The University of Texas M.D. Anderson Cancer Center
Proton Therapy Facility

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Abstract. The University of Texas M.D. Anderson Cancer Center (MDACC), in partnership with Sanders Morris Harris Inc., a Texas-based investment banking firm, and The Styles Company, a developer and manager of hospitals and healthcare facilities, is building a proton therapy facility near the MDACC main complex at the Texas Medical Center in Houston, Texas USA. The MDACC Proton Therapy Center will be a freestanding, investor-owned radiation oncology center offering state-of-the-art proton beam therapy. The facility will have four treatment rooms: three rooms will have rotating, isocentric gantries and the fourth treatment room will have capabilities for both large and small field (e.g. ocular melanoma) treatments using horizontal beam lines. There will be an additional horizontal beam room dedicated to physics research and development, radiation biology research, and outside users who wish to conduct experiments using proton beams. The first two gantries will each be initially equipped with a passive scattering nozzle while the third gantry will have a magnetically swept pencil beam scanning nozzle. The latter will include enhancements to the treatment control system that will allow for the delivery of proton intensity modulation treatments. The proton accelerator will be a 250 MeV zero-gradient synchrotron with a slow extraction system. The facility is expected to open for patient treatments in the autumn of 2005. It is anticipated that 675 patients will be treated during the first full year of operation, while full capacity, reached in the fifth year of operation, will be approximately 3,400 patients per year. Treatments will be given up to 2-shifts per day and 6 days per week.

INTRODUCTION

The application of high-energy proton beams in cancer therapy has made important advances in the last few years. While not yet considered “main stream”, proton therapy has gained wide acceptance, as evidenced by the number of new proton therapy facilities being planned and built [1]. This acceptance and growth is being driven by several factors: 1) The clinical outcomes resulting from proton cancer therapy have been generally impressive [2] and proton therapy is no longer considered to be primarily clinical research. When the United States Health Care Financing Administration (HCFA) approved reimbursement rates for proton treatment delivery, they stated that proton therapy for cancer was no longer considered to be investigational; 2) Several vendors of proton therapy equipment are now competitively selling proton therapy equipment – competition leads to efficiencies in the marketplace; and 3) Large hospital-based proton facilities are able to treat greater numbers of patients and therefore reduce the per-patient cost of proton therapy delivery. These factors tend to increase the economic competitiveness of proton therapy and, consequently, have led to new financing mechanisms for proton therapy facilities. In the past, most facilities have been publicly funded or subsidized because proton therapy was considered to be clinical research and the financial risks were substantial (high costs for facilities and no formal, widely accepted and approved reimbursement process). Private investors now have increased incentives to finance and operate proton therapy centers provided that reimbursement rates are maintained at stable and appropriate levels and the proton center is associated with a hospital or cancer center having a large number of cancer patients. The capital costs for a facility are quite high and therefore large numbers of patients must be routinely treated at predictable payment rates in order to accrue an
adequate rate of return on the investment. This paper describes the first major proton therapy facility proposed to be built using the investor-owned model. It is hoped that this model will serve to drive additional growth in the number of proton therapy facilities and make this important cancer treatment available to the cancer population at large. Proton therapy offers a great potential for improved cure rates and better treatment outcomes for many cancer patients. Therefore, insofar as is possible, we should eliminate barriers that currently exist to the access to proton therapy and allow this important treatment modality to become locally available to those patients who need it.

THE PROTON THERAPY CENTER AT THE UNIVERSITY OF TEXAS M.D. ANDERSON CANCER CENTER

The University of Texas M.D. Anderson Cancer Center (MDACC), together with a group of partners, have formed a company to develop, own, and operate the Proton Therapy Center (PTC) at the MDACC. The PTC will be built at the University of Texas Biotechnology Park, which is located near the MDACC main complex at the Texas Medical Center in Houston, Texas. The PTC will be a freestanding radiation oncology center offering state-of-the-art proton therapy to a large number of patients.

M.D. Anderson is the largest cancer center in the U.S., serving more than 58,000 cancer patients per year. It was ranked the best cancer center in the country in U.S. News and World Report magazine’s 2002 “Best Hospitals” survey. Other members of the partnership are Sanders Morris Harris Inc. (SMH), the largest Texas-based investment-banking firm, and The Styles Company, a developer and manager of hospitals and healthcare facilities. MDACC will provide the clinical staffing and medical direction for the PTC while SMH and the Styles Company will provide management services for the facility construction and operation. The total cost of the PTC will be approximately $120 million with the total therapy equipment costing approximately $45 million. Additional investors in the facility will include the Houston Firefighters’ Relief and Retirement Fund.

Hitachi, a Japan-based international company, through its American subsidiary, Hitachi America, will also be an investor in the PTC as well as the contractor for the design, procurement and construction of the proton therapy equipment. Hitachi has previously built two proton therapy centers in Japan (at Tsukuba University and Wasaka-bay). Varian, Inc. and GE, Inc. will provide information and imaging technology for the PTC.

The Proton Therapy Facility

The PTC will have approximately 83,000 sq. ft. on two floors, with the treatment level (shown in Fig. 1) being on the bottom floor and below grade. The building site is on a four-acre parcel located on a campus that will be shared with other medical and research buildings. The PTC will have a total of 4 treatment rooms: three treatment rooms will have isocentric, rotating gantries while the fourth will have two horizontal beam lines, one for large-field treatments and one for eye treatments. An additional horizontal, fixed-beam room will be used for research and development and by outside users of the facility. It is expected that the PTC will have an active program of radiation biology and materials research in addition to the primary mission of treating cancer patients.

As stated above, the PTC will be a freestanding healthcare facility, and therefore it will have all of the services and equipment necessary for the work-up, treatment and treatment follow-up of cancer patients. Accordingly, the facility will have a total component of imaging equipment including computerized tomography (CT) simulators, positron emission tomography (PET) CT scanner and a magnetic resonance (MRI) scanner. These imaging technologies will enable the PTC to offer the most advanced techniques for treatment planning, treatment and treatment outcome studies. Increasingly, both physical (e.g. CT) and biological (e.g. PET, functional MRI) imaging techniques are used in cancer treatment in order to delineate the location and extent of tumors as well as normal tissues and organs, and to understand the metabolic functions in specific regions of tumors. Modern imaging technologies, coupled with proton beam therapy, will offer the ultimate dose localization in external beam radiation therapy for cancer.

The PTC is expected to open for patient treatments in the autumn of 2005, and it is anticipated that 675 patients will be treated in the first year of operation. At full capacity, reached in the fifth year of clinical operation, approximately 3400 patients per year will be treated with treatments given up to 2-shifts per day, 6 days per week. Proton therapy is appropriate for all cancer sites for which external beam radiation therapy is a standard part of treatment, and therefore treatment protocols will be developed for a wide range of cancer types and anatomical sites. It is anticipated that MDACC will participate in multi-institution clinical studies with other major proton therapy centers and with the clinical trial groups funded by the National Cancer Institute. An application will be submitted to
the United States Food and Drug Administration (FDA) for approval of the PTC equipment and its treatment control and safety systems.

The Proton Therapy Equipment

The Accelerator System

The main accelerator will be a synchrotron with a circumference length of 23 meters. Protons will be pre-accelerated to 7 MeV in a linear accelerator (a Radio Frequency Quadrupole type Linac combined with a Drift Tube Linac) then injected into the synchrotron. The synchrotron will accelerate the protons to variable energies in the range from 70 to 250 MeV (the ring is designed for 270 MeV). The synchrotron has a variable repetition rate in the range 0.15-0.5 Hz. At 0.33 Hz, $1.25 \times 10^{11}$ protons per pulse can be extracted which is sufficient to deliver dose rates of 2 Gy/min to average treatment volumes. The extraction process is a 3rd order resonant extraction using the RF-knock-out technique.

The Beam Transport System

The beam will be transported by a conventional beam transport system to the treatment rooms. Three of the four treatment rooms will have isocentric gantries. The gantries are 13 m in diameter, weigh 220 tons, and rotate 360 degrees around the patient at a rate of 1 rpm. The rotating resolution and repeatability of the gantries are ±0.25 degree or better. The effective source to axis distance (SAD) will be ≥2.7 meters. The combination of gantry and treatment couch will provide six degrees of freedom (three translations and three rotations) for aligning the tumor to the proton beam for treatment. Three orthogonal imaging systems (x-ray tubes with image intensifiers or amorphous silicon arrays) attached to the gantry will be used to precisely locate the tumor (or tumor-associated fiducials) and, using stereotactic analysis, accurately position the patient prior to the delivery of each treatment field. The image intensifiers will allow the physician to conduct analyses of tumor motions that may take place during the treatment. The accelerator and control system will have beam-gating capabilities so that the beam can be gated (turned on and off, coincident with tumor motion during treatment).

The fourth treatment room will have a fixed, horizontal, non-moveable beam transport system and two delivery nozzles, one for large-field treatments and one small-field treatments, principally for ocular melanoma. The large-field beam line will be used for treatments such as prostate cancer and head and neck cancers, i.e., where lateral treatment fields are the preferred beam orientations. In the fixed beam treatment room, the immobilized patient is moved relative to the fixed beam delivery system in order to provide treatments at multiple beam angles. A second fixed beam room will be used for research such as dose response studies in cancer cells grown in the laboratory, or for irradiation of electronic devices used in space research. This room will also be used for development and testing of new treatment devices. One such device will be the new pencil-beam-scanning nozzle that will allow the use of intensity modulation treatment techniques to provide better dose conformation.

The Beam Delivery System

The first two gantry treatment rooms and the large-field horizontal, fixed beam room will initially have standard nozzles for treatment delivery. These nozzles have contoured passive scattering systems for spreading the beam longitudinally and range modulation wheels for spreading the Bragg peak in depth. Treatment field sizes up to 25 cm x 25 cm and spread-out-Bragg-peaks (SOBP) up to 16 cm in depth can be achieved with this system. A beam gating technique will be used to obtain the prescribed range modulation for individual treatments, thus allowing one modulation wheel to be used for all modulations in a given energy range. Modulation wheels for various energy ranges will be manually inserted. The standard nozzles will operate in conjunction with a series of extendable snouts, which hold and position the final collimating apertures and range compensators designed for shaping each treatment field dose distribution. The nozzles also contain beam monitoring and safety devices that measure the beam uniformity and penetration and control the treatment delivery.

The third gantry will be equipped with a pencil-beam-scanning nozzle. This nozzle will have magnets that sweep a pencil-beam of protons through the tumor volume, while varying the intensity of the beam and/or the speed of the sweeping pattern. The beam will be scanned through the tumor one layer at a time starting at the deepest required penetration and reducing the energy to scan each successive layer. The synchrotron is capable of pulse-to-pulse energy changes thus the layered treatments can be done very efficiently. The treatment control system will allow for the dose to be varied from point to point in the scanned volume. This advanced form of treatment, called intensity modulation, will provide three-dimensional shaping of
the dose distribution to the tumor volume and offer the optimum radiation treatment for cancer. Treatment fields up to 40 cm x 30 cm can be achieved with this technique along with beam penetrations up to 37 gm/cm² in depth. At a later date, the first two gantries may be retrofitted with scanning nozzles.

SUMMARY

The PTC will be financed and operated under an innovative investor-owned model. It is hoped that this model will provide the stimulus for additional proton therapy installations. Many more proton therapy facilities are needed so that this superior form of radiation treatment for cancer can be made available to a greater number of patients.

REFERENCES


FIGURE 1: Treatment Level of the PTC