How it works

What is proton beam therapy?

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Proton beam therapy (PBT) is a type of radiotherapy, and like other types of radiotherapy, it uses high-energy radiation to kill cancerous cells and subsequently shrink tumours. Proton beam therapy is a form of external-beam radiotherapy, which means the radiation comes from a machine outside the body, as opposed to internal radiotherapy, where radioactive material is placed inside the body, near to the cancerous cells. With external-beam radiotherapy, the patient will not become radioactive or pose any risk to others after their treatment. External-beam radiotherapy uses several sources of radiation, including X-rays, gamma rays, electrons and protons.[1] In proton beam therapy, the source of radiation is, of course, protons.

A proton is a positively charged subatomic particle that can be found in the nucleus (the very centre) of every atom in the universe. These particles can be generated in a machine called a particle accelerator (often referred to as a synchrotron or a cyclotron), and these machines are very large, complex and expensive to build. In order to penetrate the body and reach the tumour to deliver the radiation, the protons have to be given high amounts of energy, and this is done by speeding up the particles in the accelerator. The speed of the protons determines their energy, and the energy can be altered depending on the depth in the body that the protons need to travel to. The deeper in the body they need to go, the greater the energy they need, and

[1] National Cancer Institute. (2018). *NCI Dictionary of Cancer Terms*. [online] Available at: www.cancer.gov/publications/dictionaries/cancer-terms/ [Accessed 3 Sep. 2018].

accurate calculations are made based on the location of the tumour to ensure the protons are accelerated to the right speed. The particle accelerator then focuses the protons into a beam, and this beam is directed into the body to the site of the tumour using magnets. When the protons reach the tumour, they then deliver their radiation, which damages and kills off cancerous cells.

How is proton beam therapy different from conventional external-beam radiotherapy?

The most common form of radiotherapy used in the treatment of brain tumours is external-beam radiotherapy using X-rays (sometimes called photon beam radiotherapy). Whereas protons are particles, X-rays are high-energy waves made of photons and are a form of electromagnetic radiation. Just like high-energy protons, X-rays damage and kill cancerous cells. X-rays are generated in a machine called a linear accelerator (often referred to as a linac) and are focused into beams that penetrate the body to reach the tumour site.

The key difference between the two types of radiotherapy is that protons deliver the majority of their radiation at the end of their journey into the body, which is calculated to land at the site of the tumour, whereas X-rays deliver radiation along the entire length of their journey through the body, the amount of radiation diminishing as they make their way out the opposite side of the body. This means that in proton beam therapy, only the cancerous cells receive a large dose of radiation, but in X-ray radiotherapy, all the tissues in the body that come into contact with the beam as it travels through receive a dose of radiation. Nowadays, this effect is mitigated by using multiple beams of X-rays that cross over at the site of the tumour, thereby delivering only small doses of radiation to surrounding healthy tissue while delivering a higher dose to the cancerous cells.

What are the potential benefits of proton beam therapy?

This difference between X-ray radiotherapy and proton beam radiotherapy underlies the key potential benefit of proton beam radiotherapy. The protons deliver the majority of their radiation at the end of their journey, the site of the tumour. Therefore, the healthy tissues beyond the tumour do not receive high doses of radiation. In essence, the advantage of proton beam therapy is that it is highly specific in terms of where it delivers the radiation, and this can be extremely beneficial when the surrounding tissue is particularly sensitive to the effects of radiation, such as brain cells.

In the short-term, this advantage may mean a reduction in the side effects of radiotherapy during treatment. This doesn't necessarily mean the absence of side effects, but it has been shown to create significantly lower levels of toxicity in patients undergoing radiotherapy, making the treatment a lot more tolerable.[2]

[2] MD Anderson Cancer Center. (2011). *What Brain Tumors Are Best Treated with Proton Beam Therapy?* [online] Available at: www.mdanderson.org/transcripts/cancer-newsline/2011/what-brain-tumors-are-best-treated-with-proton-therapy-10-31-11.htm [Accessed 3 Sep 2018].

In the long term, proton beam therapy is especially beneficial to children and young adults, whose brains are still developing, as the risk of damaging healthy brain cells is significantly reduced. Modelling proton beam therapy has also suggested a reduction in the risk of developing secondary malignancies as a result of radiotherapy, and children are particularly susceptible to this due to their longer lifespan after radiotherapy.[3] We can also speculate that proton beam therapy may reduce the incidence of long-term side effects as a result of radiation treatment.

What are the potential drawbacks of proton beam therapy?

It's important to keep in mind that we cannot be absolutely certain of the benefits of proton beam therapy yet, which is why we can only speculate about the benefits. Although a lot of research is being conducted into proton beam therapy, the treatment simply hasn't been around long enough for us to draw any conclusions as to the long-term benefits, or indeed, drawbacks. In addition, the number of patients who have received proton beam therapy is relatively small, and therefore, there isn't a sufficient number of systematic studies to support the speculations. Indeed, there is no evidence currently that suggests that proton beam therapy is any better at curing cancer or improving patient survival than X-ray radiotherapy.[4]

[3] British Institute of Radiology. (2016). *Proton Therapy*. [online] Available at: www.bir.org.uk/media-centre/position-statements-and-responses/proton-therapy/ [Accessed 3 Sep. 2018].

[4] Cancer Research UK. (2015). *Proton beam therapy: where are we now?* [online] Available at: scienceblog.cancerresearchuk.org/2015/07/16/proton-beam-therapy-where-are-we-now/ [Accessed 3 Sep. 2018].

One drawback that we are well aware of is actually the same as its key advantage: the specificity of area in treatment. This means that proton beam therapy is only appropriate for treating a very limited number of tumours, those tumours that have a sharp demarcation. In other words, those tumours where cancerous cells do not extend beyond the boundary of the tumour. However, many tumour types, such as glioblastomas, have tumour cells that spread out from the main site, and therefore, the advantage of the sharp border in proton beam therapy is lost, and conventional X-ray radiotherapy has a greater effectiveness in these cases.

In addition, as proton beam therapy is a relatively new form of radiotherapy, there is still progress to be made in achieving the level of precision and accuracy that has already been achieved in X-ray radiotherapy. So although proton beam therapy is more specific, conventional X-ray radiotherapy has the advantage of many more decades of experience and robust study.

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Mike, Tom, Rebecca, Charlie & Sophie