7%	0.055
WHO grade	Grade 1–2 Grade 3–4	59.8% 68.9%	0.810	94.1% 88.4%	0.320
MRI based surgical extent	No residual/suspicious Definite residual disease	71.1% 49.5%	0.160	92.6% 81.8%	0.140
Interval between op and PBT	<45 days ≥45 days	59.0% 73.9%	0.470	85.8% 95.5%	0.140
Proton technique	Scattering Scanning	63.2% 67.4%	0.650	84.2% 93.4%	0.160
PBT field	Local RT Whole brain/CSI	63.0% 87.5%	0.210	88.4% 100.0%	0.290
Pre-PBT chemotherapy	No Yes	58.2% 78.3%	0.140	88.4% 93.8%	0.440
Post-PBT chemotherapy	No Yes	63.0% 71.4%	0.750	89.8% 91.7%	0.680

- Although a significant difference was observed at age 3, it was likely due to a change in treatment methods.
- No statistically significant difference in survival outcome between PS and PBS

III-B. Toxicity

Table 5. Treatment-related late toxicity

	Scattering (N=19)	Scanning (N=46)	P-value
Grade 2 or worse late toxicity	6 (31.6%)	1 (2.2%)	0.001
Brainstem necrosis	2 (10.5%)	1 (2.2%)	0.144
Hypopituitarism	4 (21.1%)	0 (0.0%)	0.002

- Statistically significant difference in grade 2 or worse late toxicity between proton techniques
- However, this may have been affected by other factors such as RT dose and chemotherapy, rather than the proton technique alone.

IV. Conclusion

- PBT provided favorable long-term outcomes in pediatric intracranial ependymoma.
- Both PS and PBS techniques provide favorable survival outcomes.