25 YEARS OF CONTINUOUS OPERATION OF THE SEATTLE CLINICAL CYCLOTRON FACILITY

R. Risler, S. Banerian, J.G. Douglas, R.C. Emery, I. Kalet, G.E. Laramore and D. Reid
University of Washington Medical Center, Seattle, WA 98195-6043, USA.

Abstract

The clinical cyclotron facility at the University of Washington Medical Center has now been in continuous operation for over 25 years. It is highly reliable, and fast neutron therapy remains its primary application, mostly for salivary gland tumors. Neutron therapy accounts for about 85% of the facility use time. In cases where the tumor involves the base of the skull, significant improvements of patient outcome have been achieved by combining the neutron treatment with a Gamma Knife® boost to areas where the neutron dose is limited by adjacent healthy tissue.

Production of 211-At and 117m-Sn with alpha particles at 29.0 and 47.3 MeV and currents between 50 and 70 μA have become routine. These isotopes are used for medical applications presently under development.

The introduction of a new control system using EPICS (Experimental Physics and Industrial Control System) is progressing systematically. All the user interfaces are up and running, and several accelerator subsystems have been migrated to the new controls. No interruption of therapy or isotope production operation is planned for the conversion to the new control system.

INTRODUCTION

The cyclotron facility at the University of Washington Medical Center in Seattle has now been in clinical operation for over 25 years. It is fully integrated in the Radiation Oncology Department, together with four linear accelerators used for standard external beam radiation therapy. Initially it was designed and built to treat tumors with fast neutrons. This remains its primary application. However, the production of certain radioisotopes for medical applications has become an important part of today's operation.

For fast neutron therapy, a 50.5 MeV proton beam is transported from the cyclotron vault into a treatment room with an isocentric gantry with 360 degree rotation capability. Neutrons are produced in a semi-thick beryllium target with copper backing. The neutrons are collimated by a 40-leaf variable collimator to achieve the desired treatment field shape. From the first day of operation in 1984, all the set-up information for patient treatments has been transferred to the neutron therapy system electronically via a network connection from the treatment planning computer, and the set-up has been verified by the control system.

Fast neutron therapy has turned out to be effective for just a few special tumor sites, primarily inoperable salivary gland tumors. Great progress has been achieved in situations where the neutron dose is limited by adjacent structures in the base of skull region by adding a precision photon boost delivered by a Gamma Knife®.

The Scanditronix MC-50 cyclotron is designed for multiple particles and variable energy. Initially, only deuteron operation was envisioned besides the protons, primarily to produce fast neutrons having a different energy spectrum. This was only used rarely. However, as demand for alpha beams emerged, the internal ion source and the central region were optimized to improve the performance for this modality. Isotope production with alpha beams has now become routine.

Over the years many components have been upgraded, in particular power supplies and other electronic parts. A major effort is in progress to replace the original Scanditronix control system based on a PDP11/23 computer and a proprietary I/O system. The new system is based on EPICS and commercially available components. Migration to the new system is being done in stages with both systems controlling part of the facility at this time.

FAST NEUTRON THERAPY

Fast neutron therapy remains a niche therapy, primarily for inoperable salivary gland tumors and sarcomas or after surgical intervention for these tumors, where gross disease is left behind. It remains the treatment of choice for these cases. Apart from the new light ion treatment beams, neutrons are the only high LET (Linear Energy Transfer) radiation available for the clinical treatment of tumors. While the local control rate and survival is excellent for certain patients with good prognostic factors, there are subgroups of patients where success is elusive. In some of these cases the cancer extends to areas where the neutron dose must be kept sub-optimal to protect adjacent anatomical structures. Because of scatter within the patient's tissues, the field edge for neutrons is intrinsically not as sharp as would be desirable. In particular for patients with salivary gland tumors involving the base of the skull, recurrences in this region were frequent. When a Gamma Knife® unit became available to the oncologists, a photon boost was added to the fast neutron treatments to supplement the radiation to the underdosed area. Several years of data are now available. The local/regional control rate for these patients

is shown in figure 1. The outcome for patients with base of skull involvement receiving a Gamma Knife® boost has now become comparable to patients without this complication [1]. This boost is now standard practice for these patients.

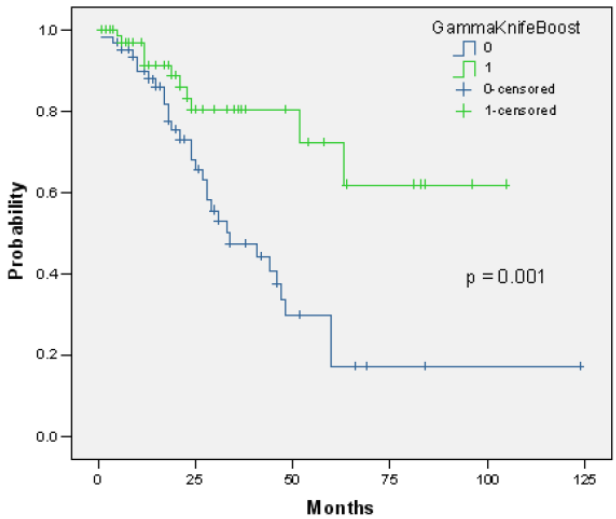

Figure 1: Local/regional tumor control for salivary gland patients with base of skull involvement. The control rate for patients receiving a Gamma Knife boost is compared to patients without a boost.

OPERATIONAL STATISTICS AND EQUIPMENT PERFORMANCE

The cyclotron system and the fast neutron radiation therapy equipment has an excellent history of reliability. Over the past three years only seven patient sessions had to be rescheduled on a subsequent day because of technical problems. Three were caused by an I/O system failure, three because of treatment head problems with mechanically damaged wiring, and one because of the RF system. Fig. 2 shows facility downtime, counted during scheduled therapy days (Tuesday – Friday, 08:00 to 18:00). Downtime events lasting four hours or longer are more serious as patients have to be postponed to a later date. For shorter events patients can frequently wait or be rescheduled later in the day.

During the whole life of the facility there has never been a scheduled downtime period more than an extended weekend (Friday – Monday). These periods were primarily required for mechanical or wiring upgrades and/or repairs of the therapy unit. All support work is being performed by local staff with excellent support from various on-campus shops. Only on one occasion did we request support from the manufacturer for a mechanical problem with the leaf collimator.

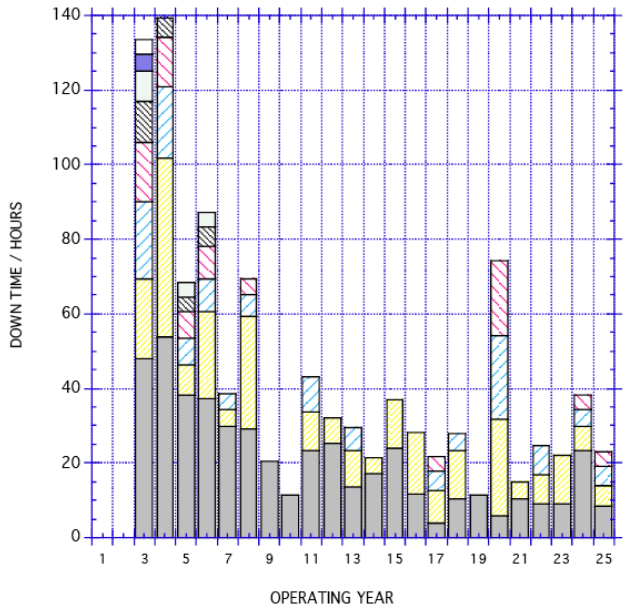

Figure 2: Facility downtime for each operating year. Downtime events lasting four hours or more are shown individually.

ISOTOPE PRODUCTION WITH ALPHA BEAMS

Initially, operation with alpha particles was not part of the program and was added when demand for 211-Astatine emerged. This alpha emitter with 7.2 hour half-life is promising for radio-labeled compounds to target distributed tumors. Several groups at the University of Washington and the Fred Hutchinson Cancer Research Center are involved in these studies [2].

After the addition of a new beam line at the zero degree port of the switching magnet, a dedicated target station for isotope production with alpha beams became available a few years ago. It is designed for solid targets installed at a 10 degree slant. They are retrieved manually after irradiation and an appropriate waiting time. Operation with alpha particles has now become routine with one run per week for 211-At, typically on Monday morning. Presently the produced 211-At is used for animal studies and chemistry development. Typical run times are under one hour. This can easily be expanded when demand rises as is expected for clinical trials. Average current on target is 50 μA at 29 MeV. There is poor transmission, around 65%, between the first Faraday Cup after the machine and the target, because there are no further focusing elements in this line and the beam is broad.

The second isotope produced is 117m-Sn using the 116-Cd(α,3n) reaction. It is produced for Clear Vascular Inc., an outside company. The customer delivers the enriched targets to the facility where they are irradiated and returned for processing. 117m-Sn has 13.6 days half life and is investigated for imaging and potentially treating vulnerable plaque, a type of plaque in the arterial wall that

can produce sudden heart attacks or a stroke [3]. Human clinical trials are presently in progress. This isotope requires typical run times of 8 to 16 hours at the maximum available energy of 47.3 MeV. These runs occur about monthly, on Friday/Saturday, with shipping on Monday after short lived byproducts have decayed. The average beam current for the most recent 20 runs is 70 μA. At the higher energy the transmission from the cup to the target is better, 85%.

The target station is open to the beam line with no vacuum window. While this is convenient for operation, it also creates a potential contamination hazard. The vacuum pumps in this line and at the switching magnet are equipped with activated carbon exhaust filters to catch any undesired air emissions. The filters are monitored after each run and have proven to be very effective, in particular for 211-At. There are additional filters in the exhaust duct from the cyclotron vault.

UPGRADE OF THE CONTROL SYSTEM TO EPICS

The aging PDP11/23 and the Scanditronix I/O system are being replaced. The new system is based on EPICS (Experimental Physics and Industrial Control System, [4]) and has been described previously [5]. At this time, the user interface is fully operational. It is similar to the original Scanditronix interface with two terminal screens at the cyclotron control console, one for interacting with the system and one for display of subsystem information only. There are six tuning module knobs which can be used to control any of about 80 analog parameters. In addition there are some dedicated knobs, pushbuttons and indicator lamps at the cyclotron control console. The necessary utilities for user login, error log files, for stopping and rebooting EPICS I/O controllers, and for storing and retrieving parameter settings are fully functional.

Presently the new system controls the cyclotron magnet subsystem, the ion source subsystem and part of the extraction subsystem. It also monitors all vacuum pump groups. The cyclotron console has temporarily been expanded to accommodate both the old and new control system components. The changeover to the new system is being performed in small steps, a few parameters at a time. The ongoing therapy and isotope production operation cannot be interrupted by this work.

CONCLUSIONS

After 25 years the cyclotron facility is running well and continues its mission to treat cancer patients with fast neutron therapy as one of the few centers worldwide, and to provide beam time in support of other medical applications, specifically production of 211-At and 117m-Sn with alpha particles.

REFERENCES

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