CLINICAL CYCLOTRON SEATTLE: ELEVEN YEARS OF OPERATION

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The clinical cyclotron facility in Seattle continues to operate in its traditional mode and over 1500 patients have been treated with fast neutrons since the beginning of operation. Favorable long term clinical trial results for neutron patients continue to emerge. The target system in the second (fixed beam) treatment room has been modified to increase the slow neutron component for the investigation of a concomitant boron-neutron capture boost, if a suitable 10-B containing tumor-seeking drug is administered before therapy. A first experimental run with a human patient has been performed. Operationally the system remains very reliable and less than 1% of the treatment sessions had to be rescheduled for machine related reasons. Improvements in the gantry magnet alignment have resulted in better beam control. Modifications were made to the cooling system for better flow and pressure control, to the controls of the moving floor in the treatment room and to the therapy control system.

1 Introduction

The clinical cyclotron facility at the University of Washington Medical Center in Seattle utilizes a Scanditronix MC50 cyclotron for fast neutron therapy and for radionuclide production for two PET scanners and has been in routine operation since 1984[1]. Beam delivery for neutron therapy as well as radionuclide production is scheduled from Tuesday through Friday. Monday is kept available for maintenance and experimental work.

2 Neutron Therapy

While, in general, neutron therapy has not been proven to be superior to conventional radiotherapy, there are some tumor sites where it is advantageous[2], in particular this is true for salivary gland tumors. Another case, which looks very promising is locally advanced prostate cancer. The clinical trial results show clearly improved local control rates at 5 years and more favorable PSA (prostatic specific antigen) levels for the neutron patients, but it remains to be seen, if these results will lead to improved patient survival with longer follow-up time. Other tumors, where there is an indication of improvement with neutron therapy are some non-small cell lung cancers and some sarcomas. For the past three years about 70 % of the patients treated with the Seattle neutron beam suffered from cancers in these groups.

Given these results, it cannot be expected that neutron therapy will become a widely available therapy in the near future. It will however play an important role in the cases, where it can be advantageous. This may change, if it becomes possible to sensitize tumors to neutron radiation for instance by depositing 10-boron selectively in the tumor and not in the surrounding tissue. As the fast neutrons interact with tissue, they are moderated and a significant thermalized component is formed in the neutron spectrum. The high thermal capture cross-section of 10-B leads to enhanced energy deposition in the tumor. Boron neutron capture therapy as a stand-alone modality is being investigated using beams from reactors. If a suitable boron carrying drug can be developed, it is expected that the dose boost from 10-B in the case of a fast neutron therapy beam can be clinically significant.

The fixed beam unit of the Seattle facility has been used to perform measurements and experiments to develop this modality. Animal studies were carried out and a first experimental run with a human patient was completed[3]. The results so far are encouraging and the effort will continue, if funding becomes available.

3 Operational Statistics

The operational statistics for the past three years as well as the eleven year summary are shown in table 1. The system remains very reliable and less than 1 % of the scheduled patient sessions could not be delivered because of machine problems, in fact there was a 13 month period without a single cancellation of a therapy run. Rescheduled sessions are counted, when they are rescheduled for a subsequent day. Minor delays during the day are not counted.

Table 1: Operational Statistics

YEAR	SCHEDULED TREATMENT SESSIONS	PERFORMED TREATMENT SESSIONS	RESCHEDULED SESSIONS, PATIENT CAUSED	RESCHEDULED SESSIONS, MACHINE CAUSED	UNSCHEDULED DOWNTIME [HOURS]	FIELDS TREATED	PATIENTS STARTED	ISOTOPE PRODUCTION [HOURS]
Oct-1992 Sep-1993	2160 100.0%	1965 91.0%	186 8.6%	9 0.4%	20.50	4671	133	80.4
Oct-1993 Sep-1994	1740 100.0%	1641 94.3%	94 5.4%	5 0.3%	11.50	4109	108	71.4
Oct-1994 Sep-1995	2080 100.0%	1976 95.0%	83 4.0%	21 1.0%	42.50	4832	120	99.5
11 Year Total	22175	19432	1722	1021		44051	1533	719.7

4 Equipment Performance

While the equipment is overall very reliable, we have experienced annoying intermittent problems, which are probably caused by bad electrical connections. Some improvements have been made by changing to different connectors in crucial locations, but it remains to be seen, whether these failures are an indication of the aging of the facility and will continue.

The second of our own beryllium targets ran to over 17'000 therapy fields until it failed with a leak from the cooling circuit to the vacuum because of tiny cracks caused by thermal stresses. Standard beam power is 3 kW for a dose rate of 0.5 Gy/min at isocenter. The lifetime of the target with our present patient load is about 4 years and is acceptable. We experienced some difficulties with cooling line breaks in the target assembly because of radiation damage to the plastic tubing. All plastic tubing has been removed from this area and the electrical isolation of the cooling lines is now achieved by a solid PVC manifold block to which the various components are connected by copper tubing. We have experienced no problems with this arrangement so far.

Measurements of the therapy gantry mechanical tolerances have shown no degradation in mechanical accuracy. The mechanical isocenter is still defined by a sphere of 4 mm diameter, the same as after installation.

5 Personnel Exposure

The radiation exposure data for the therapists who set up the patients are shown in fig. 1. The film badge readings of all the therapists were added for each month and then divided by the number of fields treated during that time period. The error bars show the standard deviation of the monthly data for each year. Most of the time there are two therapists assigned to each therapy unit and the exposure per person is therefore half the reported value.

The initial drop-off in the exposure data can be explained by increased familiarity and confidence with the equipment. The increasing trend over the past few years is probably due to more sophisticated set-up prescriptions, which require the therapists to spend more time in close proximity to the therapy unit.

The total exposure of the technical staff associated with the cyclotron system has ranged between 11 and 27 mSv per year (with one exception, where extractor difficulties lead to a total exposure of 59 mSv), shared between four to five people. There is no particular trend apparent in these data, exposures depend more on the type of work performed. The numbers reported do not include the staff working with the PET radionuclide production and radio-chemistry.

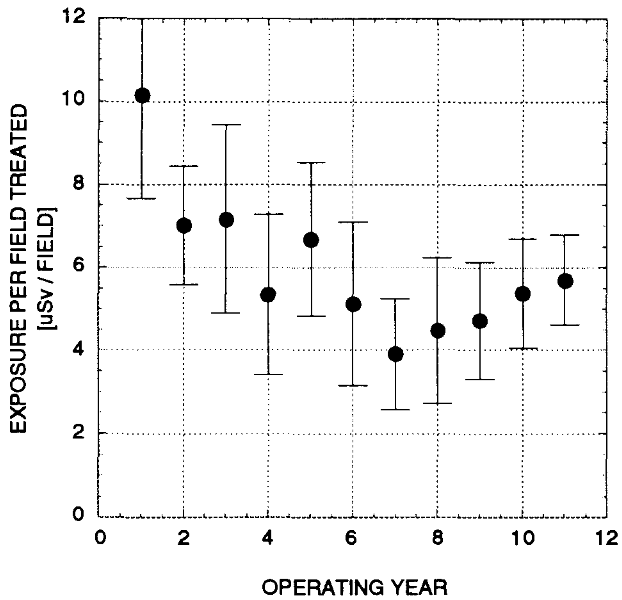

Fig. 1: Radiation exposure of therapists per neutron field treated. This exposure is typically shared by two therapists

6 Equipment Improvements

An investigation of the beam trajectory through the gantry led to the conclusion that the two gantry dipole magnets were not properly aligned. They had been originally set up with great accuracy using the factory supplied alignment pins on the magnet yokes, but these pins do not seem to accurately reflect the magnetic field distribution. The first (70 deg.) magnet was shifted downstream along the gantry rotational axis by 2.5 mm and slightly rotated by changing shims. The shims for the second (160 deg.) magnet were also changed by about 0.5 mm. The result of this change was a dramatic improvement of the beam steering through the gantry arm. The amount of steering current necessary to compensate for mechanical flex in the arm and beam misalignment of the incoming beam was reduced by a factor of 3!

As a result the beam tune is now much more forgiving and the beam can be operated without the continuous presence of a cyclotron operator. We still need the operator to switch the beam between therapy and isotope production. An operator alert system was installed, which calls the operator to the console either automatically by a machine problem of by the therapist by pushing a button. Typical operator response is less than 30 seconds. The system has been very useful, but is only used infrequently, maybe 2-3 times a week.

A protection system has been installed to prevent collisions between the moving floor and the isocentric therapy gantry. Further control work for the moving floor is in progress.

The beam defining lamp assembly has been rebuilt and many optical artifacts have been eliminated. The leaf collimator is very demanding on the beam defining lamp system, because the shallow incidence of the light on the 65 cm long leaf surfaces causes reflections, despite the fact that the leaves are painted black. Complicated field shapes with leaves protruding into the collimator opening are very sensitive to slight misalignments of the leaves or the light source. The new assembly features careful light collimation in the vicinity of the bulb to reduce stray light at the source. Also, the bulb is mounted on an X-Y translation stage to allow easy and accurate centering.

An electronic soft-start unit was installed for the main cooling pumps in order to reduce pressure surges when the pumps are started. This should reduce the number of cooling line breaks. Plastic cooling lines throughout the system were replaced by rubber hoses, which have proven to be less troublesome. Plastic is only used where electrical isolation is required. At the same time the cooling flows in the various circuits were balanced. This improved the reliability by giving more margin to several flow sensor settings.

Several older power supplies and control units were replaced as part of the long term upgrade program. Work on new control system hardware and software continued.

7 Long Term Operational Experience

The fast neutron therapy beam at the University of Washington Medical Center has now been in operation for 11 years. During this time period the system was never shut down for more than an extended weekend (Friday through Monday or Tuesday) for scheduled maintenance or modifications. Apart from one 12-day period the facility was never unavailable for therapy for more than three days in a row. The yearly down time for the past 9 years is shown in fig. 2. Down time is counted when the system is unavailable for more than 10 minutes during the standard 10 hour operating day. No data is available for the first two years of operation. Down time events of 4 hours or longer are shown individually. These long events account for about

50 % of the down time, but are responsible for about 80 % of the treatment sessions, which had to be rescheduled for technical reasons. Immediate access to local spare parts and local expertise is essential to keep these major down time events to a minimum.

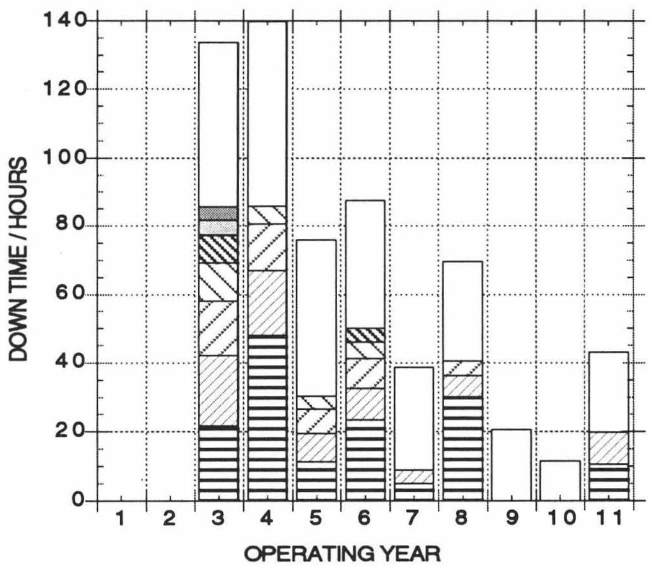

Fig. 2: Total down time for the past 9 years of operation. Events lasting 4 hours and longer are shown individually.

8 Conclusion

The Seattle clinical cyclotron and its associated neutron therapy system continues to operate reliably and to meet the demands of the clinical staff. In eleven years of operation it has been shown, that it is possible to operate an accelerator system of this nature in a hospital setting, if maintenance and operational problems are properly addressed and if the system is upgraded systematically to improve performance.

References

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