

# Proton Beam Therapy for Pediatric Malignancies

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Although major advances have been made in radiation techniques, concerns still exist about the treatment-related acute and long-term side effects. This issue is most notable in the pediatric population because of developing organs and tissues combined with longer life expectancies. Proton beam therapy has the advantage of a reduced dose of radiation with less scatter to normal tissue, which may lead to fewer adverse side effects.

## At a Glance

- Many pediatric patients with cancer receive radiation therapy.
- Radiation treatments can cause significant acute and long-term side effects.
- Proton beam therapy reduces radiation scatter to normal tissues and may decrease acute and late toxicities.

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Proton beam therapy is one of the latest advancements in radiation therapy used to treat cancer. Although initially proposed in 1946, the first patients were treated in 1958 at the Lawrence Berkeley National Laboratory in California (Merchant & Farr, 2014; Mitin & Zietman, 2014). The use of proton beam therapy in clinical practice has been slowly introduced but has gained significant ground with increasing public awareness since 2010 (Mitin & Zietman, 2014). One of the reasons this form of radiation has garnered interest is because of theoretical advantages as compared to photon therapy, with specific potential advantages in the pediatric population.

About 12,000 new cases of pediatric cancer occur each year in the United States, and about 3,000 require radiation therapy (Merchant, 2013). Although radi-

ation is an important component of many treatment regimens for pediatric cancers, it is associated with early and late side effects that can be more problematic in children because of their developing organs and tissues (Armstrong, Stovall, & Robison, 2010). The possible benefits of proton beam therapy are the reduction in dose to normal tissues and a reduction in adverse effects of radiation treatment (Merchant, 2013).

## Background

Radiation therapy for patients with cancer commonly uses external beam delivery techniques that include photons. This form of ionizing radiation releases energy and delivers radiation doses to the specific areas of a patient's body. The standard dose of radiation is the

Gray (Gy). Photons travel through tissue without stopping, resulting in continuous dosing of radiation beyond the tumor (Merchant & Farr, 2014).

Proton therapy is an external radiotherapy modality that uses protons instead of photons. Protons are positively charged particles that are accelerated by a large, expensive particle accelerator called a cyclotron or synchrotron, available at a limited number of specialized centers (Decker & Wilson, 2012). When a proton beam enters the body, it delivers a constant dose within a few millimeters of the end of the particle range, the so-called Bragg peak (see Figure 1). Beyond the Bragg peak, protons deliver almost no additional exit dose beyond the target. The benefit of this is that the proton beam stops within the patient's tumor region, and the radiation does not extend to normal tissue beyond the tumor. This allows for radiation absorption to deep tumor targets with less scatter of radiation to normal surrounding tissues and the possible safe escalation of radiation doses to enhance tumor control (Daw & Mahajan, 2013; Swisher-McClure, Hahn, & Bekelman, 2015).

## Childhood Cancer

With multimodality therapies for pediatric malignancies, the five-year survival rate exceeds 80%. As many as 60%–90% of survivors of pediatric cancer experience adverse side effects related to the cancer or the treatment received (Geenen et al., 2007). The challenge for the pediatric cancer population with solid tumors undergoing radiation is the large, irregular volume of tumors close to critical structures in the body. In addition, children, when compared to adults, have longer anticipated life spans and an increased sensitivity to the radiation from