What is cancer radiotherapy, and why do we need proton beam therapy?

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In last night's federal budget, the government dedicated up to A$68 million to help set up Australia's first proton beam therapy facility in South Australia. The government says this will help Australian researchers develop the next generation of cancer treatments, including for complex children's cancers.

Proton beam therapy is radiation therapy that uses heavier particles (protons) instead of the X-rays used in conventional radiotherapy. These particles can more accurately target tumours closer to vital organs, which can be especially beneficial to patients suffering from brain cancer and children whose organs are still developing and are more vulnerable to damage.

So, the facility will also be an alternative to conventional radiotherapy for treating certain cancer. But what is traditional radiotherapy, and how will access to proton beam therapy improve how we manage cancer?

What is radiotherapy?

Radiotherapy, together with surgery, chemotherapy and palliative care, are the cornerstones of cancer treatment. Radiotherapy is recommended for half of cancer patients.

It is mostly used when the cancer is localised to one or more areas. Depending on the cancer site and stage, radiotherapy can be used alone or in combination with surgery and chemotherapy. It can be used before or after other treatments to make them more effective by, for example, shrinking the tumour before chemotherapy or treating cancer that remains after surgery.

Most radiotherapy treats cancer by directing beams of high energy X-rays at the tumour (although other radiation beams, such as gamma rays, electron beams or proton/heavy particle beams can also be used).

The X-rays interact with tumour cells, damaging their DNA and restricting their ability to reproduce. But because X-rays don't differentiate between cancerous and healthy cells, normal tissues can be damaged. Damaged healthy tissue can lead to minor symptoms such as fatigue, or, in rare cases, more serious outcomes such as hospitalisation and death.

Getting the right amount of radiation is a fine balance between therapy and harm. A common way to improve the benefit-to-cure ratio is to fire multiple beams at the tumour from different directions. If they overlap, they can maximise the damage to the tumour while minimising damage to healthy tissue.

How it works

Wilhelm Röntgen discovered X-rays in 1895 and within a year, the link between exposure to too much radiation and skin burns led scientists and doctors to pursue radiation in cancer treatment.

There are three key stages in the radiotherapy process. The patient is first imaged – using such machines as computer tomography (CT) or magnetic resonance imaging (MRI). This estimates the extent of the tumour and helps to understand where it is with respect to healthy tissues and other critical structures.

In the second stage, the doctor and treatment team will use these images and the patient's case history to plan where the radiation beams should be placed – to maximise the damage to the tumour while minimising it to healthy tissues. Complex computer simulations model the interactions of the radiation beams with the patient to give a best estimate of what will happen during treatment.

During the third, treatment-delivery stage, the patient lies still while the treatment beam rotates, delivering radiation from multiple angles.

Each treatment generally takes 15 to 30 minutes. Depending on the cancer and stage, there are between one and 40 individual treatments, typically one treatment a day. The patient cannot feel the radiation being delivered.

Benefits and side effects

Radiotherapy's targeting technology has made a significant difference to many cancers, in particular early-stage lung and prostate cancers. It is now possible to have effective, low toxicity treatments for these with one to five radiotherapy sessions.

For early-stage lung cancer studies estimate with radiotherapy, survival three years after diagnosis is at 95%. For prostate cancer, one study estimates survival at the five year mark is about 93%.

Side effects for radiotherapy vary markedly between treatment sites, cancer stages and individual patients. They are typically moderate but can be severe. A general side effect of radiotherapy is fatigue.

Other side effects include diarrhoea, appetite loss, dry mouth and difficulty swallowing for head and neck cancer radiotherapy, as well as incontinence and reduction in sexual function for pelvic radiotherapy.

Long-term effects of radiotherapy are a concern, particularly for children. For instance, radiation to treat childhood brain tumours can have long-lasting cognitive effects that can affect relationships and academic achievement.

Again doctors will need to weigh up the risks and benefits of treatment for individual patients. Proton beam therapy is arguably most beneficial in these cases.

Other radiotherapy challenges

There are several challenges to current radiotherapy. It is often difficult to differentiate the tumour from healthy tissue, and even experts do not always agree on where exactly the tumour is.

Radiotherapy can't easily adapt to the complex changes in patients' anatomy when a patient moves – for instance, when they breathe, swallow, their heart beats or as they digest food. As a result, radiation beams can be off-target, missing the tumour and striking healthy tissue.

Also, we currently treat all parts of the tumour equally, despite knowing some of the tumour's regions are more aggressive, resistant to radiation and likely to spread to other parts of the body.

The tumour itself also changes in response to the treatment, further confounding the problem. An ideal radiotherapy solution would image and adapt the treatment continuously based on these changes.

Improvements in technology, including in imaging systems that can better find the tumour, can help overcome these challenges.

Proton beam therapy and other innovations

Proton beam therapy will help maximise benefits for many patients, including those with cancers near the spinal cord and pelvis. It requires large accelerators to give protons enough energy to penetrate deep into patients. The energetic protons are transported into the treatment room using complex steering magnets and directed to the tumour inside the patient.

Protons slow down and lose energy inside the patient, with most of the energy loss planned to occur in the tumour. This reduces energy loss in healthy tissues and reduces side effects.

The problems of changing patient anatomy and physiology in other forms of radiotherapy are also challenges for proton beam therapy.

Australia has a number of research teams tackling such challenges, including developing new radiation treatment devices, breathing aids for cancer patients, radiation measurement devices, shorter and more convenient treatment schedules and the optimal combination of radiotherapy with other treatments, such as chemotherapy and immunotherapy.

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