RADIOTHERAPY REDEFINED

A STRONGER AND MORE PRECISE FORM OF RADIOTHERAPY is poised to take a leading role in mainstream cancer therapy. It also provides options for those with previously untreatable cancers.

Cancers long considered untreatable could soon be addressed using a sought-after radiotherapy developed in Japan.

Carbon ion radiotherapy (CIRT), pioneered by QST Hospital in Chiba, Japan, offers stronger and more highly targeted doses of radiation than conventional x-ray beam radiotherapy. As evidence mounts that CIRT could deliver significantly better outcomes for patients, particularly those with intractable cancers, global uptake is taking off.

From seven operating CIRT centres five years ago, there are now 12 across Japan, Europe and China, and five more under construction or commission. In 2019, US healthcare organization, the Mayo Clinic, announced it would build North America's first CIRT facility at its Jacksonville, Florida, campus. In Japan, the therapy was recently made part of the national health insurance scheme. "CIRT has definitely reached a tipping point," says Hiroshi Tsuji, director of QST Hospital.

Precise punch

Radiotherapy is a mainstay of cancer treatment, administered to more than two thirds of cancer patients, mostly using an x-ray beam delivering ionizing radiation that damages the DNA of cancer cells, killing or disabling them.

CARBON IONS ARE MORE LOCALIZED AND DELIVER GREATER ENERGY TO THE TUMOUR SITE

The beams of ions used in CIRT also deliver radiation, but differ to x-rays in several key ways. Whereas x-rays release ionizing energy quite evenly along their path, damaging healthy cells around the tumour, ions release most of their energy in an abrupt, well-defined burst called a Bragg Peak at the end of their flight path, causing less damage to healthy tissue (see opposite, at top left). Ions, unlike x-rays, are charged particles, so can be steered using a magnetic field.

Proton ion beams also offer a more precise form of radiotherapy. However, with their larger mass, carbon ions are more localized, deliver more energy to the tumour site and their targeting is less affected by beam scattering. Overall, CIRT's relative biological effect is approximately three times that of x-rays or of protons, inflicting significantly higher DNA damage to target cells.

CIRT was developed in the United States in the 1950s. However, despite the clear theoretical advantages of carbon ions over x-rays, it required huge facilities, and research was still needed to demonstrate safety and efficacy. Feasibility studies focusing on carbon ions commenced in 1994 at QST Hospital, the world's first dedicated carbon-ion medical facility, inspired by the work in the US.

Since then, the hospital's CIRT facilities have been available to international and local scientists and radiotherapy practitioners for training and research. So far more than 800 publications have come from these collaborations, and multiple joint research projects are ongoing, says Tsuji.

Clinical trials, many conducted at the hospital, have confirmed CIRT's real-world efficacy against a wide range of cancers. "Owing to its higher biological effect, CIRT is effective in radio-resistant tumours such as bone or soft tissue sarcomas, and malignant melanomas, opening doors to a curative treatment for those deemed to be incurable," Tsuji says.

CIRT is also highly effective against more common cancers, such as lung cancer, liver cancer, and prostate cancer, he adds. "For these tumours, better quality of life with less toxicity is observed while maintaining high control rates." As a result, patients deemed too frail for x-ray radiotherapy can successfully be treated by CIRT. Even for otherwise-healthy lung or prostate cancer patients, CIRT has advantages. Such is the therapy's effectiveness, the QST Hospital team have successfully treated early-stage lung cancer patients with a one-day treatment. "Over the past 25 years, we have successfully treated more than 12,000 patients from around the world," Tsuji notes.

CIRT also has a strong safety record. In 2019, the QST Hospital team showed prostate cancer patients treated with CIRT had a lower risk of a secondary malignancy compared to x-ray radiotherapy, and an on par or lower risk than surgery.

Costs come down

Today, one of the biggest hurdles to rolling out CIRT is the expense of facilities. "We are closely working with manufacturers and other R&D facilities to realize a smaller, more affordable and simply better CIRT system, which we call the Quantum Scalpel," Tsuji explains. This system, which would fit inside a tennis court, is one fifteenth the size of the smallest CIRT system currently in operation.

The team has developed a compact rotating gantry, which holds patients in the optimum position for the carbon ion beam. The team is also planning to construct a compact synchrotron to accelerate the carbon ion beams. "We hoped to complete the Quantum Scalpel project within five years," says Tsuji, opening door to affordable CIRT systems globally.

The QST Hospital belongs to Japan's National Institute of Quantum and Radiological Science and Technology (QST), a research organisation focused on a wide range of quantum science and technology related to beam science and fusion energy, as well as the life and medical sciences. ■ *For more information on the specific cancers treated by CIRT at QST Hospital: www.nirs.qst.go.jp/hospital/en*

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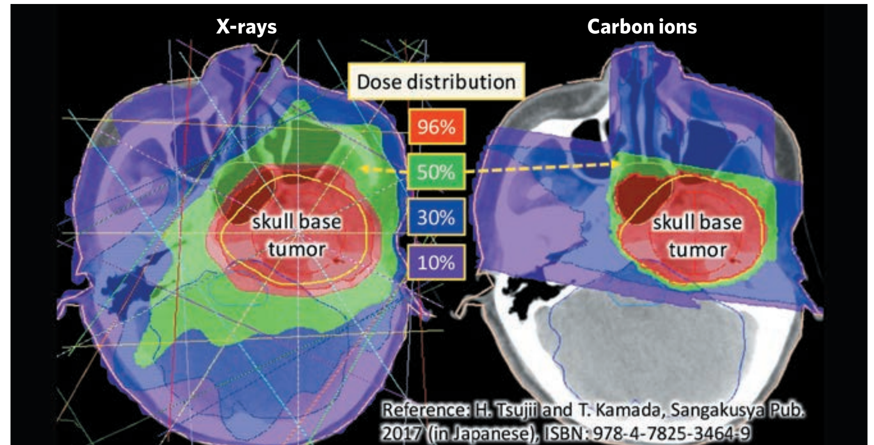

Carbon ion therapy (right) has a sharp dose distribution with minimal off-target scattering, compared to a low-dose bath from X-ray-based radiotherapy (left).

Treated organs	Number of treatments (June 1994 – August 2019) / Fraction & duration
Prostate	3,427 12 times, 3 weeks
Bone & Soft tissue	1,286 16 times, 4 weeks
Head & Neck	1,216 16 times, 4 weeks
Lung	1,055 1 time, 1 day (stage I) 16 times, 4 weeks (stage II & III)
Pancreas	716 12 times, 3 weeks
Liver	628 2 times, 2 days
Other	3,822
Total	**12,150**

Organs treated for cancer using QST's carbon ion radiotherapy facilities.


A patient being prepared for carbon ion radiotherapy on a robotic couch in a rotating gantry treatment room.

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