The Midwest Proton Therapy Center

Charles Bloch

Indiana University Cyclotron Facility, Bloomington IN 47408

Indiana University is developing a dedicated proton radiation therapy facility using the existing 215-MeV proton cyclotron at the Indiana University Cyclotron Facility (IUCF) in Bloomington IN. This facility will be operated as a regional center. An initial program based on an existing beam line and room will start early in 1997. Ultimately, a significant building addition will house several dedicated treatment rooms including one or more isocentric gantries. Present status and plans for the facility are presented.

INTRODUCTION

In 1993, Indiana University (IU) demonstrated their capability to treat cancer patients using the proton beam at IUCF with a successful treatment of a patient with a brain tumor (1). In 1994, the FDA gave permission to continue a pilot study using that prototype facility.

For the last year, IU has worked on developing a model to operate the proton radiation therapy facility at IUCF. Although this new organization is in its infancy, it seems a viable and novel approach. University and research hospitals in Indiana and neighboring states (Missouri, Kentucky, Ohio, Illinois and Michigan) were approached with an offer to become partners in the Midwest Proton Radiation Institute (MPRI). While formal agreements have not yet been reached, the response has been strong, with several institutions saying they will join this consortium.

Initial capital costs and start-up funds will be raised independently by IU. The consortium members primarily provide the source of medical expertise to direct this facility, and patients from their institutions. Because several institutions are joining together, the number of patients (and associated revenues) provided for proton treatments by any single institution initially will be small. All institutions will benefit in developing expertise in forefront technology.

IUCF FACILITIES

The Indiana University Cyclotron Facility has been using the beams from its 215 MeV cyclotron for nuclear physics research for 20 years. Since 1988, IUCF has also operated a 500-MeV electron-cooled storage synchrotron (the Cooler), primarily for research in nuclear and accelerator physics. Presently, over 50% of the cyclotron running time is spent injecting the beam into the Cooler. However, a new injector synchrotron (CIS) is presently under construction, which will replace the cyclotron for injecting the beam into the Cooler. Once CIS is on-line, the cyclotron would be idle over 50% of the time (a number that will continue to grow), unless new programs are developed which require that beam. Under the present plans, the radiation therapy program will be the primary user for the cyclotron, while the nuclear and accelerator physics programs will be conducted primarily with the synchrotrons.

PLANNED MEDICAL PROGRAM

Presently, there is one beam room dedicated to the bio-medical program. That room contains the fixed horizontal beam line, which was used for the initial patient treatment

Figure 1 Artist's rendering of IUCF including proposed radiation therapy wing.

at IUCF (2). For the past two years, it has been used extensively for radiobiology research. Within the next six months, that beam line will be recommissioned for eye treatments. Initially the focus will be on macular degeneration, a fairly common benign eye disease. The equipment will also be suitable for treating ocular melanoma, which is a relatively rare malignancy treated very effectively with protons.

A second room and fixed horizontal beam line exist which could also be dedicated to patient treatments if there is sufficient patient-load. This could be either a second "eye line", or used for head, neck and brain tumors (which can be treated effectively with a fixed horizontal beam line).

Besides using the existing space and beam lines, a parallel effort will develop a purpose-built addition (Fig. 1) to the building that will house a complete modern radiation therapy facility. Present plans call for this addition to have four treatment rooms, any of which could be equipped with fully isocentric gantries. At least one such gantry will be included initially in this facility, with additional gantries dependent on demand and patient mix. A design study for this addition has been completed, and puts the cost at $15M. About half that is civil construction (including concrete shielded treatment rooms) while the rest is for beam-transport systems. An additional $5M has been estimated for the start-up costs.

Once in operation, this dedicated facility will need to treat at least 250 patients per year to be financially viable. (The exact number depends on many details that have not yet been decided.) There will be a dedicated medical staff at the facility, providing the same expertise found in any radiation therapy department, and appropriate in size for the patient load. Some tasks (e.g., treatment planning) may be done at the partner institutions, with the local medical staff overseeing the treatment application. Alternatively, consortium members may send medical personnel to IUCF to treat patients on a part-time or full-time basis, assuming the patient load justifies it.

FIXED HORIZONTAL BEAM LINE

The existing fixed horizontal beam line has been described before (2). That beam line was designed for treating brain tumors. It produced a flat 20-cm diameter field, with a maximum range of 21 cm in water. This line is being modified and will be dedicated to treating eye diseases. For such treatments, a 3-cm diameter field with a maximum range (in water) of 3 cm is sufficient. Therefore, the dual-scattering foil beam spreading system (3) will be replaced by a simpler single (flat) foil, which will also be part of the energy degrader.

Because much smaller fields will be required, and the beam penumbra needs to be as sharp as possible, a different system of collimators will be set up. Eye positioning is generally achieved by having the patient visually fixate on a blinking LED. A system for positioning such an LED in an established coordinate system will be added. Also, a high-magnification camera will be added to provide a close-up view of the eye to monitor fixation. These modifications are being made now, and the new system will be tested later in 1996 and early 1997. Patient treatments are expected to start in the first half of 1997.

DEDICATED CLINICAL FACILITY

Once the nuclear physics program at IUCF ceases use of the cyclotron (possibly in 1998 or 1999), that beam will be available for a dedicated proton radiation therapy facility. Planning for that facility has already begun, so that it can be constructed in time to take advantage of the proton beam at the earliest possible date.

A preliminary design study for this clinical facility includes a building addition of roughly 25,000 gross square feet. This will include up to four treatment rooms (each large enough for a full isocentric gantry), a CT simulator, and other rooms typically found in a radiation therapy clinic. Civil construction costs total an estimated $7.5M.

Because the role of protons is not clearly established, such a new facility must be versatile and state-of-the-art. It must be capable of competing with 3-D conformal x-ray treatments, which have not reached their full potential. To maximize the capabilities of this new facility, it is being designed with as many potential options as possible, although they will not all be carried out initially.

The initial facility will have one isocentric gantry (360°), with the remaining treatment rooms suitable for the installation of additional gantries as they are needed. To compete with intensity modulated x-rays, the new facility is expected to use a scanned pencil beam, with intensity modulation. The IUCF cyclotron presently has a beam intensity modulation system that will be further developed for use in radiation therapy. A prototype beam scanning system also has been tested at IUCF. In the first tests, the fast (horizontal) magnet was run at 220 Hz, which allowed us to scan a 20x20 cm region in 0.3 seconds. Additional work is necessary to maximize dose uniformity of the field.

Just as with x-ray treatments, advanced computer treatment planning is necessary to fully optimize proton treatments. In the development of such software (and other areas), proton therapy has lagged behind, primarily because of the smaller "market." Recently there have been advances in this area, and proton treatment planning programs exist which provide 3-D conformal plans.

Preliminary estimates of the equipment costs for this new facility are an additional $8M (for a single-gantry facility), with the gantry being the largest single cost.

RESEARCH ACTIVITIES

Besides providing radiation therapy, there will be continued support for related research activities. Presently, there are ongoing research activities in radiobiology and medical physics.

The radiobiology research is conducted by three independent groups, each studying a different biological system. The systems being studied are: Embryos from *Xenopus Laevis*, *Coprinus cinereus* (a mushroom), and HeLa X skin fibroblast human-hybrid cells. Protons (and other charged-particle beams available at IUCF) provide a unique probe for studying radiation damage, repair and transformation because of the way these depend on linear energy transfer. These studies are aimed at questions in fundamental biology, space radiation, and oncology.

The medical physics research has targeted several problems related to proton radiation therapy. In the area of dosimetry, there are ongoing studies using water calorimetry and radio-chromic film. A recent project was started to verify beam penetration by observing induced positron emission activity. There is also an effort in the development of a sub-millimeter diameter beam. This would be useful for radiobiology studies that attempt to target a single cell (or a structure within a large cell).

CONCLUSIONS

A strong clinical group has formed with members from several Midwest hospitals and universities. Along with Indiana University's commitment to the proton therapy project, this seems to provide all the ingredients to develop a dedicated purpose-built proton therapy facility at IUCF. During the planning and construction phases of the new facility, existing resources at IUCF will be used for eye and probably other treatments.

The recent developments in (x-ray) conformal therapy indicate the medical community's desire to use every possible advantage in dose delivery. Proton beams are consistent with this goal, and a state-of-the-art facility should allow conformal therapy to go one step beyond the best that x-rays can do. The planned facility will meet these goals by incorporating features such as 3-D conformal treatment planning, 360° isocentric gantries, and intensity-modulated scanned beams.

REFERENCES

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