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ABSTRACTS

of the
NIRS International Seminar on the Heavy Charged Particle Therapy for Cancer
and the
XXVII PTCOG MEETING

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Proceedings of the Chiba PTCOG meeting will be published as a special issue of the journal of the Japanese Society of Therapeutic Radiology and Oncology. The few abstracts collected at the Chiba meeting are published here.

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Overview of Phase I/II Studies in Carbon-Ion Therapy.

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Since 1994 the clinical trials of heavy ion therapy has been carried out at the National Institute of Radiological Sciences(NIRS) using carbon-ions generated by a medically dedicated accelerator(HIMAC: Heavy Ion Medical Accelerator in Chiba). The purpose of the present heavy ion therapy project is to determine whether differential effects exist between therapeutically resistant neoplasms and normal tissues that favor the latter. Based on consideration on physical as well as biological properties of heavy ions, we chose carbon ions for cancer therapy. The RBE value of the carbon-ions was estimated to be 3.0 for acute skin reactions at the distal region of the SOBP. Interdisciplinary working groups were organized to design protocols for phase I/II dose-escalation study in various tumor sites including the head and neck, brain, lung, liver, uterine cervix, prostate, bone and soft tissue, and esophagus. The initial dose employed was 10-20% lower than the tolerable dose for musculo-connective tissues. The dose was escalated by 10% increments for every 3 to 5 patients based on careful observation of the normal tissue response. As of February 1997, a total of 230 patients were treated. So far, none of them experienced any type of major morbidities. Our preliminary judgment is that the carbon-ion therapy would be effective for those tumors with non-squamous histology such as adenocarcinoma, adenoid cystic carcinoma, malignant melanoma, and bone/soft tissue sarcoma. The HIMAC clinical trials are still in an early phase, and numerous developments have yet to be achieved for successful performance.

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World wide proton therapy experience in 1997.

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The world wide proton therapy experience for the time period 1990 - 1997 is presented. In this time period, the number of patients treated per year with proton beams more than doubled, from ~876 in 1990 to ~2019 in 1996. The number of operating facilities increased from 10 in 1990 to 16 in early 1997; it is predicted that there could be 27 - 30 facilities (or more!) operating early in the next century. In 1990, ~55% of all the patients were treated using fractionated proton therapy for tumors of the eye, while ~22% were treated using fractionated therapy for other sites. By 1996, these percentages were both ~45%, and reflects the decrease in the percentage of patients treated with a single fraction from ~23% in 1990 to ~10% in 1996. Estimates of the number of patients treated per year for selected sites are presented. These data presented must be regarded as estimates because complete information by site is not currently available for all facilities, and while all data represent the patients treated in a 12 month period, this period may not correspond to a calendar year. Nevertheless, even with these restrictions, the estimates generated do give a useful overall picture of the world wide proton therapy experience.

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Implications of Clinical Specifications.

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Ensuring that all the implications of a clinical specification are effectively communicated between the clinical users and equipment designers of a Radiotherapy Facility requires extremely close and clear communication. Part of the tools needed to obtain clarity include a very detailed set of performance requirements which flow down from the clinical specifications to the equipment subsystems performance. Then an error budget needs to be apportioned among affected subsystems. An example of an important specification of 'Beam to Target Pointing Accuracy' was presented at PTCOG 28. For the NPTC this specification reads "all points in any conceivable target can be accurately and reproducibly aligned to the beam to within ±0.5mm of their intended position".

Subsystems which can contribute to errors (both correctable and uncorrectable) relevant to this specification include the Patient Positioner System; the Gantry/Nozzle mechanical pointing; and the Beam to Nozzle beam trajectory correction capability. Analysis have been carried out to evaluate the errors which can arise from these systems as well as the ability to correct the correctable portion of these errors. The design of the subsystems reflects these analyses. Also, for the NPTC data has been taken for the Patient Positioning System and the Gantry structure portion of the isocenter pointing capability. The following table summarizes the error contributions at the present time:

Error Source	***Magnitude***
Patient Positioner Correctable Accuracy	±0.2mm
Gantry Angle Correctable Accuracy	±0.2mm
Beam Trajectory Assumed Accuracy	±0.2mm
Radiograph to Beam Accuracy Assumed	±0.2mm
Total RMS error	±0.4mm

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Evaluation of Beam Delivery Systems with the Beam Emittance.

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Based on the Liouville's theorem, the beam emittance denoted by phase volume is an important constant of motion in particle accelerators and beam transport systems. It can be applied directly to a spot scanning system. It is no more conserved when beams pass through scatterer(s) or non-linear ion-optical elements. After them, however, a different emittance can be assigned to the beam, so that it can be applied to a passive beam delivery system. In a spread-out Bragg peak, the highest-energy beam component is the biggest component and makes its distal edge. Also this component only contributes to distribute dose in accordance with a bolus. Since, in principle, it is possible to remove any absorber to this component between the scatterer and the target, the emittance is conserved in this region and can be used to evaluate the most important component of a beam.

A ridge filter has discrete structure in the direction perpendicular to metallic bars. To make flat dose distribution in this direction steadily, a large emittance is needed even for the highest-energy component, but it makes penumbra large and prevents to distribute dose precisely in accordance with a bolus. By taking the emittance into consideration using "pencil and paper", a set of absorbers close to the scatterer is proposed instead of multiple metallic bars. It would make both flat dose distribution and small penumbra simultaneously.

From a viewpoint of the beam emittance, the range modulator is better than the ridge filter and the single scatterer is better than the ring stopper, the double scatterer or other sophisticated non- linear beam spreading system.

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The Non-orthogonal Fixed Beam Arrangement for the Second Proton Therapy Facility at the NAC.

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The medical user group at the NAC is currently unable to treat all eligible patients with high energy protons, since a maximum of only 80 patients per year can be treated on the existing proton therapy facility. Furthermore there are limitations with the existing treatment facility where patients can only easily be treated in a sitting position which really only allows head and neck irradiations. It was decided to construct a second treatment vault for 200 MeV proton therapy at the NAC. This is viable since an empty vault, suitable for housing a second treatment room, is already available at the NAC and also because the 200 MeV proton beam is currently under-utilized during proton therapy sessions. This is due to the fact that the patient irradiation time represents only a small portion of the total treatment time which includes accurate patient positioning.

The second proton therapy treatment room will be equipped with two non-orthogonal beam lines, one horizontal and one oblique at 30 degrees off vertical. The two beams will have a common isocentre. This beam arrangement together with a versatile patient positioning system, which will allow the patient to be tilted and rolled by a maximum of 15 degrees, will provide the radiation-oncologist with a diversity of possible beam arrangements and will allow a wider range of lesions to be treated. It offers a reasonable cost-effective compromise compared with an isocentric gantry which would be too expensive under the present financial constraints. Both beamlines will be equipped with spot-scanning beam delivery systems. The required bending magnets, quadropoles and power supplies to construct the oblique (near vertical) beam line are available from a dismantled physics experiment.

In the concept phase of the project it was clear that having two non-orthogonal beams, one horizontal and the other near vertical will be advantageous. It was however not so easy to decide what the orientation of the near vertical beam should be. A mini workshop was arranged involving all the main role players and a list of possible conditions to be treated was compiled. A planning exercise was done for each condition looking at possible treatment scenarios. The majority of cases favoured the 30 degrees off vertical arrangement.

The main advantages of the 30 degree off vertical beam line is that it provides a bigger solid angle between beam portals. Since it is assumed that the patient cannot be rolled or tilted by more than 15 degrees, "gantry angles" between 0 and 15 degrees are not possible. A "0 degree" gantry angle can however be obtained by rotating the patient through 90 degrees in which case the near vertical beam orientation will be 30 degrees off the vertical in the sagittal plane and 0 degrees in the transversal plane. It was also easier to construct the 30 degrees off vertical beamline using the existing magnets.

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Project for the new dedicated Proton Therapy Facility at PRMC, University of Tsukuba

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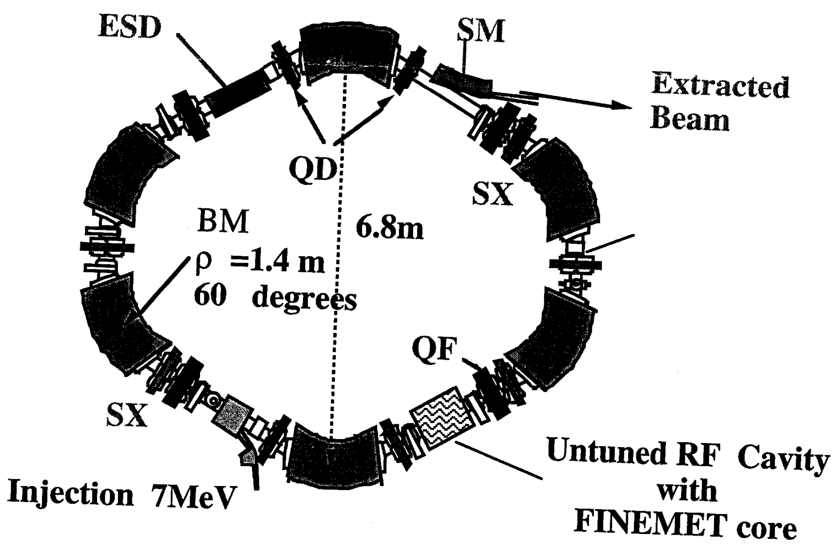
Project for building the new facility dedicated to proton therapy in the University campus has been funded to promote the clinical and basic research related to the proton therapy. The facility construction will be completed at the end of FY 2000. Two rotating gantries will be installed for proton therapy. Two fixed beam ports will be made for basic studies of radiation biology and for development of conformal irradiation technique. In FY 1997, 270 MeV proton synchrotron will be manufactured. Diffusion extraction method will be used to obtain the stable beam from the accelerator. The respiration-gated operation of the accelerator will be made using the pre-trigger signal from the respiration sensor. Passive scattering method will be used for beam delivery to obtain the stable irradiation field because our main targets are the tumors in the abdominal and thorax region which are moving with respiration. When the energy scan will become feasible, the beam delivery system can be upgraded to make a conformal therapy using the scanning technique.



The Layout of the Synchrotron

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Comparison of dose distribution produced by gammas and protons

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Performance of gamma and proton therapy is compared to a simple model where a circular centered tumor is irradiated from N sides. The dose distribution curves for the proton and gamma irradiation were computed and compared. The efficiency of irradiation in this simple model was found to be about 2 - 3 times better for protons than for gammas. The mean dose for the healthy part of the body in an “ideal” case is about 3 times smaller for protons than for gammas and its range is 3 - 9% for protons and 10 - 25 % for gammas for a typical tumor size.

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