IV. 4. Treatment Planning System Developed for Proton Therapy at CYRIC

Terakawa A\textsuperscript{1}, Totsuka Y\textsuperscript{1}, Chiba T\textsuperscript{1}, Ishizaki A\textsuperscript{1}, Miyashita T\textsuperscript{1}, Yamamoto T\textsuperscript{1}, Arikawa J\textsuperscript{1}, Togashi T\textsuperscript{1}, Yamashita W\textsuperscript{1}, Akiyama H\textsuperscript{1}, Koyata H\textsuperscript{1}, Fujita Y\textsuperscript{1}, Honda T\textsuperscript{1}, Ishii K\textsuperscript{1}, Itoh N\textsuperscript{2}, Sano T\textsuperscript{2}, Wada S\textsuperscript{2}, and Orihara H\textsuperscript{3}

\textsuperscript{1}Department of Quantum Science and Energy Engineering, Tohoku University
\textsuperscript{2}School of Veterinary Medicine and Animal Sciences, Kitasato University
\textsuperscript{3}Department of Intelligent Electronics, Tohoku Institute of Technology

In recent years the proton irradiation system has been developed\textsuperscript{1} at CYRIC for research programs of proton therapy using small animals and their clinical application to cancer treatment for companion animals. During the construction of the proton irradiation system, we have developed a treatment planning system for simulating a depth-dose distribution of a therapeutic proton beam as well.

The depth dose generated in a patient from the proton irradiation can approximately be estimated based on computer tomography (CT) through the conversion of the CT number into the proton stopping power ratio as shown in Fig. 1. Thus, the depth dose along the proton path is calculated pixel by pixel for each slice image. Three-dimensional dose simulation has been obtained using a pencil-beam algorithm in which depth and lateral dose profiles of the mono energy beam is approximately described with an analytical function\textsuperscript{2} and a Gaussian distribution, respectively. The treatment plan for the patient animal is done with the help of graphical user interfaces (GUI) developed with the Lab-view soft ware\textsuperscript{3} (Fig. 2).

The validity of the simulation was checked by comparing the simulation results in the case of two phantoms (Phantom-1 and Phantom-2) with measured dose distributions. The Phantom-1 is composed of PMMA, water-equivalent material and bone-equivalent material and equipped with a collimator. The dose distribution generated in water-equivalent material located downstream of the Phantom-1 was measured with the imaging plate\textsuperscript{4} (IP). The Phantom-2 is a circular cylinder of PMMA with a collimator and a bolus. Dose control was made so that the maximal dose was delivered into a spherical target volume near the surface of the Phantom-2. The dose distribution in the Phantom-2 was measured.
with the IP. In both cases an 80-MeV proton beam with the spread-out Bragg peak was provided from the wobbler system\textsuperscript{1).}

In Figs. 3-5, the phantom designs and comparisons between the dose predictions and the experimental results are summarized. Good agreement has been obtained in both cases. Figure 6 shows examples for treatment plan in proton therapy for a mouse and a dog. We are planning to perform proton therapy experiments on mice or rats by using the present treatment planning system in the next phase.

References

1) Terakawa A., et al., CYRIC Annual Report\textsuperscript{T} 41 (2005) The current status of the proton therapy system at CYRIC will be described in the present CYRIC Annual Report.

![Graph](image)

Figure 1. Relation between attenuation-coefficients of an X-ray used in CT-scan for various materials relative to that for water ($\mu\text{ m/\mu w}$) and the corresponding proton stopping powers relative to that for water {$(dE/dx)m/(dE/dx)w$}.
Figure 2. GUI of the treatment planning system.

Figure 3. Design and photographs of the phantom-1.
Figure 4. Comparison between the simulation and the measured dose distributions in the water-equivalent material located downstream of the phantom-1.

Figure 5. Design of the phantom-2 and simulated dose distribution compared with the experimental result.
Figure 6. Depth dose simulations in proton therapy for a mouse (a) and a dog (b).