Established just four years ago as a state-of-the-art facility for cancer therapy, the Gunma University Heavy Ion Medical Research Center is taking next-generation ion beam therapy even further with precise unrivalled beam control and dose shaping, bringing non-invasive microsurgery closer to reality.

It is an unfortunate fact of modern life that each of us has an almost 50 per cent chance of being diagnosed with cancer within our lifetime. This lifetime cancer risk has risen steadily in developed countries from as low as one in four 40 years ago, and is predicted to continue to rise alongside life expectancy. This close association with advancing age and cancer incidence is of particular importance in Japan.

“Cancer care is a pressing issue for Japan,” says Takashi Nakano, director of the Gunma University Heavy Ion Medical Research Center, “not only in terms of developing therapies to increase cancer survival rates, but also in the need for minimally invasive therapies that emphasize a high quality of life.”

“For many years, X-ray radiation therapy has been one of the few treatment options available for inoperable cancer. Radiation therapy can be effective but the procedure is not sufficiently precise to prevent radiation damage to surrounding healthy tissue. This is particularly true in the brain and for tumours near radiation-sensitive tissue, as is the case for prostate cancer and pancreatic cancer. In the 1990s, proton beam therapy was introduced in hospitals as an alternative to radiation therapy, offering more precise dose targeting and lower extraneous radiation damage. The technique has since been adopted widely throughout the world with over 40 facilities now available, mostly in Japan, the United States and Europe. However, proton beam therapy still has its limitations.

“Proton beam therapy has superior dose distribution to radiation therapy, but it is not perfectly sharp and still results in some radiation damage to surrounding tissue,” explains Nakano. “In addition, because of its similar biological effectiveness to X-rays, some types of tumour tissue are also resistant to proton irradiation, such as hypoxic tumour cells and cancer stem cells, which are recognized as being quite important factors in cancer control. In the 1990s when proton beam therapy had just been introduced, my colleagues and I began researching an alternative beam therapy involving the use of heavy ions, specifically carbon ions, at the National Institute of Radiological Science (NIRS). Twenty years later, we now have this state-of-the-art, next-generation carbon ion radiation therapy centre here in Gunma.”

**THE MANY BENEFITS OF CARBON IONS**

Carbon ion radiation therapy has some very specific advantages as a therapeutic tool even compared to proton beam therapy. For a start, because of its stronger biological effectiveness than X-rays and protons, all cancer cells, even radiation-resistant cells, are affected almost equally by the carbon ion beam, meaning that tumour cells resistant to other forms of radiation therapy, including hypoxic tumour cells and cancer stem cells, are treated effectively. The dose distribution can also be ‘shaped’ in three
Carbon ion radiation therapy is still relatively expensive due to the limited facilities currently available around the world, the treatment is attractive compared with the other available options, offering the possibility of significantly improved survival rates and much higher quality of life compared with difficult palliative therapies such as chemotherapy.

**SURGICAL PRECISION**

There are now a handful of heavy ion beam therapy units in operation around the world, but where the Gunma facility stands out is in its unmatched beam control. “We have developed systems that provide control of the position of the beam and the shape of the dose with sub-millimetre precision,” explains Nakano. “At this level of precision, highly responsive and accurate respiratory gating is very important, as well as precise knowledge of the location of the tumour. We use computed tomographic image guidance to achieve the sub-millimetre resolution of tumour boundaries we need to target the beam and dose. We are also developing an even more advanced and precise imaging system based on Compton cameras at multiple wavelengths. We are continually pushing the limits of this technology.

With a tool this precise, a range of other uses for the carbon ion beam become possible. One of the most exciting potential uses of the technology is in non-invasive microsurgery. “This is something found nowhere else in the world. We have a treatment room at the Gunma facility set aside for the development of this microsurgery technique. Not only can we treat tumours in very sensitive locations, such as adjacent to the spinal cord, we can also treat other benign diseases, such as vascular lesions, acoustic neuroma near the inner ear, and age-related macular degeneration – all conditions that would be difficult to treat even by a surgeon, yet we expect to be able to achieve even greater surgical precision.”

**A GLOBAL RESEARCH CENTRE**

Nakano has been involved in the development of the carbon ion beam technology since the idea was first proposed at the NIRS. He then moved to Gunma University as a professor of radiation oncology, where he began work on the carbon ion radiation therapy facility. In collaboration with the NIRS, Nakano’s team began developing a compact carbon ion beam technology. With the support of Gunma Prefecture and the technical expertise of Mitsubishi Electric Cooperation, construction of the compact Gunma facility adjacent to Gunma University Hospital began in 2008 and the medical centre was finally opened in 2010. Nakano became head of the new medical centre, and continues to drive its development through the establishment of world-class doctoral programs aimed at cultivating global leaders in ion beam therapy. “There is a shortage in Japan of the radiation oncologists and medical physicists needed to develop ion beam therapy further,” says Nakano. “Our centre has received a significant grant from the Japanese government to run a PhD program to develop the next leaders in this field.”

Establishing Gunma Prefecture as a global technological centre of excellence for ion beam therapy is also one of the major aims of the Gunma University Heavy Ion Medical Research Center. Nakano has secure government funding to cultivate the medical and engineering industries needed to support and advance the technology, with the Gunma centre acting as a think tank.

“I believe that in the future, most developed countries will be able to offer carbon ion radiation therapy and enjoy its many benefits,” says Nakano. “The technology might be expensive and difficult to access now, but in the same way that computers have evolved from room-sized calculators to powerful multi-function devices that can fit in the palm of your hand, it is not hard to imagine that ion beam therapy may one day be found in most cancer centres, providing precise, non-invasive therapies for everything from simple lesions to advanced cancer.”