20 YEARS OF CLINICAL OPERATION WITH THE FAST NEUTRON THERAPY SYSTEM IN SEATTLE

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Abstract

The Clinical Neutron Therapy System at the University of Washington Medical Center in Seattle has now treated patients with fast neutrons for 20 years. During the past three years roughly 75 % of the treatments were for salivary gland tumors, where neutron therapy is the treatment of choice. After the installation of a small dedicated cyclotron in the Nuclear Medicine department for PET isotope production this service is no longer required from the Scanditronix MC50 cyclotron. Instead, a new beam line has been added for the production of 211-At using an alpha beam. The clinical operation remains very reliable with an 18 month time period where not a single patient session had to be cancelled for machine reasons. During the same time period all major system components were secured seismically, which required considerable construction activity during weekends with normal therapy operation continuing during the week. Besides the continuing upgrade and replacement of system parts a program is under way to migrate the accelerator / beam line controls to an EPICS based control system.

INTRODUCTION

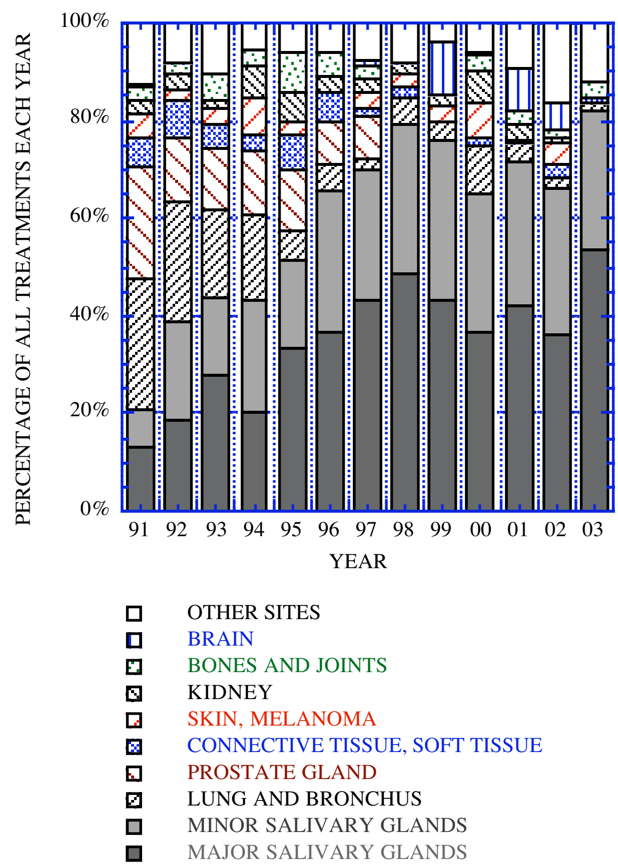
The clinical cyclotron facility at the University of Washington Medical Center in Seattle is based on a Scanditronix MC50 variable energy cyclotron. Its primary purpose is to provide a 50.5 MeV proton beam for the production of fast neutrons for cancer radiotherapy. Therapy is performed in a treatment room equipped with an isocentric gantry with a 65 cm long multi-leaf collimator. The distance from the beryllium target to the isocenter is 150 cm. A second treatment room with a fixed horizontal beam is available for neutron beam development and radiobiology experiments. In addition, the cyclotron provides proton beams to a target station in the cyclotron vault for experimental PET (positron emission tomography) radionuclides. Routine PET radionuclide production has been transferred to a new dedicated cyclotron (CTI Eclipse, 11 MeV protons) nearby. A new beam line and target station has been installed in the vault for 211-Astatine production using a 28 MeV alpha beam.

FAST NEUTRON THERAPY

At the University of Washington fast neutron therapy is primarily used to treat cancers of the salivary glands. This is a relatively rare tumor, however, over 70% of the neutron patients fall into this category. Some sarcomas, lung cancers and melanomas also respond favorably to neutrons [1].

Fig. 1 summarizes the anatomical sites treated over the past 13 years.

Figure 1: Treatment sites treated 1991 to 2003



A typical course of neutron treatments consists of 16 fractions over a time period of four weeks. Therapy days are Tuesday through Friday, with Monday reserved for maintenance and other activities.

The use of a 40-leaf collimator to shape the treatment fields, the internal wedge system and a field size dependent flattening filter requires an automated set-up for these parameters. Since the very beginning all patients have been treated with a set-up prescription transferred from the treatment planning system via a network connection. The system was deliberately designed without the possibility to enter patient data manually directly into the therapy control system.

OPERATIONAL STATISTICS AND EQUIPMENT PERFORMANCE

Over the past few years the number of patients treated with neutrons has been around 90. This is considerably less than the capacity of the facility and is primarily limited by the referral network for these relatively rare tumors. A total of 2371 patients have been treated since the beginning of operation in 1984. Patient statistics are illustrated in Fig. 2. Additionally, 604 patients were treated prior to 1984 with a neutron beam produced with deuterons on beryllium at the University of Washington Nuclear Physics Laboratory cyclotron.

Figure 2: Number of patients treated each year.

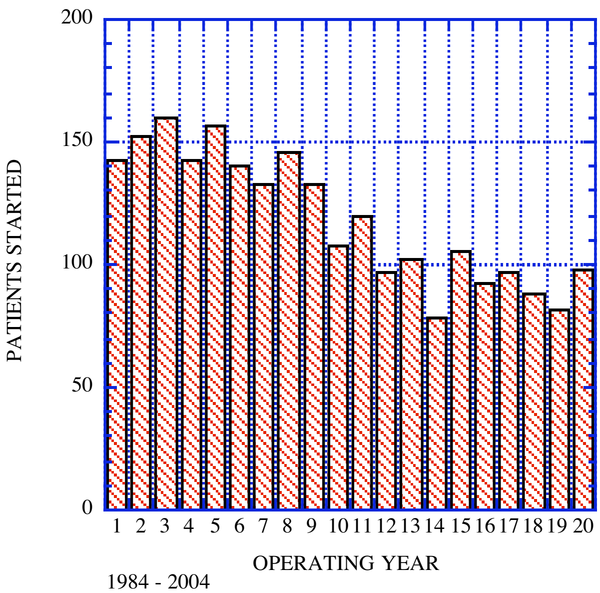
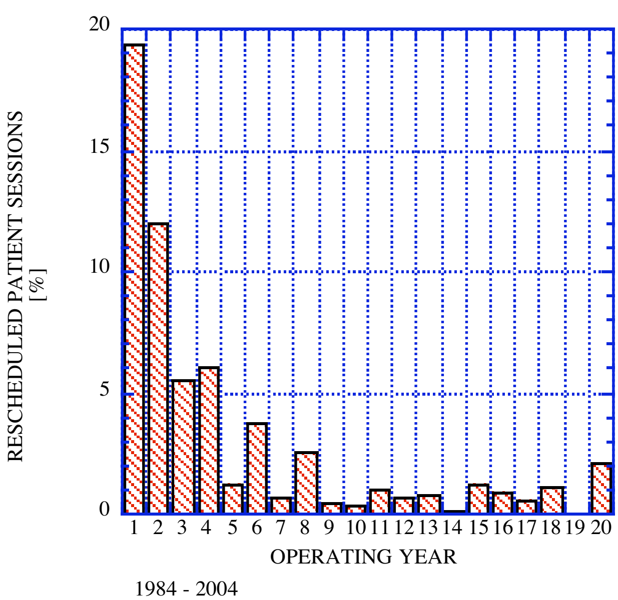


Figure 3: Percentage of patient sessions canceled



In general, the equipment has proven to be very reliable with downtime below 2% and canceled treatment session for equipment reasons below 1%. However, during the past year there were three incidents, where the system was down for 2 to 2 1/2 therapy days, resulting in 3.6% downtime with 2.1% canceled patient sessions. Fig. 3 shows the statistics of canceled sessions over the years.

During the first years of operation multiple components were replaced or modified to improve reliability. Some of the more recent major failures can be attributed to the aging control system or the mechanical components in the therapy head of the gantry.

Several control components have been replaced, such as the original programmable logic controller. Others will eventually be replaced, however, this requires a major redesign of the accelerator and beam line control system.

The problems with the therapy head are usually not very serious, but access to these mechanisms is complicated and time consuming, as the collimator must be removed. Most problems center around the internal wedge system, used to shape the dose distribution. In the long run these problems might be eliminated by achieving the same dose distribution by applying multiple smaller fields using the leaf collimator (IMRT = intensity modulated radio therapy), similar to techniques in use with electron linacs.

Shorter but annoying problems are caused by bad contacts, resulting in erratic behavior, in particular where analog signals are involved. Replacing connectors and switching to extensive digital controls with a new control system will eventually improve this situation.

RF drive amplifier failures have been relatively frequent, but can easily be overcome by switching to a spare. Changing from 300 W to 500 W amplifiers may make a difference.

Substantial experience has now accumulated with the neutron production target in the therapy head [2]. With a dose rate of 0.5 Gy/min, requiring 55-60 μA of proton current, two targets lasted for 13000 and 17000 therapy fields. At 0.6 Gy/min, corresponding to 66 to 72 μA the life time dropped to 6900 to 7500 fields. There is no information available on the number of additional runs performed, such as for calibrations etc. As the number of fields treated per year is roughly 4000, the targets now last close to 2 years, which is deemed acceptable. The standard failure mode of the targets is the development of small cracks in the copper stop behind the beryllium, leading to a leak from the cooling water into the vacuum. A rise in pressure, when the beam is turned on, is the first indication of failure. The leak tends to seal when the beam is turned off. By reducing the beam intensity and increasing the vacuum alarm points it is usually possible to finish the therapy day and then replace the target in the evening. The operation at 0.6 cGy/min requires 80 μA of extracted beam from the cyclotron, which is above the original specifications. A further increase in dose rate would require considerable effort both on the accelerator as well as the target side.

RECENT SYSTEM MODIFICATIONS

After completion of an engineering study many hardware components were secured to better withstand a seismic event. Heavy concrete pads and steel beams were retrofitted at the cyclotron and the two shielding doors and steel angles and additional tie-downs were added to the therapy units. All work was performed on weekends, including Mondays, and therapy operation continued on the regular schedule.

The arc power supply for the cold cathode ion source has been upgraded to a commercially available supply, which can easily be replaced in case of problems. At 3 kV and 1300 mA the new supply is also suited for alpha beam operation.

The upgrade of the programmable logic controller has made more cabinet space available to add functionality to this system. In particular some of the discrete input / output functions were removed from the old PDP11/23 computer and more moves are planned for the near future. This will facilitate the eventual removal of the PDP.

Many control functions for the therapy gantry and patient support were originally handled by relay logic. This has been moved to a second programmable logic controller. Relays are still used for safety back-up.

The therapy control system with software running under VxWorks on a VME controller, which was installed in 1999 has been running with just some rare glitches. The server from which the VME controller boots and gets the necessary information such as the prescribed patient set-up has been changed to a PC running under Linux.

A beam line was added to the zero degree port of the switching magnet. It has its own vacuum system equipped with a turbodrag pump backed by a scroll pump. This has so far worked well and the other beam line pump groups will also be upgraded to this set-up. There have been some problems with water leaks in the original diffusion pump baffles and the rotary vane pumps start showing their age.

At the end of the new beam line a target station for the production of 211-At was installed. It was designed and built by the Applied Technology Group at TRIUMF [3]. The water cooled aluminum target plate is slanted and has a depression for the bismuth target material. Beam transmission from the first Faraday cup to the target is only about 60% as there are no additional focusing elements in this line. To increase the available alpha beam intensity, Dee tip 2 was modified by installing a solid puller plate with a window facing the ion source slit. Up to 70 μA of He^{++} have been observed at the target location, but more common intensities are closer to 40 μA. It is expected that a routine target current of 50 μA will be achievable by adjusting the puller geometry.

To monitor and if necessary trap air emissions from the Astatine production, an additional charcoal filter was installed in the cyclotron vault exhaust duct.

OTHER PROJECTS AND PLANS

The collaboration with the Idaho National Engineering and Environmental Laboratory (INEEL) regarding a potential boron neutron capture (BNC) boost is continuing with additional activation foil measurement to refine the knowledge of the neutron spectrum [4].

Besides the original beryllium-tungsten target configuration [5] designed to enhance the BNC boost, combinations of beryllium with iridium, platinum and gold were built and evaluated by measuring fast neutron and BNC depth doses. These targets all gave similar results. In addition two targets with beryllium/thorium and beryllium/uranium were built. They gave a considerably higher BNC component, however, the residual gamma radiation was roughly three times higher. Without additional shielding, these targets were not considered usable for everyday operation.

The plans to replace the original Scanditronix control system for the cyclotron and beam lines by an EPICS [6] based system are progressing. A test set-up has been built and operated to gain experience with this approach and evaluate the real time performance of a critical subsystem. The test consisted of a control knob connected to one VME processor in the accelerator control console, connected via the dedicated private network to another processor in the power supply room, which controlled three harmonic correction coil power supplies for the cyclotron. The test set-up worked well without any latent delays in the response of the supplies. It is planned to introduce the new system in stages by migrating the controls from the PDP11 to VME processors subsystem by subsystem.

CONCLUSION

The clinical cyclotron facility at the University of Washington continues to deliver a reliable neutron therapy beam. In addition it is well suited to support the interest of the local research community with 211-Astatine production.

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