NEUTRON THERAPY - A PROGRESS REPORT

by Arlene Lennox

Radiation has been used to treat certain forms of cancer since Roentgen's discovery of x-rays in 1895. Radiation sources commonly used in hospitals today include cobalt and electron linacs which produce photons by bombarding tungsten with electron beams having energies from 4 to 25 MeV. Clinical research has shown that certain tumors cannot be controlled by photon treatment. Radiation oncologists classify these tumors as "radioresistant" tumors. Unlike photon therapy, neutron therapy induces irreparable changes in the chromosome structure independent of the metabolic or biochemical state of the cells. For the past 25 years there has been an international clinical research effort to determine whether neutrons could be used to control otherwise radioresistant tumors.

Funded by the National Cancer Institute, Fermilab's Neutron Therapy Facility (NTF) began treating patients having radioresistant, inoperable tumors in 1976. The neutron beam was produced by bombarding beryllium with 66-MeV protons from the Linac. A freight elevator located about halfway down the Linac Gallery was converted into a treatment room so that the part of a patient's body to be treated could be aligned relative to the Linac beam. At that time NTF had the highest energy neutron therapy beam in the world. Other facilities were typically using cyclotron-produced proton or deuterium beams with energies around 15 MeV. As the international group of researchers compared clinical results over a period of years it became clear that better local control, with fewer side effects, was achieved with the higher energy beams [1]. Consequently, facilities having lower energy machines either stopped treating patients or upgraded to higher energy accelerators. In 1988, the National Accelerator Center in South Africa began treating patients using a 66-MeV proton beam from a separated-sector cyclotron. As of this writing, Catholic University of Louvain is using a 65-MeV proton beam, Clatterbridge Hospital in England has a 62-MeV beam, and the University of Washington in Seattle is using a 50-MeV proton beam. Several European facilities are in the process of upgrading to 65 MeV. Fermilab's work has set the standard for other facilities worldwide!

A summary of international clinical results for long-term local control of radioresistant, inoperable tumors is shown in Table 1. Though the treatment is not 100% effective it should be noted that, at least presently, there is no better treat-

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ment for these tumor types. In addition, an eight-year study has shown significant improvement in long-term survival of patients receiving neutron therapy for advanced carcinoma of the prostate [2]. The results of this study are not included in Table 1 because advanced prostate cancer does respond to photon therapy in some cases.

Table 1

Control rates for neutron therapy of radioresistant, inoperable tumors (international experience through 1987)

Tumor Type	Control Rate
Salivary gland tumors	71%
Sarcoma of bone	66%
Soft tissue sarcomas	50%
Melanoma	71%
Recto-sigmoid cancers	33%
Bladder cancers	48%

In 1985, after we had treated 1300 patients, officials at the National Cancer Institute decided that the efficacy of neutron therapy had been established and that research funds would be better spent in other areas, such as developing and testing new chemotherapeutic drugs. Hence, they did not renew our research grant. Both the Laboratory and the physicians working at NTF were committed to keeping this mode of treatment available for patients. The physicians formed a partnership, the Midwest Institute for Neutron Therapy, which operated the facility on a fee-for-service basis under a contract with the Universities Research Association (URA). Once again, NTF took the lead in moving neutron therapy from an experimental modality to being the treatment of choice for certain radio-resistant tumors. Convincing Medicare and the other medical insurers to cover the cost of treatment was a non-trivial project, but we have succeeded and have made the way easier for other facilities that are now beginning to offer neutron therapy on a fee-for-service basis. A further proof that this once-experimental treatment is becoming accepted in the medical community is the fact that Rush-Presbyterian-St. Luke's Medical Center has agreed to collaborate with URA in operating the facility. Over 500 patients have been treated since the grant was terminated. We continue to see about 500 follow-up patients each year at no additional cost to the patient.

Though other facilities are beginning to approach Fermilab's capability of providing relatively high proton energies for neutron therapy, our facility has the highest dose rate because we can take advantage of the high proton current available in the Fermilab Linac. Facilities using cyclotrons are limited by practi-

cal problems such as higher power requirements and higher radiation levels. A high dose rate is important because it minimizes the amount of time a patient must remain immobilized during treatment and increases the number of patients that can be treated each day. From a financial point of view it is important because proton accelerators used for neutron therapy can also be used to produce short-lived, medically useful radioisotopes. Facilities using cyclotrons for therapy and isotope production have found that the two uses interfere with each other. Some are in the process of purchasing a second cyclotron to satisfy the requirements of both activities. Our experience in using the Linac for both high-energy physics and neutron therapy by means of a fast switching magnet, coupled with new technology that can dramatically reduce the size of a 66-MeV proton linac, has led to the proposal that new neutron therapy facilities should use a linac, rather than a cyclotron, as the proton source [3]. Once again, Fermilab is taking the lead: this time by finding a way to make neutron therapy practical and cost effective in a hospital setting.

References

[1] T. Griffin, T. Pajak, G. Laramore, L. Davis, Analysis of Neutron Radiotherapy Treatment Complications, Bull. Cancer(Paris), 1986, Vol 73, 5, pp. 582-586.

[2] K. J. Russell, G. E. Laramore, J. M. Krall, F. J. Thomas, M. H. Maor, F. R. Hendrickson, J. N. Krieger, and T. W. Griffin, Eight Years Experience With Neutron Radiotherapy in the Treatment of Stages C and D Prostate Cancer: Updated Results of the RTOG 7704 Randomized Clinical Trial, The Prostate, Vol 11, 1987, pp. 183-193.

[3] A. J. Lennox, F. R. Hendrickson, D. A. Swenson, R. A. Winje, and D. E. Young, Proton Linac for Hospital-Based Fast Neutron Therapy and Radioisotope Production, Proceedings of the International Heavy Particle Workshop, Villigen, Switzerland, Sept., 1989 and Fermilab TM-1622.