**916** POSTER

### A new treatment modality for the destruction of solid malignant tumours that utilizes alpha-emitting intratumoral radioactive wires

T. Cooks[1], L. Arazi[2], M. Schmidt[2], I. Kelson[2], Y. Keisari[1]. *[1]Tel Aviv University, Human Microbiology, Tel Aviv, Israel; [2]Tel Aviv University, Nuclear Physics, Tel Aviv, Israel*

**Background:** Alpha particle irradiation that can be lethal for cancer cells is currently not used effectively in the treatment of solid tumors. We developed a new approach in which tumors are treated with a new type of intratumoral radioactive source that continually releases short-lived alpha-emitting atoms. These disperse in the tumor and deliver a lethal dose over a region measuring 5−10 millimeters in size. We implement this scheme using 228Th to generate wires bearing 224Ra, which, once inside the tumor, release its progeny by recoil. The proposed method was termed Diffusing Alpha-emitters Radiation Therapy (DART). We studied the effect of DART in models of malignant squamous cell (SQ2) and Lewis lung carcinoma (LL/2) in mice.

**Methods:** Tumor cells were injected subcutaneously to normal Balb/c (SQ2) or C57Bl/6 (LL/2) mice. Tumor bearing mice with 5−10 mm in diameter tumors received a single DART treatment by insertion of a stainless steel radioactive (224Ra) needle (0.3 mm-diameter and 3−5 mm long), having a 224Ra activity in the range of 1.4−81.4 KBq, into the tumor under anesthesia. Animals were monitored for tumor development and for survival.

**Results:** A single treatment with DART sources of 141 Balb/c mice bearing subcutaneous SQ2 tumors resulted in significant tumor growth retardation, which was dose dependent. DART significantly extended the mean survival time of tumor bearing animals from 14.3±2.6 to 25±5.4 days, and two animals were completely cured. Twenty days after DART the average volume of the treated tumors was 80% smaller than the non-treated tumors in SQ2 bearing mice and 60% smaller in LL/2 bearing mice, Dosimetric studies of the alpha emitters' distribution inside SQ2 tumors revealed doses of 10 Gy up to 5 mm away from the source. Measurements of the liver, kidney, spleen and lungs in DART-treated mice bearing tumors showed local 212Pb activities ranging from 0.05% to 2.5% of the total 212Pb activity released from the wire.

**Conclusions:** Our long-term goal is to establish DART as a more efficient, safe, and low cost alternative treatment to external radiation radiotherapy. DART can also be combined with surgery, chemotherapy and immunostimulation in order to provide a longer life expectancy, and improved quality of life, and organ preservation.

**917** POSTER

### Organ at risk atlas-based automatic segmentation for the planning of glioblastoma radiotherapy: validation study for the brainstem

D. Weber[1], N. Boch[1], F. Betting[1], G. Dipasquale[1], J. Delavelle[2], B.M. Dawant[3]. *[1]University Hospital of Geneva, Radio-oncology, Geneva 14, Switzerland; [2]University Hospital of Geneva, Neuro-radiology, Geneva 14, Switzerland; [3]Electrical Engineering and Computer Science, Vanderbilt University, Nasville, USA*

**Background:** Radiation therapy (RT) of high-grade glioma requires high dose delivery. Delineation of the target and non-target volumes are thus of paramount importance. This study aims to evaluate the accuracy of an atlas-based automatic segmentation algorithm in defining the brainstem in a large cohort of glioblastoma (GBM) patients.

**Materials and Methods:** Pre-existing brainstem data of 40 patients with GBM planned for RT were used as the basis in this study. These manually-defined brainstems (MDB) were delineated on the planning CT prior to RT. The brain atlas was generated from a high-resolution diagnostic 16-barett CT dataset. The automatic delineation took the patient images and the atlas images and structures as inputs, and provided the delineation on the patient's image as output. Post-processing image registration was based on level-set segmentation techniques. The volumes of the MDB and automatic-defined brainstem (ADB) were compared.

**Results:** The median volume of the MDB and ADB were 27.0 (range, 19.3−43.3) and 23.7 (range, 9.5−35.1) $cm^3$, respectively. The MDB and ADB inter-variability was overall modest: the composite ASB-MSB volume was 20.0 $cm^3$, but ranged from 8.1 to 29.2 $cm^3$. This range of values is explained by the substantial inter-variability increase with head-flexion: the median composite ASB-MSB volumes were 22.6 (range, 9.5−29.1) and 27.5 (range, 21.0−35.1) for the flexed and non-flexed patients, respectively. Thus, the median and minimum percentage of composite ASB-MSB volume increased substantially from 72.6−41.3% for flexed patients to 75.2−69.5% for non-flexed patients.

**Conclusion:** The results indicate that our atlas-based automatic segmentation algorithm provides accurate and reproducible brainstem segmentation for the RT planning of GBM.

**918** POSTER

### The responses of quiescent cell populations in solid tumors to 290 MeV/u carbon ion beam irradiation in vivo, compared with those of total cell populations

S. Masunaga[1], K. Ando[2], A. Uzawa[2], R. Hirayama[2], Y. Furusawa[2], S. Koike[2], K. Ono[1]. *[1]Research Reactor Institute Kyoto University, Particle Radiation Oncology Research Center, Osaka, Japan; [2]National Institute of Radiological Sciences, Research Center for Charged Particle Therapy, Chiba, Japan*

**Background:** High-linear energy transfer (LET) radiation gives a higher relative biological effectiveness value for cell killing, a reduced oxygen effect, and a reduced dependence on the cell-cycle, making it superior to low-LET radiation in the treatment of cancer. However, almost all these radiobiological characteristics of high-LET charged particle beams were based on the response of total tumor cell populations as a whole using in vitro cell cultures or in vivo solid tumors. Thus, we clarified the radiobiological characteristics of irradiation with 290 MeV/u carbon ions versus gamma-rays based on the responses of quiescent and total tumor cell populations in vivo.

**Materials and Methods:** SCC VII tumor-bearing mice received a continuous administration of 5-bromo-2'-deoxyuridine (BrdU) to label all intratumor proliferating (P) cells. Then, they received 290 MeV/u carbon ions or gamma-rays. Immediately or 12 hours after the irradiation, the tumors were isolated and incubated with a cytokinesis blocker, and the micronucleus (MN) frequency in cells without BrdU labeling (= Q cells) was determined using immunofluorescence staining for BrdU. The MN frequency in the total (= P+Q) tumor cell population was determined using tumors that were not pretreated with BrdU.

**Results:** The difference in radiosensitivity between total and Q cell populations was markedly reduced with carbon ion beams, especially those with a higher linear energy transfer (LET) value, compared with low LET gamma-rays. Potentially lethal damage repair by Q cells was efficiently inhibited with the carbon ion beams, again especially those with a higher LET value, compared with $\gamma$-rays. Carbon ion beam irradiation could efficiently reduce the dependency of radiosensitivity on the heterogeneity in solid tumors.

**Conclusion:** From the viewpoint of controlling solid tumor as a whole, including intratumor Q cells, carbon ion beams, especially with higher LET values, were very useful for suppressing the dependency on the heterogeneity in solid tumors, compared with low LET gamma-rays.

**919** POSTER

### FDG-PET based planning of limited stage small-cell lung cancer changes radiotherapy fields: a planning study

J. van Loon[1], D. De Ruysscher[1], M. Hochstenbag[2], G. Bootsma[3], W. Geraedts[4], C. Pitz[5], J. Simons[6], A. Dekker[7], S. Wanders[7], P. Lambin[7]. *[1]MAASTRO Clinic, Radiation Oncology, Maastricht, The Netherlands; [2]Academical Medical Hospital, Pulmonology, Maastricht, The Netherlands; [3]Atrium medical centre, Pulmonology, Heerlen, The Netherlands; [4]Maasland hospital, Pulmonology, Sittard, The Netherlands; [5]Sint Laurentius Hospital, Pulmonology, Roermond, The Netherlands; [6]Sint Jans Gasthuis, Pulmonology, Weert, The Netherlands; [7]Maastro Clinic, Radiation oncology, Maastricht, The Netherlands*

**Background:** The treatment of patients with limited disease small cell lung cancer (LD-SCLC) consists of concurrent chemo-radiotherapy, at the expense of dose-limiting acute esophagitis and lung damage. A straightforward strategy to reduce toxicity is to diminish the radiation fields. In NSCLC, radiation fields could be safely reduced by selective nodal irradiation, based on CT, and even further based on FDG-PET scans. However, in a phase II study in LD-SCLC, we observed 11% of isolated nodal failures. As literature suggests that also in SCLC, PET scan is more accurate than CT in identifying regional lymph nodes, we hypothesized that in patients with LD-SCLC, there would be less geographical miss by using PET scans compared to CT and hence there would be changes in the radiation exposure of normal tissues.

**Methods:** Twenty-one consecutive patients with LD-SCLC were studied. For each patient, two three-dimensional conformal treatment plans were made where only the pathological lymph nodes were included in the GTV, either based on CT or on FDG-PET scan, both to a dose of 45 Gy in 30 fractions (1.5 Gy BID). From the dose-volume histograms and dose distributions on each plan, the dosimetric factors associated with lung (MLD: Mean Lung Dose; V20) and esophageal toxicity (Dmax: maximal esophageal dose; MED: Mean Esophageal Dose) were analyzed and compared. All values are expressed as mean±SD. Wilcoxon's signed rank test was used to compare differences.

**Results:** Of the 21 patients, 5 (24%) had mediastinal nodal involvement in different areas on PET compared to CT. In three patients, there were

less nodal stations involved on PET vs. CT (stations 10, 5, 7; 4R and 4L, respectively); in two patients, PET identified CT-negative mediastinal stations (station 5 and 7, respectively). PET based planning thus resulted in an increased nodal GTV in 2 patients (9.5%) and a decrease in 3 patients (14.3%). Taken all patients together, however, there were no significant differences in GTV, lung, and esophageal parameters between CT and PET-based plans. For CT vs. PET: V20 25.6±12.4 vs. 25.6±12.3% (p = 1.00); MLD: 13.7±5.6 vs. 13.7±5.6 Gy (p = 0.89); MED: 24.4±8.6 vs. 24.1±8.5 Gy (p = 0.50); Dmax: 45.8±2.9 vs. 45.7±2.9 Gy (p = 0.32). For the three patients in whom the nodal GTV decreased with PET, the V20 decreased from 25.5±4.9 to 22.0±7.1% (p = 0.10); MLD from 13.2±2.5 to 11.6±3.3 Gy (p = 0.10); MED from 25.0±8.5 to 21.0±5.7 Gy (p = 0.10); Dmax from 46.2±0.21 to 45.5±0.71 Gy (p = 0.32).
**Conclusions:** Incorporating 18FDG-PET information in radiotherapy planning in patients with LD-SCLC changed the treatment plan in 24% of patients compared to CT. Both increases and decreases of the GTV were observed, theoretically leading to the avoidance of respectively geographical miss or a decrease of radiation exposure of normal tissues. Based on these findings, a phase II trial, evaluating PET-scan based selective nodal irradiation is ongoing in our department.

**920** POSTER

**Profile of radiotherapy departments contributing to the EORTC Radiation Oncology Group (ROG) in the 21st century**

T. Budiharto[1], E. Musat[2], E. Aird[3], Z. Bernstein[4], P.H. Poortmans[5], C. Hurkmans[6], J.B. Davis[7]. *[1]EORTC Data Center, Radiation Oncology Group, Brussels, Belgium; [2]EORTC Data Center, Medical Affairs Department, Brussels, Belgium; [3]Mount Vernon Hospital, Medical Physics Department, Northwood, United Kingdom; [4]Rambam Medical Center, Oncology Department, Haifa, Israel; [5]Dr. Bernard Verbeeten Instituut, Radiotherapy Department, Tilburg, The Netherlands; [6]Catharina Ziekenhuis, Radiotherapy Department, Eindhoven, The Netherlands; [7]Universitaetsspital, Radiation Oncology Clinic, Zurich, Switzerland*

**Purpose:** Since 1982, the EORTC-ROG has pursued an extensive Quality Assurance (QA) program of all radiotherapy (RT) centers participating in clinical trials. The first step is the evaluation of the departments' human, technical and structural resources and their ability to provide high-tech RT.
**Materials and Methods:** A facility questionnaire (FQ) was initially developed in 1989 and circulated to 50 centers in the early 1990s. From an analysis of these data it was possible to introduce the proposition for a first set of minimum requirements for RT departments' infrastructure and resources. Since then, the FQ was updated and adapted to the latest evolutions of the RT techniques. We report here on the facilities available at 58 centers from 18 countries currently involved in clinical trials of the EORTC-ROG and who completed the updated FQ after December 2005.
**Results:** The centers' equipment and staffing vary widely. Comparisons with data collected previously are shown in the table. Currently, only 9 centers still use a Cobalt unit, all centers perform 3-D Conformal RT and 74% of them can perform IMRT. 88% of the centers have access to a MRI and can plan treatment using image co-registration. 69% can perform image co-registration using PET or PET-CT. All but one center (film) uses portal imaging to verify patient set up. External dosimetry audit was performed in 79% of the centers for electrons and in 90% for photons, but it was recent (<2 years) in only 52% and 55%, respectively.

| | 1990–1992[1] (50 Centers) Mean (range) | 2006–2007 (58 Centers) Mean (range) |
|---|---|---|
| nb. Cancer Pts treated/year | 1452 (300–3600) | 1987 (470–6969) |
| nb. Cancer Pts/Equipment x year | | |
| Simulator | 1192 (300–2341) | 991 (251–2700) |
| Treatment unit | 506 (234–1033) | 520 (69–1675) |
| nb. Cancer Pts/Staff x year | | |
| Radiation Oncologist | 316 (60–1243) | 259 (108–480) |
| Radiation Physicist | 464 (166–1052) | 434 (177–827) |
| Radiation Technologist | 131 (36–420) | 141 (40–1350) |
| % Centers using CT for RT planning | 72% | 100% |
| % Pts with planning CT | 20−25% | 84.2% (range: 30–100) |
| % Centers with In vivo dosimetry | ±30% | 81% |

[1]Bernier et al. IJROBP 1996

**Conclusion:** Between 1990 and 2006, the pre-treatment workload shifted from simulator to CT. The radiation technologist's workload increased, but their work might be facilitated by the use of MLC and computerized set-up. The newest RT techniques are already widely implemented in the clinic. External dosimetry audits should be performed more often. Repeated assessment using the FQ is warranted to document the evolution of the European RT centers.
This work was supported by a grant from the Vlaamse Liga tegen Kanker

**921** POSTER

**Non-respiratory stomach motion in healthy volunteers**

B. Wysocka, J. Moseley, G. Lockwood, G. Wilson, A. Kirilova, M. Haider, C. Menard, K. Brock, J.P. Bissonnette, J. Ringash. *Princess Margaret Hospital, Radiation Oncology, Toronto Ontario, Canada*

**Background and Purpose:** Intrafraction organ motion refers to the change of organ position during radiation therapy (RT) delivery. In the chest and upper abdomen, it is dominated by respiratory displacement. Peristalsis, cardiac motility and variable filling of hollow organs are other physiologic sources of organ motion, but less is known about their influence on planning target volume (PTV). Currently, patients receiving RT for gastric carcinoma or lymphoma are treated 1 hour after a standard meal. The aim of the study is to characterize stomach displacement in the fasting state and during the hour after a standard meal.
**Methods:** Ten consenting healthy volunteers (8 female, 2 male) underwent 2D Fiesta cine MRI studies on 1.5T GE scanner in 30-second voluntary breath hold. At each time point, series were acquired in axial, coronal and two oblique planes. Fasting series (T0) were followed by a standard meal. Scanning was performed at T5, T15, T30, T45 and T60 minutes after the meal. For each series, conversion to a Pinnacle compatible format (ie. time coordinate converted into Z) using RMP Dicom Viewer [Graham Wilson] was followed by contouring of the stomach. Deformable perimetric analysis was conducted on Matlab v 7.1 [The MathWorks, Inc]. Each 2D contour was sampled with 200 evenly spaced points and matching points were found for all contours in the same 30-second acquisition. For each patient, the mean magnitude and standard deviation (SD) of displacement of each point was determined. Maximal, minimal and median values are provided to summarize the population, both in any direction and in 6 cardinal directions.
**Results:** Median displacement (pooled across time) in the right-left (RL), sup-inf (SI) and ant-post (AP) directions was 0.3; 0.8; and 0.3 mm, respectively. The extreme values for deviations in each direction were 4.4; 7.7; and 3.6 mm. The greatest extreme of motion was seen in the SI direction, but differences by direction were typically small. Median standard deviation (SD) is shown in the table for each direction and time point. No statistical difference in the range of the displacement or in variance was found when comparing between fasting and all postprandial phases using the Kruskal-Wallis test.
**Conclusions:** Non-respiratory intrafraction stomach displacement is small with extreme values usually in the range 4−8 mm for the SI direction and rarely exceeding 4 mm for RL and AP. The stability of stomach position does not differ between the fasting and postprandial states when a small, standard meal is taken. Radiotherapy may be delivered at any time within the first hour after eating without significant compromise of planned PTVs.

| Median SD | RL | SI | AP |
|---|---|---|---|
| T0 | 2.6 | 2.7 | 2.8 |
| T5 | 2.2 | 3.3 | 2.2 |
| T15 | 2.9 | 3.5 | 2.9 |
| T30 | 3.2 | 3.3 | 2.7 |
| T45 | 3.1 | 3.6 | 2.7 |
| T60 | 2.5 | 3.5 | 2.1 |
| p-value | 0.09 | 0.55 | 0.71 |

**922** POSTER

**Estimated dosimetric impact of IGRT in liver SBRT with breath-hold**

C.L. Eccles, T.D. Craig, L.A. Dawson. *Princess Margaret Hospital University Health Network, Radiation Medicine Program, Toronto, Canada*

**Background:** Active breathing control (ABC) for liver immobilization and image guided radiation therapy (IGRT) can be used to improve setup accuracy for liver cancer stereotactic body radiation therapy (SBRT). A simple IGRT strategy, using orthogonal imaging with the diaphragm as a surrogate for liver often places the liver within 5 mm of its planned position. Purpose/Objective: Estimate dosimetric impact of IGRT in patients undergoing liver cancer SBRT with ABC.
**Materials and Methods:** 21 patients treated in exhale breath-hold on a 6-fraction SBRT liver protocol were evaluated. All had daily image guidance with orthogonal images and repositioning for offsets >3 mm. The diaphragm was used for cranial-caudal (CC) alignment and vertebral bodies for anterior-posterior (AP) and left-right (LR) alignments. Offsets