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SUBJECT: Physics Report on the 1977 AAPM Meeting Regarding π^- Radiotherapy

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Comments and questions from our colleagues at the 1977 AAPM meeting with regards to our papers on pion dosimetry and pion beam treatment planning were numerous and quite pointed. In some areas we were praised and others criticized, although in general I believe people were impressed with our work. Most criticisms were directed to the lack of physics having been completed at a level to adequately justify our 3-D treatment planning. I believe most were empathetic with the present philosophy of the project which emphasizes the treatment of patients first and the physics understanding second. However, I assured our colleagues that we are working and have plans to work on the physics which allows to adequately plan and know patient doses. I feel that upon our next grant review or site visit these same criticisms will arise and that unless we have more refined physics by then that we could face drastic cuts in the physics budget or cut on the entire grant. In order to accomplish this goal while still retaining a large patient load I believe we should follow some basic guidelines:

1) Acquire sufficient technical help so the physicists can do physics as opposed to doing technician's work which has been a full time job for over the past six months;

2) Have PIPLAN available for patient use as soon as possible for static field treatments;

3) To begin development of the fan tunes and dynamic treatments, but not to begin their use on patients until (a) static treatments are understood in terms of physical dose and biological dose and (b) PIPLAN has proven that it can work for dynamic treatment planning.

Below is a summary of presentations and comments at the meeting which seemed pertinent to the pion project.

I. CT Scanning

A. Mike Goittien in refresher course RCIO emphasized the reproducibility of patient positioning from CT scans. Their solution at Massachusetts General was to make the CT patient table identical to the treatment table. Our system of lightcasting is probably acceptable in accomplishing this.

B. Talk T5 presented data which shows that the skin surface could only be accurately depicted by having a wide window setting on the ACTA scanner. Errors of approximately 1 cm in 15 cm were obtained with the narrow window setting. This may or may not be a problem for the scanners we use but should checked by scanning an appropriate phantom.

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C. Talk N5 presented a quality control preview of CT scanners in the Los Angeles area, which showed one machine not to have a uniform step size. The scanning tables at Massachussetts General have table markers which can verify step size. As a minimum we should incorporate into phantom design a way of measuring step increments.

D. George Chen in T4 presented an algorithm for calculating relative stopping powers from CT numbers. This is the topic of John Hill's thesis and is something directly applicable to bolus design. George discussed a single energy scan method versus a dual energy scan method, and felt that a single scan method would be sufficient for treatment planning. Bone was simulated by K_2PO_4 solution to give an effective Z close to that of compact bone. We should incorporate K_2PO_4 solution into our CT phantom and should adopt the algorithm converting CT numbers to relative stopping powers:

1) Solve for α in, $\mu_x = \alpha\mu_1' + (1-\alpha)\mu_2$, where μ_x = attenuation coefficient of unknown tissue at CT energy

$\mu_x \geq \mu_{H_2O}$ ($\mu_x \leq \mu_{H_2O}$) $\left\{ \begin{array}{l} \mu_1 = \text{attenuation coefficient of } H_2O \text{ (air) at CT energy} \\ \mu_2 = \text{attenuation coefficient of ICRU compact bone } (H_2O) \text{ at CT energy} \end{array} \right.$

2) Using α solve for μ_x', which should be proportional to electron density, $\mu_x = \alpha\mu_1' + (1-\alpha)\mu_2'$, where μ_1', μ_2' are same as μ_1, μ_2 but evaluated at 1MeV.

E. In summary we should develop a CT phantom which serves the following purpose:

1. Check surface deformation vs. window setting.

2. Check spatial calibration by having spaced discontinuities so that calibrati will be independent of resolution.

3. Check step size increments.

4. Check CT #s by having air, water, K_2PO_4, ect inhomogeneities.

II. Patient Immobilization and Localization

A. Compliments were received on the quality of our Lightcasts, and a few people were interested in our immobilization techniques and bolus construction techniques.

B. Mike Goittien at Massachusetts General has done a study indicating that 30% of conventional therapy treatments result in misalignment. They are concentrating on constructing special patient alignment devices to increase their accuracy, especially for proton irradiations. One particular example was a rectal applicator used for reproducing alignment and mucousal sparing in prostarate irradiations. To confirm alignment back projecting X-ray units were used to verify localization.

C. Heavy ion therapy at Berkeley is using in-vivo diode measurements in esophageal irradiations and film stack techniques in order to localize beam penetration.

D. In Conclusion we need to continue improving our immobolization techniques, develop localization techniques which could mean visualization(as X-ray verification will be of reduced use for patients treated with a scanning beam).

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III. Bolus Construction

A. In general we can expect the most problems from our colleagues, and rightfully so, in our use of bolus. Several questions were asked concerning our Rx planning with bolus. Most charged particle groups felt that sharp discontinuities in Rx volume are impossible to precisely correct for due to multiple scattering. This is quite true and we have enough data, which was presented in dosimetry paper, to confirm this; however, we do not have enough data to completely understand the problem. Berkeley feels that their preser level of understanding could lead to improper bolusing and hence under dosing of the parts of the tumor volume. We need to continue our study of bolus affects for simple and complex geometices. This should may even be done in the Rando phantom using in-vivo dosimeters. Ir any case, physics needs to devote more time to physical measurements. Probably most importar is the development of PIPLAN by November for static beam treatments to help design patient bolus and the distributions before treatment. It is probably a very grave mistake to begin dynamic beam patient treatments before understanding the static beams problems. This may take 6 months to a year, however begining dynamic treatment prematurely will only confuse the issue and endanger the primary goal of the project to comprehend the affect of π^- on various tissue.

B. In designing bolus there was concern over changes in internal anatomy with patient breathing. We probably need to take some scans at inspiration and expiration for various tumor sites to get an idea of how much border to put on the tumor wolume, i.e. treatment volume required to cover the tumor volume throughout these two extremes.

C. There was also questions as to whether it is best to fix the bolus to the patient or not because it might change position with breathing which could cause quite a different bolus pattern above places with steep bolus gradients. PIPLAN might shed some light on the matter if it could tell what happens for slight errors in bolus alignment.

D. To verify that our Rx planning is working property we should continually emphasize our work in in-vivo dosimetry and pion visualiztion.

IV. General Re

A. The Vancouver group suggested that maybe only High LET (stop π^-) and total dose are important for biological correlation. It would be interesting to comprehend their reasoning behind this.

B. The heavy ion group is prescribing equivalent dose not physical dose. This emphasizes our present need to make attempts to calculate equivalent dose in order to know how to design range shifter functions.

V. Conculsion

A. In addition to the excellent questions and remarks from our colleagues, many expresed their complements to our efforts and progress we have made recently. I think we must realize ourselves as one of the pioneers of charged particle therapy and must do our best to understand more the physical aspects of the pion beam.

B. To summarize the above remarks I feel certain measurements should be made as soon as possible.

1. Construction of CT phantom to be used for patients having CT measurements made.

2. A treatment plan for the Rando Phantom and verification of total dose and stopping using TLD and Al pellets.

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3. Continued development of in-vivo dosimeters.

4. Continued work on visualization and ways of treatment verification.

5. Immediate work on inhomogeneity studies.

C. In attempt to better correlate RBE vs. LET, we should follow up on our committment as of 9 months ago with the intercompartion of Chain Richman's and J. Dicello's spectra. The radiobiologists should include a statistical analysis of their data in teams of RBE and furnish this to the physicist who could look for correlations.

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