TWO YEARS OF OPERATING EXPERIENCE WITH THE SEATTLE CLINICAL NEUTRON THERAPY FACILITY

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Summary

After five years of planning, equipment acquisition, facility construction and beam testing the Seattle Clinical Neutron Therapy facility became operational in October 1984. In the past two years nearly 300 people have been treated in clinical trials. During this time 82% of the planned treatment sessions were performed on schedule, 3% had to be rescheduled for patient related reasons and 15% because of equipment problems. The facility is at present running on a 5 days/week schedule: three ten-hour treatment days, one maintenance day and one research day (radiobiology, therapy related physics). Short runs for short lived isotopes are done between patient treatments.

The isocentric gantry, capable of 360 rotation is equipped with a variable collimator with 40 independent leaves. This collimation system allows the use of complex field shapes without the necessity of handling radioactive components like collimator inserts or blocks. It has turned out to be a very essential part for the efficient operation of the facility.

Major causes for equipment downtime were associated with the control system, the beryllium target system, RF and magnet systems and the treatment gantry.

Introduction

During the past decade neutron therapy has become an established form of cancer therapy. Promising results have been demonstrated, in particular, for certain slow growing cancers like tumors of the prostate and salivary glands.[1,2] Several hospital based cyclotrons designed primarily for therapy applications are now in use. In addition to neutron therapy these facilities often produce short lived isotopes for use with PET (Position Emission Tomograph) scanners which are becoming operational in increasing numbers. Such a scanner is at present being installed at the University Hospital in Seattle.

Facility Description

A detailed description of the facility lay-out and the installed equipment was given at the last cyclotron conference.[3] A Scanditronix MC50 cyclotron provides beams to three target stations: one treatment room with an isocentric gantry, one treatment room with a fixed horizontal beam and an isotope production station located in the cyclotron vault. The cyclotron can produce protons from 33 to 51 MeV. At present the machine is run practically only with 50.5 MeV protons used both for therapy and isotope production.

Day to Day Facility Operation

Under normal operating conditions Monday is used for maintenance, Tuesday, Wednesday and Thursday for neutron therapy and Friday for experimental work. If there are machine caused delays on a treatment day or a treatment day falls on a holiday, Friday is also used for therapy. All treatment protocols used at present call for 3 treatments per week and this requirement is followed as closely as possible. In order to provide 10 hours of beam availability to therapy the cyclotron operator starts the system at 6:30 a.m., tunes it and runs a consistency check of the dosimetry system. The beam is then turned over to the medical technologists for therapy or an experimentor from 0800 to 1800. Isotope production runs can at present easily be fitted in between patient treatments as there are only a few. A larger number of such runs on a tighter schedule are expected with the installation of a PET scanner in the near future.

Patient Treatment Schedule and Patient Set-Up

A standard patient treatment consists of 12 treatment sessions spread over 4 weeks time. Within one session a patient gets irradiated from one to four different directions with different collimater set-ups (fields). On the average the patients were treated with 2.2 fields. A two-field treatment takes on the average 30 minutes with about 20 minutes for set up and a total "beam on" time of 6 to 12 minutes depending on available beam intensity and prescribed dose. During the set-up time of a patient the beam can be used for other purposes like isotope production or for therapy in the second (fixed beam) treatment room. Because of the limited capabilities of the second room it has not been used for patients so far.

Before the first therapy session the treatment set-up is verified by taking an X-ray picture of the field. Additional films are taken during the course of the treatment as required. For this purpose an X-ray tube is installed in the treatment head.

The capability to produce X-ray verification films is considered essential by our physicians.

Gantry Operation

One goal for the hospital based neutron therapy systems was to provide treatment capabilities similar to standard radiation therapy units to make any comparative studies meaningful. The gantry with the Beryllium target and the collimator can be rotated 360° around the treatment location. The target rotates on a circle of 150 cm radius. To compensate for gantry flex and other small errors, an X-Y steering magnet in the gantry arm is used to keep the beam on target. It is automatically controlled using signals from current pick-up quadrants in front of the 10 mm diameter target. Once the beam is centered on the quadrants control is turned over to the dosimetry chambers which provide neutron beam symmetry information. This system then uses the XY steerer to keep the neutron beam symmetric.

The system works well and the gantry can be rotated during a treatment for so-called arc therapy. However, this modality has not been used so far because of other problems. The moving floor which covers the pit underneath the unit runs only manually instead of automatically tracking the gantry.

Variable Leaf Collimator

The Scanditronix collimator has 40 individual steel leaves which can be positioned to achieve a large number of irregular field shapes. The largest field is 29 x 32.5 cm measured at the isocenter distance of 150 cm. The leaves are driven by individual motors and the position is determined from a leaf driven potentiometer setting. The collimator is set to the desired field shape by the control computer. Manual leaf adjustments are possible.

The leaf collimator has been very successful and mechanically reliable. The technologists do not have to handle radioactive components and the set-up time is very short. The fact that the second treatment room is not equipped with this style collimator and requires changing of cumbersome inserts is the main reason for not using it for patient treatments so far.

The therapy head with the collimation system produces the following neutron beam characteristics: dose rate in air 5 cm outside the field edge less than 2.5% of the central axis dose rate, flatness of ± 3% over 80% of 10 x 10 cm field, maximum asymmetry of 3% .

Isotope Production

The primary goal for the isotope production station at present is the production of short lived isotopes for the PET scanner.

To make optimal use of the beam time available between neutron therapy runs the same proton beam energy of 50.5 MeV is used for isotope production. Aluminum degraders in front of the targets reduce the beam energy to the 15-20 MeV region best suited for the production of some of the PET isotopes. Beam switching between therapy and isotope station takes about 1 minute, primarily determined by the setting of the switching magnet.

Equipment Performance

Figure 1 shows the patient treatment statistics for the first two years of operation. The graph shows the number of treatment sessions scheduled and the actual number of performed treatments. If a treatment was not carried out, that is had to be rescheduled, a distinction is made between patient related causes (sickness, no-shows etc) and equipment malfunctions.

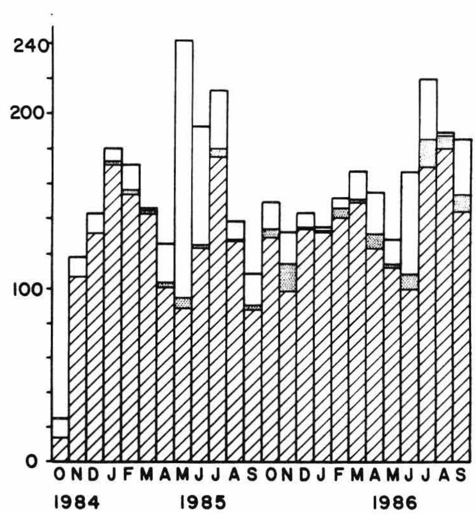

FIG 1. Patient Treatment Statistics. The graph shows the number of patient sessions scheduled for each month, the number of treatments actually performed (hashed) and the treatments missed for patient related reasons (dotted) or equipment reasons (empty).

	Sessions Scheduled	Sessions Performed	Sessions Missed Patient Related	Sessions Missed Equipment Related	Number of Patients Started
First Year	1806	1430	27	349 (19.3%)	142
Second Year	1937	1623	83	231 (11.9%)	152

Table 1. Treatment Statistics

It should be noted that it is very essential that the treatment beam is available during the normal clinic hours. It is practically impossible to catch up lost time in the evening primarily because of the loss of support personnel (physicians, nurses, receptionists) and logistics problems for the patients. The only way to compensate for lost time is to make the "experimental day" on Friday available for this purpose.

Repairs must be done rapidly and without delay, and a good set of spares needs to be on hand. This way faulty units can be quickly replaced and actual repairs can be done later.

Table 2 shows a breakdown of the equipment related losses of treatment time:

System		Sessions Missed Number	Sessions Missed Percentage
Control System			
I/O System	50		
Leaf Collimator Controller	35		
Control Software	19		
Other	16		
TOTAL		120	20.7%
Beryllium Target		65	11.2%
RF System			
Anode Power Supply	31		
Other	22		
TOTAL		53	9.1%
Magnet System		50	8.6%
Gantry/Patient Support		35	6.0%
Ion Source		31	5.3%
Beam Line Power Supplies		28	4.8%
Cooling System		27	4.7%
Diagnostics (Probes & Faraday Cup)		24	4.1%
Collimator (leaf motors)		13	2.2%
Floor Drive		13	2.2%
Extraction System (HV connector)		8	1.4%
Power Outages		7	1.2%
Vacuum System		3	0.5%
Dose Monitor Ion Chamber		2	0.3%
Shielding Door		2	0.3%
Miscellaneous		99	17.1%
TOTAL		580	100.0%

Table 2. Treatment Sessions Missed Sorted by Systems Causing the Problem.

Under "Miscellaneous" various other causes are grouped like a man-made water accident which flooded the cyclotron tank, breakdown of the computer link between the treatment planning computer and the cyclotron/therapy control computer, unspecified tuning problems etc.

There were several disturbing failures of the target systems which were finally overcome by an improved design. We are at present running routinely at 50 μA corresponding to a dose rate of 45 cGy/min.

Many failures in several systems can be attributed to the failure of packaged low voltage power supplies. Apart from some cases where the supply was underdesigned these failures might have been caused by a general overtemperature problem in the Power Supply Room. The air conditioning system was underdesigned. This has been rectified by installing a second unit, more than doubling the capacity. A similar problem had been corrected earlier in the cyclotron vault where a heat pump was added.

Crew Requirements

At the moment the continuous presence of a cyclotron operator during therapy is required. When the machine is running well this requirement might be dropped. Experience so far has shown that the beam position at the exit of the cyclotron is not stable enough and slow drifts and occasional jumps occur which have to be corrected by the operator in order to keep losses within specified values. The presence of an operator is necessary for isotope production and switching to the isotope line. Switching between therapy rooms can be done by the technologists. It has proven to be very advantageous to have the therapy treatment consoles located in the same room as the cyclotron controls. The cyclotron operator immediately becomes aware of problems and can assist the technologists. The operator also acts as coordinator between therapy and isotope production which lets the clinical staff concentrate on patient related work.

Maintenance

Without the support available at a major research laboratory and the remoteness of the cyclotron manufacturer, maintenance has to rely primarily on a good set of spare parts. Any major work has to be done by external support like service facilities of manufacturers of subcomponents. Some support is available from the Hospital Physical Plant Staff, primarily for building related aspects, but also for pumps and some other components. For special parts other shops within the University system can be asked for support. The work of the cyclotron support team is limited to actual work on the equipment, troubleshooting, some minor repairs and redesign work, and to organizing any outside support. Test equipment and other support tools have to be matched to these requirements. Only a small mechanical workshop is attached to the facility as no major mechanical work is planned. On the other hand, support equipment for work on the equipment, like the availability of a hoist in the treatment room, has proven to be very essential.

Conclusions

The first two years of operation have shown that the neutron therapy facility in Seattle runs well to fulfill the everday requirements of a hospital clinic. Equipment related downtime must be further reduced by building up a larger stock of spare parts and by improving subsystems which cause delays. With the limited staff available in the therapy department, major changes and upgrades will have to be acquired from outside suppliers. The present system has a good potential for improvements necessary for more advanced techniques in radiation therapy, in particular in conjunction with the variable leaf collimator.

This work is supported by Contract N01-CM-97282 from the US National Cancer Institute of the NIH.

References

1. T.W. Griffin, T. P. Pajak, G.E. Laramore, W. Duncan, F.R. Hendrickson and M.P. Richter. Neutron Irradiation of Inoperable, Recurrent and Unresectable Malignant Tumors of the Salivary Gland, to be published in Journal of Clinical Oncology.

2. G.E. Laramore, J. M. Krall, F. J. Thomas, T. W. Griffin, M. H. Maor, F. R. Hendrickson and J. N. Krieger. Improved Local Control and Survival for Advanced Prostate Cancer: Results of Fast Neutron Therapy, to be published in Journal of Clinical Oncology.

3. R. Risler, J. Eenmaa, J. Jacky, I. Kalet and P. Wootton. Installation of the Cyclotron based Clinical Neutron Therapy System in Seattle, Proc. of the 10th International Conference on Cyclotrons and their Applications, East Lansing 1984.