HIMAC OPERATION IMPROVEMENT FOR MORE PATIENTS WITH LESS OPERATORS

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Abstract

In order to increase efficiency and accuracy of irradiation for cancer therapy, many R&D projects have been carried out in HIMAC since June 1994: Respiratory gated irradiation system, layer-stacking irradiation system for three-dimensional heavy-ion radiotherapy, and so on.

At the start up period of HIMAC, the accelerator operation needed six operators. We have aimed to decrease the number of operators per one shift in order to keep the time of maintenance duties for HIMAC performance enhancements. We report on details and the problems about the operation by two operators which was realized since September 2006.

Annual patient throughput now exceeds 500 at HIMAC, where about 70% of the patients pay the fee for the treatment. Since the number of patients will keep growing, we have taken several measures for higher efficiency and reliability. We explain about the purpose and the effect of three representative samples; multi-layer ionization chamber (MLIC), beam on/off control not by shutters but by Radio Frequency Knock-Out (RFKO), and Quality Assurance (QA) of the dose calibration factor of the monitor unit (Gy/count).

HIMAC OUTLINE

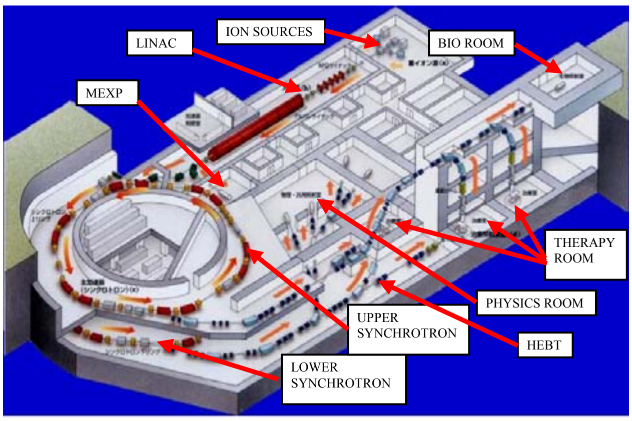

Figure 1 HIMAC bird's-eye view

By using three ion-sources, HIMAC can supply three kinds of ion beam by time sharing mode. The beam accelerated by a linac chain is divided into three rooms, medium energy experimental room (MEXP) and upper synchrotron(USYN) and lower synchrotron(LSYN). Further accelerated beams from synchrotrons are carried to each therapy room and the experimental room through high energy beam transportation system (HEBT) as shown in figure 1. [1]

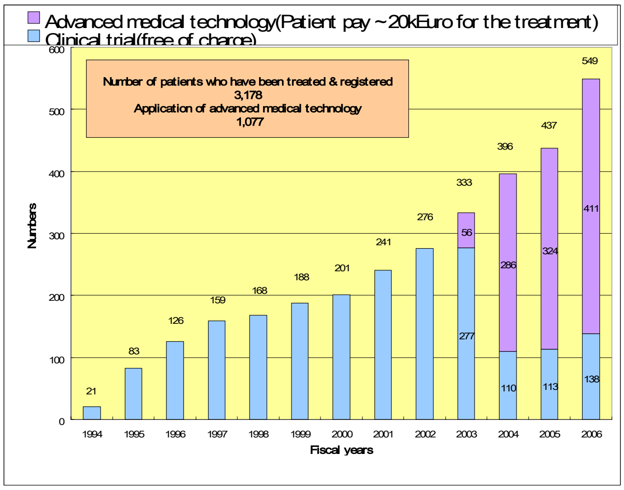

Figure 2 Annual number of patients in HIMAC carbon ion thrapy

Annual patients throughput now exceeds 500 at HIMAC, where about 70% of the patients pay the fee for the treatment as shown in Figure 2. [2]

Accelerator Engineering Corporation (AEC) was established in 1992. AEC performs not only accelerator operation but also accelerator development and design for radiotherapy in HIMAC and other accelerator facilities, which includes National Cancer Center Hospital East , Hyogo Ion Beam Medical Center and RIKEN.

In HIMAC, the periodic proactive/preventive maintenance is executed twice a year based on the contract between National Institute of Radiological Sciences and AEC for the performance maintenance of the system. AEC also undertakes routine work of treatment planning according to direction of medical doctors.

REDUCING THE DAY OPERATION CREW SIZE TO TWO

Right after the commissioning of HIMAC, the operators of the accelerator were divided into three parts of INJ, SYN and HEBT. Individual operator belongs and works exclusively in one part only. The operators have little knowledge about other parts. One part was driven by two operators, so totally six operators are needed to operate HIMAC. However, by the enhancement of operation skill and the operability improvement of the system as well as the stability of the device, it was realized to operate the machine by three operators in 1998-2006 as shown in Figure 3. During 2005-2006, we aimed at the improvement about operating of therapy time (8:30-19:30). The operation by two operators was achieved in September,2006, we report process and a future plan.

Figure 3 Transition of number of operators

While we prepared for two operators scheme, several concerns were expressed from operators. They were classified basically into the following three points.

1. **Timing where one operator takes rest**
2. **Distance between the operator and the operand (button, key, switch etc) can be too large to respond instantly**
3. **Operator needs wide knowledge of all 3 parts**

These points are discussed in the following,

To solve 1

We set up the monitor display that tells us a status of the therapy in real time. We placed it so that we can watch it from any position of the control room as shown in Figure 4. Figure 5 shows the display where the treatment status of three treatment rooms can be grasped at one view without manual request. As a result, forthcoming event is more predictable, and it becomes easy to take a break.

In order to keep the operators on the shift from the choir like taking a telephone call that is not essential to the operation, the position of the telephone was changed.

With three operators scheme, the third one can go to the ion source room when the ion source's preparation is necessary on site during the day shift for experimental use at night. Since it is impossible with two operators scheme, we agreed to assign an extra operator and charge him to work on the ion source.

Because the time for therapy extends 11 hours (8:30-19:30), it is difficult for an operator to keep alert during the entire period. Then, the duty time was shortened by dividing it into two teams sitting at 8:30-13:00 and at 13:00-20:30. For that reason, to keep the operator's concentration were done by decreasing the shift to seven hours from 11 hours

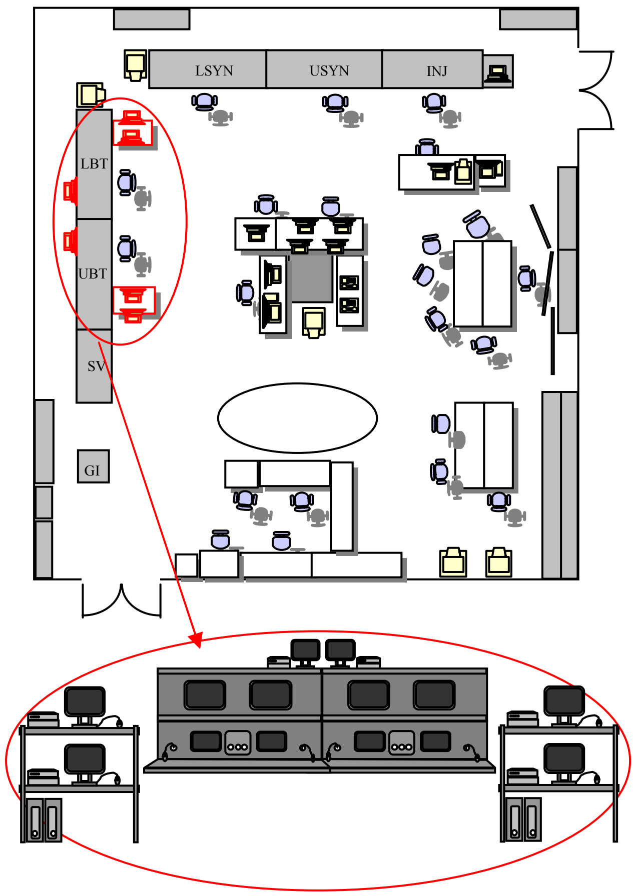

Figure 4 Accelerator control room layout

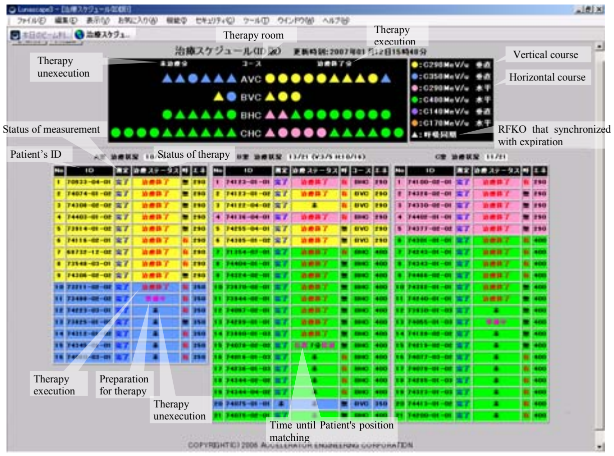

Figure 5 Monitor which displays a therapy situation on real time

To solve 2

Individual device can be controlled through the console of particular part only. Because there are consoles separated for the injector, the upper synchrotron, the lower synchrotron, upper HEBT, lower HEBT, and the supervisor system, one might have to walk 10 m just to acknowledge an alarm. A system using PC selector was considered as shown in Figure 4. The PC selector is a system to which the control and the display are freely switched in some PC. We discussed that six sets of PCs were required in order to prevent an operation mistake. However, we did not execute it this time because it cost too much.

To solve 3

The accelerator operating group is divided into two teams (the injector team and the SYN/HEBT team), and each team doesn't know the tuning skill of the other team so much. Then, to understand all processes of beam adjustment of the other team, we began educating program on selected operator for three months by man-to-man way.

Summary

We were able to reduce one operator in accelerator operation at the time of the therapy by the following actions without extra expense.

1. **Installation of the electronic panel which displays a therapy situation on real time.**
2. **The position of the control room's telephone was changed**
3. **On-site preparation of the ion source for night shift is separated from the day shift crew and assigned to the third operator.**
4. **Operating time is divided in the morning shift and afternoon shift, to keep the operator's concentration.**
5. **Education/training to expand operator's knowledge over the three parts of HIMAC accelerator.**

As the next approach, PC selector will be introduced and a burden will be made small by narrowing an operator's moving range. Furthermore, when the routine procedure of the therapy beam tuning is simplified and automated more, we think that the personnel can be reduced more.

IMPROVEMENT IN THE IRRADIATION SYSTEM OPERATION FOR BETTER EFFICIENCY AND RELIABILITY

There are measurements necessary to do the treatment irradiation at HIMAC. One is daily 'standard' measurement and the other is calibration measurement for each port of individual treatment plan.

The standard measurement is to determine the calibration constant of the dose counter on the day, by measuring the depth-dose relation of a standard Spread-Out Bragg Peak (SOBP) of the beam under the identical condition every day. It is done for each energy and course condition of the treatments. Monitor count value at the center of SOBP and range parameter are recorded and watched for change every day. (so called 'trend management')

The treatment plan measurement is done in each and every treatment plan before treatment irradiations. Under the same beam condition as the treatment irradiation, we do two kinds of measurements, to decide calibration constant at the instruction point (i.e., isocenter) and to obtain depth-dose distribution in the actual condition.

To measure the depth-dose curve, we had been using the binary filter (BF) to control depth in the standard measurement and the treatment plan measurement. About 25 points in the depth were required, and it took about 20 minutes to measure.

The measurement to decide the calibration constant is with fixed setup of the binary filter in the instruction point, but we need to measure five times under the same condition, then we adopts the mean value. Thus the measurement takes about five minutes.

INTRODUCTION OF MULTI-LAYER IONIZATION CHAMBER

The multi-layer ionization chamber (MLIC) was developed to shorten the measurement time for the dose distribution in the depth direction. It has been introduced since 2002.

The MLIC alternately mounts the detection substrate and the bias substrate, and can obtain measurements of 64 points at a time. The interval at the measurement position is about 4.2mm, and it is possible to measure the depth up to 270 mm. Figure 6 shows a front view of the MLIC which is positioned for a measurement.

The measurement time in the MLIC is one minute or less even if it repeated five times. And in the treatment plan measurement, the measurement that decides the calibration constant in the instruction point and the measurement of the confirmation of the depth-dose curve can be done simultaneously.

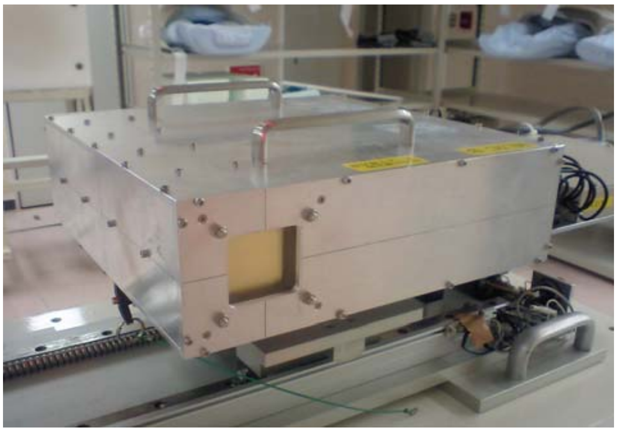

Figure 6 Multi-layer ionization chamber (MLIC)

BEAM ON/OFF CONTROL BY RADIO FREQUENCY KNOCK-OUT

The above-mentioned measurements were carried out in an automatic sequence with preset parameters for each point. However, it is necessary to stop the beam between the measurement points, and we had been using the shutters to stop the beam. It could take as long as 30 seconds for the operation in a motion and communication among computers. Therefore, time to wait for the opening and closing of the shutter was longer than actual measurement time.

We now control the beam on/off for the measurements not by shutters but by Radio Frequency Knock-Out (RFKO) only. As a result, waiting time was shortened greatly, as indicated in Fig.7.

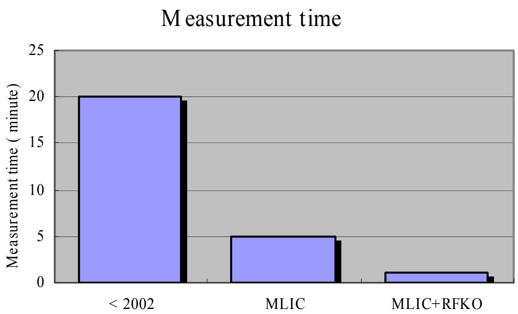

Figure 7 The trend of measurement time

QUALITY ASSURANCE ON THE DOSE CALIBRATION FACTOR OF THE MONITOR UNIT

For the 'daily' measurement, trend watching is efficient for checking malfunctioning or parameter errors. However, for treatment plan measurement variety of the conditions makes it difficult to find such errors.

As we accumulated data for various conditions, we have tried to fit measured relative dose as a function of the primary variable, the thickness of the range shifter.

We are now able to compare the estimated value from the fitting with the measurement, which provides the quantitative basis for verifying the measured result.

Fig.8 illustrates the comparison.

This quality assurance technique has been operated temporarily since 2006, and we are examining effectiveness for the official operation.

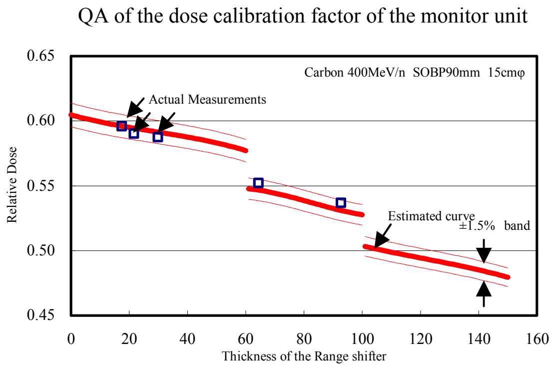

Figure 8 Comparison of measured value with estimated calibration factor as a QA tool for the treatment plan measurement.

Improvement for further efficiency and high-reliability are in progress.

Acknowledgments

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References

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[2]H. Tsubuku et al., "Present Status of HIMAC, NIRS", the 4th Annual Meeting of Particle Accelerator Society of Japan and the 32th Linear Accelerator Meeting in Japan(2007) (in Japanese)