Featured Articles

Particle Therapy that is Easy on Patients

Hiroshi Akiyama, Ph.D.
Kenta Mochizuki
Masumi Umezawa

OVERVIEW: Hitachi has drawn on the beam control technology it built up through its participation in large accelerator projects to enter the market for particle therapy systems, with five facilities currently in operation and five more in commissioning or under construction. Current marketing focuses on systems that use the spot scanning technique developed at the MD Anderson Cancer Center. On individual projects, Hitachi also works through collaborative creation with customers to develop and supply the latest technologies, including spot scanning, tumor tracking, and CBCT. Along with taking on the ongoing challenge of new technology in order to offer it to the market in a timely manner, Hitachi also intends to continue developing technology so that it can supply particle therapy systems as integrated solutions.

INTRODUCTION

RECENT years have seen growing demand for radiotherapy for cancer treatment. Particle therapy techniques such as those that use proton beams or carbon ion beams have attracted attention in the field of radiotherapy because of their ability to focus the beam on the affected area only and thereby keep damage to healthy tissue to a minimum.

Hitachi has built up skills in accelerators and related beam technologies through its participation in national projects that involve building large particle accelerators for physics experiments. Having utilized these technologies in the development of particle therapy systems, Hitachi entered the market for this equipment by supplying a proton beam therapy system to the Proton Beam Therapy Center, University of Tsukuba Hospital. This system commenced operation in September 2001, and has since treated more than 3,300 patients.

This article describes Hitachi's expansion into the market for particle therapy systems, its product range, and the development of advanced technologies through collaborative creation with customers.

EXPANSION INTO THE MARKET FOR PARTICLE THERAPY SYSTEMS AND PRODUCT FEATURES

Expansion into the Market for Particle Therapy Systems

Hitachi is actively expanding into overseas markets as well as in Japan.

Hitachi became the first Japanese supplier[*1] to enter the US market for particle therapy systems in December 2002 when it received an order for a proton beam therapy system from The University of Texas MD Anderson Cancer Center (MDACC). Hitachi was also the first supplier of particle therapy systems in the world[*1] to successfully implement a spot scanning system. Spot scanning is a new technique that minimizes unintended irradiation of healthy tissue by targeting the dose on the affected area. As of August 2015, of the more than 6,200 patients who had received treatment at MDACC, more than 1,400 were treated using spot scanning.

The proton therapy system at the Nagoya Proton Therapy Center in Nagoya in Aichi Prefecture commenced operation in February 2013. This system also supports spot scanning, making it the first in Asia[*1] to use proton beam scanning. The Nagoya system has treated about 900 patients in the two years and five months since it opened, treating about 500 over a one year period in 2014. The three systems at Tsukuba, MDACC, and Nagoya have already treated a total of more than 10,000 people.

The molecular tracking proton therapy system installed at the Proton Beam Therapy Center at Hokkaido University Hospital incorporates a variety of new technologies, including Real-time Image Gated Particle Therapy, robotic couch, and cone beam computed tomography (CBCT). It commenced operation in March 2014.

*1 Based on research by Hitachi, Ltd.

Orders for two proton beam therapy systems were received from the Mayo Clinic in May 2011 for their Rochester, Minnesota and Phoenix, Arizona campuses in the USA. The Rochester system commenced treatment in June 2015.

Another order for a proton beam therapy system was received in February 2012 from St. Jude Children's Research Hospital in the USA. This system commenced treatment in November 2015.

In 2014, a project got underway to supply Hitachi's first heavy ion particle therapy system to the provisionally named Osaka Heavy Ion Particle Cancer Therapy Clinic. Further orders for proton beam therapy systems were received for the Sibley Memorial Hospital, a member of Johns Hopkins Medicine in the USA in June 2015 and for the Nagamori Memorial Center of Innovative Cancer Therapy and Research at the University Hospital of the Kyoto Prefectural University of Medicine in July 2015.

Features of Hitachi Particle Therapy Systems

Hitachi supplies systems based on scanning technology. Compared to broad beam techniques used in the past, scanning can target the beam at the affected area and results in less generation of secondary particles. By eliminating the need for patient-specific components like the range compensators and apertures, scanning also has lower running costs and can shorten treatment times.

For its proton beam therapy systems, Hitachi uses the compact synchrotron accelerators developed for Hokkaido University Hospital. It is also developing an accelerator that is designed for small size for use in heavy ion therapy systems. Hitachi offers three different rotating gantries to suit customer needs: a standard 360º model, a small 360º model, and a 190º rotating model. The options for the imaging system used for positioning are a standard dual-axis X-ray imaging system, and CBCT, CT on Rails in treatment room. The options for image registration are a 2D/2D mode that works with dual-axis X-ray imaging; a 2D/3D mode, which uses a large number of digitally reconstructed radiography (DRR) images created from the computed tomography (CT) image used for treatment planning and compares these to the X-ray images during positioning to calculate any deviation automatically; and a 3D/3D mode that works with CBCT and an in-room CT system.

Hitachi has also developed its own particle treatment planning system. The version for proton therapy is already in use at three facilities in Japan.

Fig. 1—Example Treatment Room Design.
The photograph shows the Proton Beam Therapy Center at Hokkaido University Hospital.

Another version of heavy ion therapy is currently under development. While it is one thing to develop the latest particle therapy techniques, to be released on the market they must be supported by a treatment planning system. By developing its own particle treatment planning system, Hitachi is able to bring new technology to market in a timely manner.

Easy-to-use Systems that are Conscious of People and Environment

Previous accelerator systems operated non-stop to ensure stability. For the University of Tsukuba Hospital system that entered service in 2001, Hitachi implemented a system that saved energy by only operating when needed. The MDACC system that started operation in 2006, meanwhile, featured operator-less operation with all of the parameters for the accelerator and radiotherapy system set automatically. This provides an efficient system in which the beam generation system function operates automatically in response to therapist requesting the beam after positioning is complete.

Furthermore, the design division of Hitachi designed the interior of the therapy room to provide a relaxing treatment space with soft lines (see Fig. 1).

Compact System

Growing demand is anticipated in the future for proton beam therapy systems, not only from major hospitals, but also from smaller facilities and urban clinics where space is limited. In response, Hitachi is developing a system with a single-room gantry that has a much smaller installation footprint thanks to use of the small gantry and the compact accelerator developed for the Hokkaido University Hospital system (see Fig. 2).

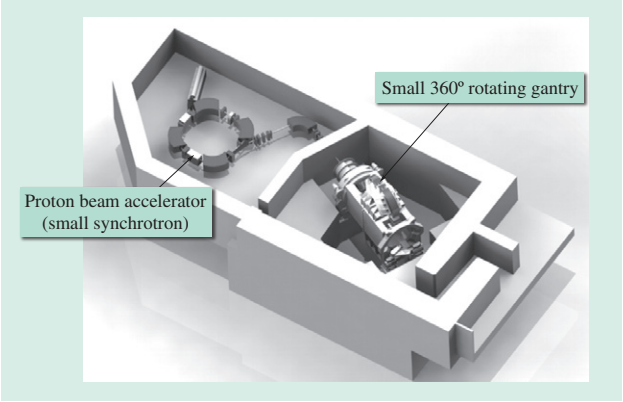

Fig. 2—Overview of Single-room Proton Beam Therapy System.
The system achieves a smaller installation footprint by combining a proton beam accelerator with a single therapy room with a rotating gantry.

DEVELOPMENT OF NEW TECHNOLOGY THROUGH COLLABORATIVE CREATION WITH CUSTOMERS

Hitachi has been developing and implementing world-leading particle therapy technologies in collaboration with worldwide customers. Examples include the development and implementation of the scanning technique with MDACC[1], and the combination of real-time image gated technique and scanning irradiation developed in collaboration with Hokkaido University Hospital through the "Advanced Radiation Therapy Project: Real-time Tumor-tracking with Molecular Imaging Technique" project of the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST Program)[2]. The following sections describe notable examples of this work along with the plans for the future.

Improvements in Radiotherapy Accuracy

Work on improving image-guided radiotherapy (IGRT) is ongoing in all areas of radiotherapy with the aim of achieving greater accuracy, with tumor tracking and CBCT imaging having already been implemented for proton beam therapy systems through joint development with Hokkaido University Hospital.

Fig. 3 shows a control screen for tumor tracking in which the current marker position is displayed both in numeric format and as a radiography image. The system operates such that the proton beam is only delivered when the marker is within a designated tolerance of the location determined during treatment planning. Approval for manufacture and sale of the system that combines tumor tracking and proton beam scanning

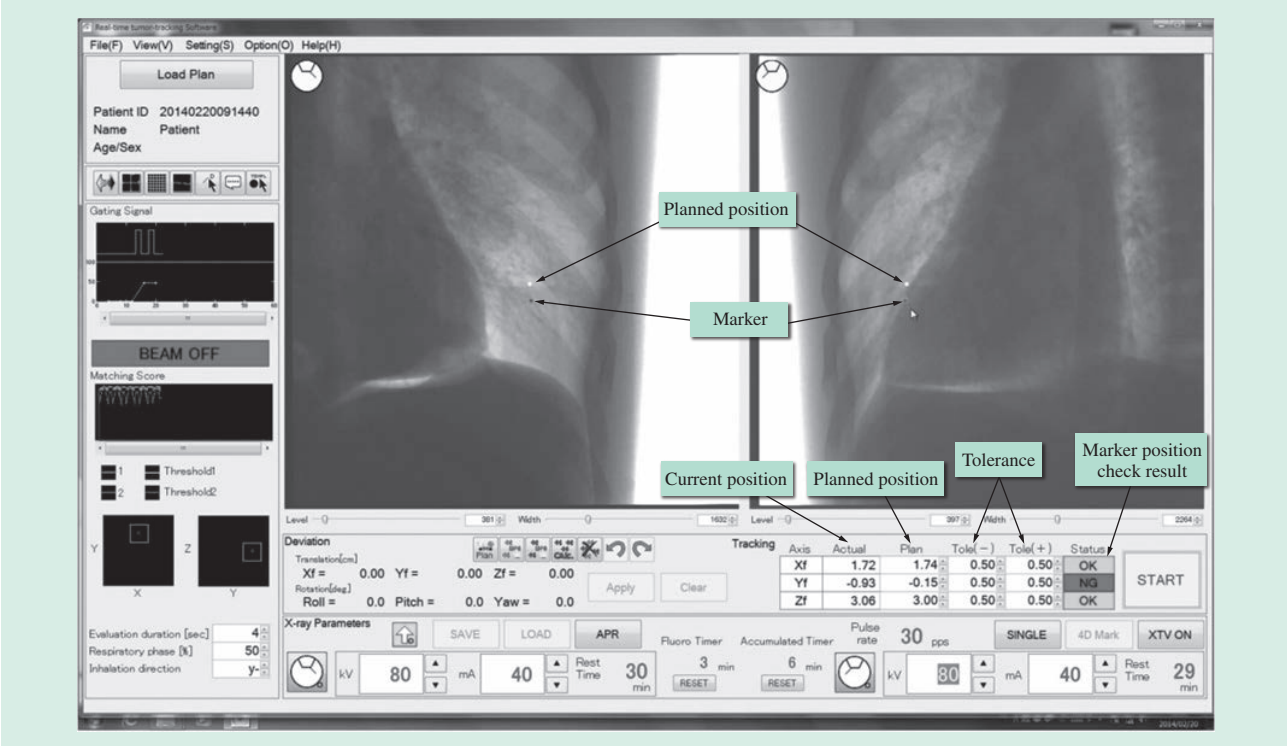

Fig. 3—Control Screen for Tumor Tracking.
The proton beam is only output when the marker position, determined from the radiography image refreshed 30 times per second, is within a designated tolerance of the planned position. The radiography images shown here are from a test run conducted using a phantom (a simulated human body) in which a marker has been inserted for testing purposes.

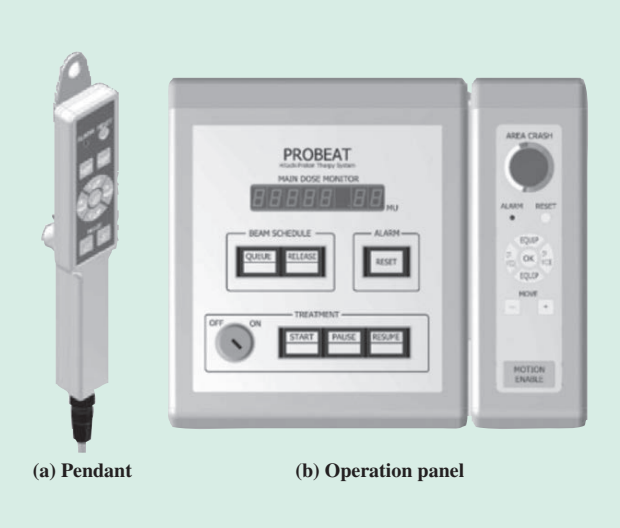

Fig. 4—New Control Unit Design.
(a) shows the pendant used to operate the gantry, couch, laser marker, and other therapy room equipment.
(b) shows the operation panel used to perform operations such as turning the beam on or off.

was obtained under the Pharmaceutical Affairs Act in August 2014, with treatment commencing in December of that year.

To provide regular assessments of the condition of the patient's tumor and perform more accurate positioning, Hitachi has developed a CBCT imaging technique that utilizes the X-ray imaging system housed in the rotating gantry. The technique obtains a CBCT image by rotating the gantry, using the same imaging system as that used by conventional positioning and the tumor tracking technique described above.

Improvements in Ease-of-use

In addition to technical performance enhancements, wider adoption of particle therapy systems will also require that they be made easier to use from the customer's perspective. Hitachi is consulting with customers to improve the design of its control units and other components with which users come into contact. Notably, as part of the discussions following the order from Mayo Clinic, the therapists planning to operate the system were invited to the design section at Hitachi where the design was being undertaken to talk to the engineers face-to-face. Fig. 4 shows the designs of the mechanical control unit called the pendant and the operation panel used for particle therapy, which were the outcomes of this work. These features have also been offered to subsequent customers and adopted for their simplicity and ease-of-use.

Future Development Plans

The market for particle therapy systems is shifting toward demand for systems that are suitable for a wider range of customers, such as the compact single-room system described above. Accordingly, in addition to the ongoing development of leading-edge technologies through collaborative creation with customers, it is also essential to develop systems that deploy these technologies in ways that are easier and simpler. To achieve this, Hitachi intends to go beyond the development of the therapy systems themselves to collaborate with partners both internal and external on the development of comprehensive systems that also consider things like the process before and after therapy and the movements of patients and staff.

CONCLUSIONS

Hitachi operates its particle therapy business globally, based on leading-edge technologies developed through collaborative creation with major hospitals in the world. While its particle therapy systems are currently ranked in the top three in terms of market share and sales[*2], Hitachi aims to increase this ranking to number one through initiatives such as increasing sales of heavy ion therapy systems and offering packages that provide compact single-room systems suitable for installation at mid-sized private hospitals. Hitachi also aims to operate an information technology (IT) service business in the healthcare sector by utilizing joint research with the major US hospitals that are customers for particle therapy systems to establish techniques that utilize IT platforms to provide things like more sophisticated treatment planning and shorter treatment times.

In the future, Hitachi intends to contribute to healthcare around the world by improving the quality and efficiency of medical practice in its role as a leading supplier of healthcare innovation.

*2 As of August 2015, based on research by Hitachi, Ltd.

REFERENCES

(1) K. Matsuda et al., "World-first Proton Pencil Beam Scanning System with FDA Clearance —Completion of Proton Therapy System for MDACC—," Hitachi Review **58**, pp. 225–232 (Oct. 2009).
(2) M. Umezawa et al., "Development of Compact Proton Beam Therapy System for Moving Organs," Hitachi Review **64**, pp. 506–513 (Nov. 2015).

ABOUT THE AUTHORS

Hiroshi Akiyama, Ph.D.
Radiation Oncology Systems Division, Healthcare Company, Hitachi, Ltd. He is currently engaged in technology management for particle therapy systems. Dr. Akiyama is a member of the Japan Society of Medical Physics (JSMP) and the Atomic Energy Society of Japan (AESJ).

Masumi Umezawa
Radiation Oncology Systems Division, Healthcare Company and Applied Energy Systems Research Department, Center for Technology Innovation – Energy, Research & Development Group, Hitachi, Ltd. He is currently engaged in technology management for particle therapy systems. Mr. Umezawa is a member of the JSMP.

Kenta Mochizuki
Radiation Oncology Systems Division, Healthcare Company, Hitachi, Ltd. He is currently engaged in sales promotion for the particle therapy business.