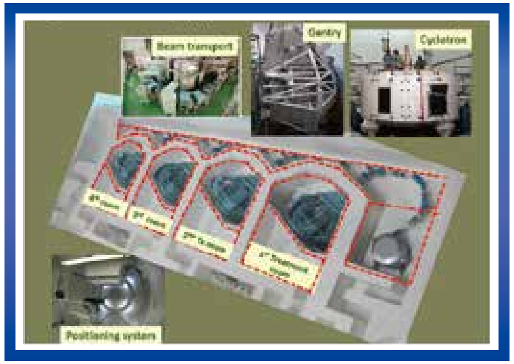
IV. The equipments for proton therapy

Proton therapy is currently the most expensive and advanced medical facility in the world. As shown in Figure 3 (below), there are four treatment rooms in the proton center of Chang Gung Memorial Hospital. The proton beam is accelerated by the cyclotron to reach high energy sufficient for treating deeply-located tumors, and is distributed to each room by beam transport system. Since proton beam can't be distributed to multiple rooms at same time, only one patient receives irradiation at one time and patients in other rooms are on preparation and positioning. To be able to treat the tumors by any angle, each room is equipped with a huge rotating gantry to control the beam direction. Each gantry is 140 tons in weight and 10.6 meters in diameter, and 20 meters floor height is required to accommodate it and gantry base. The allowed error of the axis in rotation is less than 1 millimeter. To perform the accurate set-up for treatment, each room is equipped with the advanced imaging system and a robot couch with six degrees of freedom to adjust patient's position and angle. The nozzle on the gantry can provide pencil beam scanning or wobbling treatment, depending on the clinical need in different type of tumors.

Figure 3: Porton therapy system of Chang Gung Memmorial Hospital



V. The preparatory process and actual treatment for proton therapy

The preparatory process for proton therapy is similar to that for X-ray treatment. Therapist will first make a body mold or mask for patient to fix the treatment position, and then acquire a CT simulation by same position for treatment planning. Some patients may require a MRI simulation to help physicians more clearly define the location and extension of tumor. Through the help of different imaging modalities, the physician will delineate the treatment target and normal tissues in contouring system and medical physicist will design the treatment plan according to the priority and constraints prescribed by physician. The treatment will be delivered after the confirmation and proof by the physician.

Proton treatment is given in general once per day and five days a week. Time for each treatment is around 15-30 minutes, but longer time might be needed for pediatric patients or treatment with high complexity. The total treatment course will range from one to eight weeks, depending on the protocols of different type of tumors. Patient will not sense any discomfort while receiving proton treatment and no residual radiation is present in the body after treatment.

Introduction of Proton Beam Radiation Therapy

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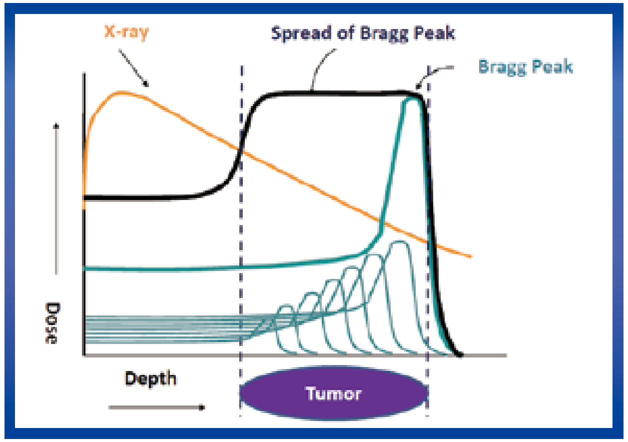
I. The important role of radiation therapy in cancer treatment

Radiotherapy and surgery are the major treatment modalities to eradicate localized tumors. Due to the anatomical location, the characteristics of tumor invasion, preservation of organ function, and the patient's general condition, surgery has its limitations in different types of cancers. Radiotherapy (or in combination with chemotherapy) could achieve high control rate in many tumors such as head and neck cancer, breast cancer, rectal cancer, prostate cancer, cervical cancer and many others. In Taiwan, around 35-40% of cancer patients received radiotherapy as part of their cancer treatment, while this figure is high up to 60% in the United States. Since failure in local treatment is often life-threatening, radiotherapy plays a very important role in cancer treatment.

II. The differences between proton and X-ray (photon)

X-ray (photon) emitted by a linear accelerator is the most common treatment beam for current radiotherapy. As shown in Figure 1 (below), as compared to proton beam the X-ray has the disadvantages of a higher entrance dose in front of the tumor and remarkably residual dose after the tumor; thus X-ray is more prone to damage the adjacent normal tissue. Whereas proton passes through tissues with lower entrance dose, but releases large amounts of energy when it reaches the desired depth of treatment (the Bragg peak), and deposits no dose to the normal tissues behind tumor. Since a single Bragg peak is not wide enough to cover whole tumor, summation of multiple peaks (Spread-out Bragg peak) is needed to broaden the coverage into the tumor size.

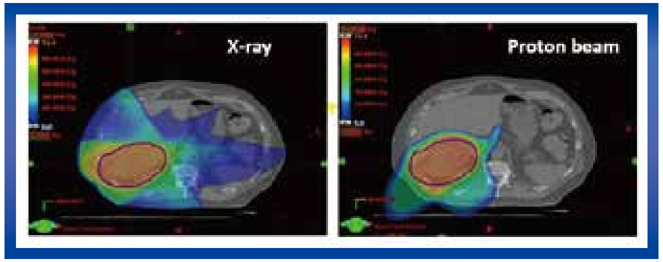
Figure 1: Comparisons of the physical characteristics between proton beam and X-ray



III. A clinical example illustrating the differences between proton therapy and X-ray (photon)

Liver tumor (HCC) is a common cancer in Taiwan and a good example to illustrate the differences between proton beam and X-ray. As shown in the left side of Figure 2 (below), the strategy of X-ray (photon) therapy to reduce normal tissue damages is to employ multiple X-ray beams from different directions but focusing on the tumor, the consequence is to expose more normal liver tissue to a low-dose bath. Because liver tissue is very sensitive to the radiation damage (especially under the condition of viral infection or liver cirrhosis), it is very difficult to give high-dose radiation via photon except in small tumor. X-ray therapy therefore plays a limited role for treatment of liver cancer. In the right side of Figure 2 displays the dose distribution of proton therapy for liver tumor. Because of the Bragg peak, most of the normal liver does not receive radiation dose and we are able to deliver very high radiation dose to the liver and increase the likelihood of tumor control. Excellent treatment outcome by using proton beam in livertumors had been reported from several proton centers in Japan.

Figure 2: Comparisons between proton beam and X-ray in treating liver tumor



Except in disseminated diseases, tumors with diffuse infiltration or tumors in organ with unpredictably large organ motion between or during the treatment, proton therapy can be applied to the tumors of various parts of the body such as the brain, eyes, head and neck, lungs, abdomen, pelvis and extremities. In the treatment of pediatric brain tumors, radiation exposure to normal tissue is avoided by proton therapy and the detrimental effects of radiation to intelligence, development, and chances of second cancer after treatment are reduced. Proton therapy for nasopharyngeal cancer greatly reduce the radiation dose to oral cavity, hypopharynx, and esophagus, thus decrease the early and long-term side effects caused by radiotherapy. Generally speaking, the proton therapy has more pronounced protection effects for normal tissue when a tumor leans on one side of the body. By the above principles, all kinds of tumor in the body and some benign disease can be treated by the proton therapy.