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ABSTRACTS

of the
XXVIII PTCOG MEETING

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CONTENTS

Quick check of isocenter alignment at the NPTC gantry.

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We are developing a device to perform a quick verification of the alignment of the NPTC-gantry with respect to the isocenter. We use a metal sphere at the isocenter, attached to the patient positioner. The proton field which is used, is somewhat larger than the diameter of the sphere. The protons that hit the sphere will be degraded and scattered. Downstream of the sphere a scintillating screen is mounted and it is observed by a CCD camera. From the position of the "shadow" of the sphere within the beam spot on the screen, the quality of the alignment of the beam at the isocenter can be derived. We have performed Monte Carlo calculations, to determine the optimal setup parameters. An experimental verification of these simulations at the Harvard Cyclotron has shown a good agreement between the calculations and measurements. We have made an algorithm to automatically detect the position of the shadow with respect to the beam position. First results from measurements at the NPTC gantry show that we are able to detect an off-centering within 0.1 mm (1SD) using a simple 8 bits CCD camera normally used for PC-video-conferencing. The simulations show that a more advanced CCD camera would yield an accuracy of better than 0.05 mm. A final version of the setup is being built and it will be mounted in the gantry and used at the commissioning tests.

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Development of Nanodosimetry for Biomedical Applications.

R. W. M. Schulte, Department of Radiation Medicine, Loma Linda University Medical Center

This is an interim report on the development of a new dosimetry technique in the nanometer domain, which may eventually help to better define the RBE of particle beams. In October of 1997 the U.S. National Medical Technology Testbed awarded a one-year grant for the development of a novel nanodosimeter to an interdisciplinary group of investigators at LLUMC (R. Schulte, George Coutrakon, D. Miller), the Radiation Detection Group at the Weizmann Institute of Science in Israel (Amos Breskin, Rachel Chechik, Sergey Shchemelinin), and the Department of Radiology at UC San Diego (John F. Ward, Jamie Milligan). During the first six months of the project, we have made significant advances towards the development of the nanodosimeter. Biophysical modeling studies based on theoretical Monte Carlo track structure data (provided by the Genome Stability Unit of the UK Medical Research Council) were performed, using the assumption of an energy deposition threshold for irreparable DNA damage in nanometer sites. These studies demonstrated that a simulated cylindrical volume of 2 nm diameter by 16 nm length would be the most relevant to predict cellular effects of ionizing radiation of different quality. The single ion counting nanodosimetric technique in low-pressure propane was successfully implemented at the Weizmann Institute and first nanodosimetric spectra were measured. In particular, the Weizmann group showed that, with the help of a differential pumping system, sensitive cylindrical volumes of the size of the DNA helix can be achieved. The investigators at UCSD have been successful in developing an assay for rejoining of radiation-induced DNA breaks with cellular extracts from Xenopus laevis eggs, which will be used to investigate the correlation between nanodosimetric and biological data.

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Patient selection for the initial phase of treatments at the PSI Proton Gantry.

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The experience of the first period of patient treatments at the PSI-Proton-Gantry and the analysis of the data shows, that the patient with the irregularly shaped PTV can have an additional benefit from the spot scanning technique - which is the unique development of the Paul Scherrer Institute in Villigen, Switzerland - in addition to the known capabilities of applying highly conformal doses with scattered protons. We compared 4 cases (8 plans) with regularly shaped ptv's with 5 cases (6 plans), where the outlines of the ptv's were quite irregular. The conformity indices (volume of the 70%-isodose / volume of the ptv) were 1.58 in the irregularly shaped ptv's and 2.03 in the regular ones. The dose delivered outside the ptv was 66% in the cases with the regularly shaped ptv's and only 47% in those with the irregularly shaped ptv's.

The patients tolerated their proton therapy very well, even at high dose levels. We treated 4 patients with cerebral tumors (2 low grade gliomas, 1 metastases of a SCLC and 1 meningeoma) and 5 patients with tumors of the abominal/pelvic region (2 sacral chordomas, 2 osteosarcomas and 1 malignant fibrous histiocytoma)

Furthermore, our data show, that the dose distribution in those cases with the irregularly shaped ptv's is particularly well conformal by using spot scanning technique.

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Real Time Tumor Tracking for Precision Radiotherapy.

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Precision cancer radiotherapy needs the exact knowledge of the position of the tumor to be irradiated. For that reason the patient is aligned and firmly positioned in the reference frame of the irradiation facility. But due to respiration, circulation and peristalsis certain tumors in the abdomen and in the chest move inside the patients body. This impairs the precision of the confor mity of the dose distribution to the target volume. A solution of this up to now unsufficiently solved problem requires the direct measurement of the tumor position in real time. Irradiation at facilties with fast beam steering could then dynamically be adjusted to the changing tumor position.

We developed a position measurement system to track a miniaturized marker coil in 3D space. The coil can be placed next to the tumor inside the patients body or on the patients skin such that it follows the tumors movement. An externally generated slowly modulating magnetic field penetrates the human tissue undisturbed and couples to the marker coil. This is used to measure the position of the coil, and with it the position of the tumor, at a rate of 50 Hz with a spatial resolution of 1 mm.

The system is developed for precision conformal proton therapy at the PSI Proton Irradiation Facility with its unique spot scan technique. But it can also improve the treatment precision at other hadron facilities or at modern photon machines and in connection with catheters it can be used in minimal invasive surgery and in telemedicine.

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An Innovative System for Monitoring Patient Motion.

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This is a preliminary report on the use of a non-invasive patient motion monitoring system, developed at LLUMC, to evaluate the amount of head motion occurring prior and during proton radiation therapy sessions. The output from two optical displacement sensors placed close the patient's forehead and temple was used to detect any displacement of the patient's head. Motion statistics was accquired during (1) the setup session, i.e., the time used to analyze alignment radiographs, and (2) the treatment session, i.e., the time between leaving and re-entering the treatment room. Up to now, we have recorded and analyzed the head motion during 43 setup and 41 treatment sessions in 7 patients immobilized with standard face masks and during 9 set-up and 17 treatment sessions in 5 patients immobilized with vacuum-assisted dental fixation. It should be noted that face-mask patients underwent a multi-fractionated proton treatments, while dental fixation patients were treated with single-dose or two-fraction stereotactic proton radiosurgery. Therefore, the motion statistics of the two patients groups was acquired under different conditions, with dental fixation patients, generally, having longer sessions. For the setup session, the displacement between the patient's start and finish position was 0.30 +/- 0.32 mm (mean +/- SD), range 0.03-1.67 mm, for face mask patients and 0.32 +/- 0.28 mm (mean +/- SD), range 0.06-0.98 mm for dental fixation patients. The corresponding values for the treatment session were 0.21 +/- 0.20 mm (mean +/- SD), range 0.02-1.04 mm, for face mask patients and 0.30 +/- 0.42 mm (mean +/- SD), range 0.01-1.71 mm, for dental fixation patients. The maximum displacement occurring anytime during the treatment session was 0.61 +/- 0.57 mm (mean +/- SD), range 0.08-2.34 mm, for face mask patients and 0.64 +/- 0.51 mm (mean +/- SD), range 0.11-1.86 mm, for dental fixation patients. We will continue to collect this valuable information.

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Measurement of Proton Beam Dose Profiles Using a Sensitive Scintillation Screen Observed by a CCD Camera.

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Efforts have been made to develop a rapid method of measuring dose profiles using a sensitive scintillating screen observed by a CCD camera. The main advantage of this sort of dosimetry system is its ability to do near real-time observation and analysis of the proton beam; the system offers a practical and timesaving method of quality control. Experiments have been carried out in TRIUMF's Proton Therapy Facility using beam energies and intensities well matched to clinical doses. A scintillating screen enclosed in a light tight box is placed in the path of the proton beam, and is observed by a CCD camera. The CCD camera, which views the screen through a 45-degree mirror, has an integrating mode for increased sensitivity and a frame grabber for immediate viewing. Various commercial intensifying screens have been evaluated and one screen Rarex PFG (ZnCdS:Ag) has been found to be 17 times more sensitive than the more commonly used LANEX (Gd_2O_2S:Tb) screen. The system has demonstrated to be useful for measuring lateral dose distributions to look at collimator scattering, beam steering, and effect of wedges. By mounting the screen on a Lucite wedge, the system can also be used to measure the raw Bragg peak. The results obtained with our system are consistent with diode-collected Bragg peak measurements. Initial analysis indicates there is little or no light quenching due to saturation of the scintillating material. Work is continuing to enhance the system in order to integrate over longer periods of time to allow a modulated beam to be monitored. The beam profile thus obtained could be seen online on an ordinary video display in order to monitor continuously the actual beam during treatment, making the technique suitable for use in a quality control system. Some results of the sensitivity and linearity measurements of the scintillator output for both protons and X-rays will be presented along with several examples of use of this technique for rapid visualization of dose distributions.

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Proton beam delivery system with partially shaded ridge filter.

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Performance of a proton beam delivery system with partially shaded ridge filter is studied. In the last PTCOG meeting of 1997, we have proposed an irradiation method with partially shaded ridge filter. This method is intended to realize conformal irradiation by only putting shading elements on the ridge filter. This method is completely passive and applicable to the conventional irradiation systems.

In the present meeting, dose rate distribution by this system is analyzed in detail for incident energies of 125, 175 and 230MeV. The depth-dose-curves in the water target are obtained by numerical calculations with a Monte Carlo method. It is found that this system is able to lower the dose rate in proximal region by more than 20% while those in distal region is uniform. The lateral and distal dose rate distributions and lateral penumbra are obtained with an analytical method for various distances from the ridge filter with shading elements to the iso-center. It is shown that the shorter distance between ridge filter and the iso-center results in the steeper variation of SOBP and the larger lateral penumbra.

The proton beam irradiation with the present partially shaded ridge filter should lower the dose rate in normal tissues when the treatment volume is large and distorted.

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The Project of PTF at Moscow Oncologic Hospital #62.

V. Breev, V.S. Khoroshkov and others, ITEP, Moscow

The preliminary phase (technical and economic substantiation, in Russian terminology) of the PTF project located at the largest Moscow Oncologic Hospital #62 is to be completed in April, 1998 within a frame of Moscow regional oncologic program. The six following institutions are involved in the project, which is being financed by Moscow Local Government: The Institute of Theoretical and Experimental Physics (scientific leader of the project), The Institute of High Energy Physics, Moscow Radiotechnical Institute, Moscow Oncologic Hospital #62, Oncologic Scientific Center, Scientific Research Oncologic Institute (See poster to be presented at XXVII PTCOG for the full list of authors).

PTF includes:
11 Mev linac used both for synchrotron injection and for USLR production,
230 Mev H^- syncrotron, intensity - $5*10^{10}$ p/pulse, repetition rate - 1.5 Hz, flattop - 350 ms,
extraction system - 6 independent recharge targets (1 for stand-by mode with the beam stopper, 3 for procedure rooms, 2 for further PTF enhancement),
4 procedure rooms (2 with horizontal fixed beams, + 2 with gantries),
necessary environment.

PTF features:
external proton beam emittance - 10^{-7} m*rad,
active dose delivery (spot scanning) is used for both horizontal beam and gantries,
classic type (45^0+45^0+90^0 magnets) gantries, weight - under 20 tons, diameter - 7 m,
treatment floor area - 2800 m^2.

At the moment PTF cost estimated at $M 23.3.

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Proton Radiography at PSI[a].

J. De Boer[1], J. Besserer[1], M. Dellert[1], G. Graw[1], M. Moosburger[1], E. Pedroni[2], H. Stauble[2], P. Pemler[3], U. Schneider[3], [1]Sektion Physik, University of Munich, Germany, [2]Paul-Scherrer Institut, Villigen, Switzerland, [3]Stadtspital Triemli, Zurich, Switzerland.

A detector system is under developmentat the PSI gantry which allows to take radiographic pictures by shining protons ($E_{p,max}$ = 270 MeV) rather than X-rays through the patient's body along the z axis. It consists of two position-sensitive scintillating-fiber hodoscopes - one in front of and another behind the patient - followed by a telescope of scintillating tiles to determine the remaining range of the protons. The three detectors record triple coincidences. The sensitive area of the detector measures 220 mm x 32 mm. The patient table is moved in the x direction in discrete steps of 2 - 5 mm, whereas the y direction is scanned by magnetically displacing a 8 mm FWHM pencil beam by a total of ±10 cm in 5 mm steps.

For proton paths moving parallel to a density inhomogeneity multiple Coulomb-scattering processes are responsible for a single trajectory to probe both parts of the sample, leading to an increased straggling in the energy loss, detectable by the remaining-energy detector. So far the detector system was used to generate proton radiographs of plexiglass sheets into which cylindrical holes of varying diameter and depth were drilled parallel to the beam direction. The radiographs show the expected range variations (hole depth) and range stragglings (inhomogeneity parallel to the beam).

These results show that the apparatus is suited to generate proton radiographs serving to check the positioning of the patent, exhibiting density inhomogeneities, and give values for the stopping power integrated along the proton path that are very useful for the patients' proton-treatment planning. The radiation exposure to the patient is at least 10 times less than the one obtained with conventional X-rays.

Future work will involve optimization of system adjustments, hardware, and software to quickly generate pictures usable in routine patient treatment.

[a]Work supported by the Bavarian Minister of Environment.

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Development of the Proton Treatment Planning System.

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As effectively as possible to make use of such a merit of proton beam that the dose distribution is much more localized than X-ray or electron beam, we focus on the treatment planning system which enable to realize three-dimensional or non-coplanar irradiation. The brief description of the features is as follows. (1) Volume rendering technique: 3D figures of the patient's body or the internal organs displayed on a voxel basis. (2) Region growing technique: 3D regions of interest(ROI) can be extracted semi-automatically in a manner that the voxels around the seeds set in the ROI are connected upon criteria step by step. (3) Pencil beam algorithm: 3D dose distribution can be calculated more accurately than conventional methods including some scattering effects by the materials in the beam delivery system. (4) Interactive operations: all the techniques above are realized in an interactive manner and a response can be made in practical processing time.

The system consists of the following processes: confirmation of the image data, registration of the regions of interest(ROI), specification of the irradiative condition, determination of the shapes of bolus and collimators, dose distribution calculation, and display or print of results.

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Detectors for therapeutic proton beam dosimetry.

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Absorbed dose measurements in JINR’s therapeutic proton beams are performed with air- and tissue-equivalent (A-150) ionization chambers. The calibration of these chambers was made against the reference ^{60}Co sources of the Prague Nuclear Physics Institute. The use of different parameters for the proton conversion factor calculation is discussed.

Spatial dose distribution measurements of proton beams are performed with the miniature silicon, diamond and thermoluminescent detectors. The main characteristics of these detectors were investigated. The depth-dose distributions measured with different types of detectors practically coincided for all detectors, the maximal deviation between various detectors at the Bragg peak is less than ±1.5%. Thus, the distortion caused by energy dependence of detector sensitivity is insignificant for our proton beams.

It is found that the accuracy of the JINR phasotron proton beam dosimetry with the parameters recommended in the “Code of Practice for Clinical Dosimetry” is about 3%. This accuracy was confirmed in the international intercomparison dosimetry measurements (NAC, South Africa, 1995) and meets the international requirements for the therapeutic proton beams.

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