

### Image-Guided Adaptive Radiation Therapy: The Wave of the Future

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The Main Objectives are 1) To define and describe image-guided radiation therapy (IGRT) and adaptive radiation therapy (ART), 2) To demonstrate the benefits and need for IGART, 3) To show the trends and future directions of IGART.

Recent technological advances in radiation treatment have been achieved through the evolution of computer technology. Intensity modulated radiation treatment uses sophisticated automated inverse optimization software in treatment planning computers combined with computer-controlled multileaf collimator delivery systems. However, such precise planning and dose delivery would be of limited value if we cannot determine the exact location of the tumor and critical structures. In its narrower definition, image-guided radiation therapy consists of the use of imaging to guide the daily treatments to account for setup uncertainties and anatomical changes. Examples include electronic portal imaging, ultrasound guidance, on-board kV imaging, on board MV CT imaging with tomotherapy or conventional linacs, or kV cone-beam CT on conventional linacs. In a broader sense, image-guidance includes the use of different imaging modalities for determining tumor composition, location, extent, stage in addition to daily image-guidance techniques. Examples include CT, PET, SPECT, MRI, and ultrasound. True adaptive therapy also has a broad and narrow definition. On the one hand, adaptation consists of using imaging to determine the unique pathology and make-up of the tumor so that there will be a patient-specific prescription. It also consists of daily adjustments of treatment setup with the use of an imaging modality in combination with the recalculation and reoptimization of the treatment technique while accounting for the anatomy of the day. Specific examples of image-guidance and adaptive treatments will be described. While image-guided radiation therapy is already in clinical use in various places, routine image-guided *adaptive* radiation treatment is still at an early stage of application.

### The current position of advanced breast ultrasound technology complementary to mammography in diagnostic and screening

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Breast ultrasound is the most frequently used complementary imaging tool in addition to mammography. Especially the

mammographical dense breast tissue (ACR grade 3 and 4) reduces the sensitivity of mammography to 50-60% and is the reason for additional ultrasound in breast cancer screening and diagnostic work up. Three-dimensional (3D) and four-dimensional (4D) mammasonography is the most recent development in breast ultrasound technology providing additional aspects to conventional 2D sonography. 4D ultrasound offers almost real time 3D rendered image information and is taken as a basis of multidimensional imaging of the breast. In the following section volume contrast imaging (VCI), inversion mode rendering, virtual computer-aided lesion analysis (VoCal), tomographic ultrasound imaging (TUI), extended view (XTD View) documentation and real-4D breast biopsy in combination with 3D-targeting technique will be discussed. **Static volume contrast imaging (VCI)** offers to study a static three-dimensional dataset with preselected slice thickness (1-10 mm) at the same time in all three planes with different render algorithms. **Dynamic Volume Contrast Imaging** is a real-time 4D ultrasound technique which offers thick- slice rendering (6-10 mm slice thickness) or thin-slice rendering (2-4 mm slice thickness). The advantage of the VCI technique compared with conventional 2D ultrasound is the contrast enhanced representation of almost isoechogenic lesions compared to the background. Echopoor breast lesions are suitable to be rendered by the **inversion mode** technology. The volume of interest (VOI) has to cover the entire lesion. The inversion mode is a tool which offers a quick access to the three dimensional morphology of the investigated breast mass. The basic principle of **volume calculation VoCal** is to combine geometric surface information with the volume dataset of a lesion. On the condition that the lesion is circumscribed with clear contours, the VoCal software enables automated or manual volume calculation.

**Tomographic ultrasound imaging (TUI)** presents the diagnostic informations of a static 3D dataset in a two-dimensional documentation e.g., thermoprint or laserprint, comparable with CT or MR scans. A topogram tells exactly the spatial position of the slices obtained from the 3D data set and the customized distance between the different slices. **Extended view documentation (XTD View)** is a 2D technique that estimates the probe movement through analysis of subsequent images. Based on the computed movement all images of a sequence can be mapped into a common reference system, thus generating a compound panorama image. **3D-targeting** is a needle position check in all 3 planes. The Voluson technique offers the option to acquire a 3D US volume data set with one and the same transducer without freehand movement of the probe. Conclusion: Advanced 2D, 3D and 4D ultrasound technologies are helpful tools, fit for daily breast cancer screening complementary to mammography and perfectly suitable for the diagnostic assessment of breast lesions.

## **Intraoperative Radiotherapy (IORT) of Breast Cancer**

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**Introduction:** Intraoperative radiation therapy (IORT) delivers a concentrated beam of radiation to tumors while they are exposed during surgery. This technique allows to administer high doses of radiation to tumors, mostly by electrons (IOERT) without exposing the nearby healthy organs to radiation. **Materials & Methods:** In Salzburg, IOERT is used mainly as a boost followed by external beam therapy. A single dose of intraoperative radiation may have the same effect on the tumor as 10 daily radiation treatments. IOERT is performed in a special operation theatre at the department of radiotherapy using a dedicated high-end linear accelerator. Salzburg has outstanding experience in IOERT of breast cancer. Breast conserving operation is exclusively performed by breast surgeons of the University Clinic of Special Gynaecology. IOERT is delivered during the operation as anticipated boost preceding whole breast irradiation after wound healing. With over 1400 patients treated since 1998, we are the worldwide leading institution in Breast-Boost-IORT. Therefore we conducted a pooled analysis among five European institutions that are treating according to the Salzburg Concept. **Results & Discussion:** After five years of median follow up, local tumor control amounts up to 99.1%. IOERT is successfully applied in head & neck cancer, sarcoma and locally recurrent gynaecologic, genito-urinary and gastro-intestinal cancers. Our radiation therapy services (Salzburg Comprehensive Breast Cancer Center) are the only multi-center clinic in Austria being accredited by both the German Krebshilfe as well as by EUSOMA, the European Society of Mastology. To earn accreditation, a center must meet specific requirements involving equipments, quality assurance programs, imaging and treatment records.

## **Pregnancy and Breast cancer**

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Breast cancer remains the most common cancer in pregnant and post partum women occurring in about 1 in 3000 pregnancies. Nulliparity is associated with increased risk and parity reduces the risk although there is evidence that the risk of breast cancer is transiently increased within 3 years of childbirth. Early menarche and late age at first pregnancy increases the risk. Women should be advised to breast feed as this is likely to reduce the risk of

breast cancer. Delay in diagnosis is common due to physiological changes in breast during pregnancy. The overall survival may be worse in pregnancy due to delayed diagnosis. Termination of pregnancy has not shown any beneficial effect on breast cancer. Procedures used in determining the stage of breast cancer should be modified to avoid the risk of radiation exposure to the fetus. Surgery is first line treatment during pregnancy and lactation should be suppressed if surgery is planned chemotherapy should be avoided in first trimester and tamoxifen is contraindicated in pregnancy (category D by FDA classification). Radiation therapy is recommended in the postpartum period. It is recommended that pregnancy should be deferred for at least 2 years after the treatment. Long-term survival after breast cancer does not appear to be affected by pregnancy. Women should not breast feed during the treatment with chemotherapy or radiotherapy. The outcome of pregnancies with breast cancer or soon after breast cancer managed at the Royal Hospital, Muscat will be discussed during presentation.

## **Surgical Management of Retroperitoneal Sarcomas associated with External and Intraoperative Electron beam Radiotherapy**

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Aim is to report outcomes of adults with retroperitoneal sarcoma (RS) treated by surgery, external beam radiotherapy (EBRT) and intraoperative electron beam radiotherapy (IORT). **Methods:** From July 1988 to February 2001 24 patients with primary and recurrent RS were diagnosed and treated. The median dose and energy of IORT delivered was 15Gy/9meV. EBRT dose varied between 45–50Gy. **Results:** There were five primary and 19 recurrent tumors. One primary and five recurrent tumors underwent R0 resection. There were 12 liposarcomas and 19 grade I tumors thirteen patients developed local recurrence and three developed distant metastases.

Twenty-two patients received IORT associated with EBRT eleven patients developed recurrence. Six patients had Neurotoxicity (4 grade II and 2 grade III). Disease free survival and overall survival at 5 years was 28 and 56% respectively. **Conclusions:** EBRT with IORT treatment is a promising technique for local control. Lower recurrence rates are associated with radical (R0) surgical procedures.

## Re-irradiation following Radical Radiation Treatment: Patterns of Practice Among Canadian Radiation Oncologists

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**Introduction:** Cancer recurrence in previously irradiated volumes presents a challenge. Many radiation oncologists approach this issue differently. The objective of this study was to survey the patterns of practice of re-irradiation (re-RT) among Canadian Radiation oncologists (CRO). **Methodology:** An electronic survey was sent out to 271 CRO identified via the CARO directory. A total of 183 responded (67.5%). The survey consisted of case scenarios from the six most common sites where in field recurrence commonly occurs. The results were analyzed using SAS 9.1.3 software. **Results:** Majority of CRO were involved in the practice of breast or genitourinary sites (47.5% and 42% respectively). Forty nine percent of CRO expressed interest in re-RT for infield recurrence. Treatment intent varied from curative intent (32%), local control (80%), quality of life improvement (99%), or inclusion as part of clinical trial (38%). The minimum KPS and life expectancy to consider curative intent therapy for most CRO was 50% and three months respectively. The results also looked at CRO demographics, referral patterns, eligibility and exclusion criteria for re-RT, treatment planning, follow-up, and patterns of practice based on site specific clinical scenarios. **Conclusions:** There was growing interest among CRO in re-irradiation of infield recurrence. A wide variation existed between the CROs, but a trend towards usage of newer technologies was noted with the aim of better conformity and better normal tissue avoidance. Despite this trend there was still lack of consensus for optimum treatment. This lack of consensus is fueled by the lack of evidence in clinical merits of re-RT. We hope that this will spark nation wide studies and collaboration in order to formulate evidence based patterns of practice for re-RT.

## Gastric cancer risk predisposition and prognostic significance of vascular, endothelial growth factor (VEGF) gene polymorphisms in an Omani population

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**Background:** Gastric cancer (GC) in Oman presents in advanced stages that result in overall poor treatment outcome. Moreover, we have shown that p53 immunohistochemistry predicts survival compared to p21, p27 and Her-2/neu in Omani GC patients. It is now recognized that VEGF gene polymorphisms at various loci and gastric cancer (GC) risk pre-disposition and their prognostic significance were studied previously with controversial results. **Methods:** Analysis of 3 VEGF polymorphisms ( +405 G/C, -460 T/C, and +936 C/T ) was done by extraction of genomic DNA from peripheral blood of 130 GC patients and 130 control subjects followed by VEGF genotyping using PCR-RFLP analysis and the determination of the polymorphisms GC risk pre-disposition and their prognostic significance. **Results:** There was no significant association between the VEGF polymorphisms and gastric cancer risk. There was a significant correlation between +405 C/C genotype and poor tumor differentiation (p=0.007) and lymph node metastasis (p=0.03) and 460 T/T genotype and poor differentiation (p=0.03) with statistical trend for lymph node involvement (p=0.05). VEGF gene polymorphisms had no significant effect on survival, but VEGF +405G/G genotype had lower survival with hazard ratio 1.6 [95% CI, 0.9-2.9] compared to VEGF +405 CC/GC combined genotype (p=0.04). Multivariate analysis showed that disease stage at diagnosis, and +405G/G genotype was independent variables of adverse prognostic significance. There were no associations between the common six haplotypes identified and GC risk predisposition and survival. **Conclusions:** The current study suggests that VEGF polymorphisms in GC patients may have predictive and prognostic significance.

## Tailoring Treatment for Hodgkin's Lymphoma

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Hodgkin's Lymphoma (HL) is one of the frequently curable neoplasms in adults. Between 60-90% of the patients are considered cured with the modern day chemotherapy regimens. With a high degree of success, comes the inevitable need to strike a balance between reducing the long-term toxicity without compromising the efficacy, and to further enhance the chances of cure in the 10-40% of the cases who would ultimately die of their disease, despite the combination chemotherapy regimens. Hence it would be prudent to think of HL as a spectrum of disease, which extends between good-risk disease requiring minimal treatment and poor-risk disease, where attempts should be made to enhance

the chance of response and durable remissions. It is logical to think of HL as nodular Lymphocyte Predominant Hodgkin's Lymphoma (nLPHL) and classical Hodgkin's Lymphoma (cHL). Furthermore, both histological sub-types should be considered as either early stage or advanced stage. There are different definitions of early stage and include stages IA & B, and stage IIA non-bulky disease. Some others include stage II B, and even stage IIIA non-bulky disease, while yet others include bulky disease as well. Early stage disease should be further classified as favorable and unfavorable groups. For early stage favorable disease currently 2 cycles of ABVD followed by involved-field radiotherapy or 4 cycles of ABVD chemotherapy are considered standard-of-care. For early stage unfavorable disease, either 4 cycles of ABVD followed by IFRT or 6 cycles of ABVD are considered standard of care. IFRT should be added to standard chemotherapy in case of either bulky disease, or PET-positive small volume residual disease. Advanced stage HL should be further staged using the clinical characteristics of the disease by International Prognostic Factor Project (IPFP), which includes, age more than 45 years, stage IV disease, male gender, low Hb, high WBC, low lymphocyte count and low albumin, as adverse prognostic factors. Patient presenting with up to 3 adverse prognostic factors could be treated with ABVD followed by IFRT in selected cases. However, patients presenting with 4 or more prognostic factors should be considered to be treated with more intense combinations such as, BEACOPP or escalated BEACOPP regimens. More recently PET scans performed after 1-3 cycles of chemotherapy have shown to have important prognostic value, with a negative predictive value (NPV) of as high as 98%. However, with a positive scan, there are no data yet to support that a change in treatment plan is likely to increase the chances of cure. Patients with stage I nLPHL require treatment with only radiotherapy for curative purposes, whereas, patients with more advanced stage disease need combination chemotherapy. More recently, anti-CD20 antibody, Rituximab is also being added to the combination regimen. With the above stated measures, it is possible to identify groups of patients requiring less treatment without compromising the efficacy, or more treatment with a hope of increasing chances of long-term remission. There is a further need to characterize the individual's disease even better by either molecular or genetic markers. Furthermore, there is a continuing need to enhance the efficacy of the current treatment regimens, especially using the targeted therapy.

The presence of leukemia-associated phenotypes is independent predictor of induction failure in acute myeloid leukemia

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Immunophenotyping of acute myeloid leukaemia (AML) has controversial implications with regards to prognosis. The aims of the present study were to determine the frequency of leukaemia-associated phenotypes (LAP) in AML and to correlate their presence with response to induction chemotherapy. We analyzed bone marrow samples at diagnosis from 84 AML patients using triple staining flow cytometry with routine standard panel of monoclonal antibodies. The association of LAP and response to induction chemotherapy was evaluated retrospectively. LAP were observed in 54 (64%) patients lineage infidelity in 19 (35%), asynchronous antigen expression in 28 (52%), and lack of expected lineage specific antigens in 19 (35%). Significant correlation was found between LAP and responses to induction chemotherapy. Response to induction chemotherapy was more frequent in the absence of LAP ( $p < 0.05$ , estimated risk ratio of 1.6, 95% CI, 1.0- 2.6) in a multi-variate analysis. These findings would favour leukaemia associated phenotypes being reflective of the malignant transformation of the leukaemic cells as opposed to them being epiphenomenon related to the dysregulated cell machinery. Furthermore, we showed that LAP is independent of the cytogenetic subtype. This is not surprising because the LAP is more a functional read-out of the transformation process, subject to both oncogenic as well as epigenic events. In conclusion, our data shows that the presence of LAP in AML is an independent predictor for response to induction chemotherapy and risk of relapse and should be considered for counseling patients and planning therapy.

### **Perspectives from RapidArc™, intensity modulation with volumetric arcs**

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**Purpose:** The presentation will focus on the background of Intensity modulation volumetric arc therapy RapidArc™ from Varian Medical Systems aiming to highlight the technical and clinical rationale of fast delivery with a minimum number of arcs and a minimum number of monitor units. **Material and Methods:** A brief description of a modern technique, RapidArc in its implementation at planning and delivery level show the areas of potential advantage and the quantitative expected benefit of volumetric modulated arcs. Applications of this treatment in cervix uteri, head and neck, brain, paediatric, para-spinal cases will be highlighted. RapidArc optimises dose distribution from dose-volume objectives with inverse planning methods achieving a maximal degree of modulation by letting MLC shapes, dose rate and gantry speed be continuously variable during delivery. **Results:** Volumetric intensity modulated arc therapy with RapidArc achieves some results of clinical value:

fast delivery impacts on clinical throughput, patient comfort and treatment reproducibility. Low number of monitor unit impacts on the risk of toxicity and secondary cancer induction from undue irradiation of healthy tissues. In total higher degree of conformal avoidance can be proved for most of the clinical indications. In general, the same degree of conformality and target coverage can be achieved with RapidArc while, depending on the treatment site, significant sparing of organs at risk have been observed ranging from few percent to more than 50% improvement. The peripheral dose delivery can be improved to up a factor 2. Usage of multiple arc is necessary, to overcome mechanical limits, for very long treatments (e.g. paediatric medulloblastoma) while it does not seem to improve results in other cases as will be shown for head and neck and anal canal cases. Preliminary data from the first group of patients treated in few European clinics will be reported to quantify the various aspects discussed. Treatment time resulted to be of the order of ~70-90 seconds for 2Gy fractions in all treated patients letting space for accurate imaging processes of patient's positioning. Results from pre-treatment quality assurance procedures will also be summarised to show reliability of delivery and accuracy of calculations. With standard acceptance criteria (DTA=3mm, DDose=3%) all clinics achieved high quality standards with more than 95% of agreement between calculations and measurements. **Conclusions:** It is expected that in the short term future, volumetric modulated arc techniques will be widely adopted in the clinics and progressively replace conventional IMRT with fixed gantry beams due to their high potentials. It will be necessary to establish careful investigations to assess the better delivery methods (single vs. multiple arcs, coplanar vs. non coplanar delivery, single vs. multiple isocentres) in order to properly tailor these innovative treatments to the various clinical indications. Clinical experience is needed to assess the benefit in treatment outcome while it is already evident, from first experience, the benefit in terms of logistics and patients comfort.

### **Frameless SRS and SRT with ExacTrac X-ray 6D**

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The safety margins used to define the Planning Target Volume (PTV) should reflect the accuracy of the target localization during treatment that comprises both the inter- and intra-fraction motion of the target. A reduction of this margin implies a reduction of the setup margin and/or the internal margin. Daily Image Guided Radiation Therapy (IGRT) is introduced in the patient setup

to optimize the reproducibility of the daily patient setup and minimize the interfraction motion. Daily patient positioning and target localization is in our department performed by ExacTrac 5.0/ Novalis Body<sup>®</sup> (ET/NB) (BrainLAB AG, Feldkirchen, Germany) in combination with the Robotic Tilt Module<sup>™</sup> mounted underneath the Exact Couch<sup>®</sup> top. The patient positioning is based on Infra-Red (IR) reflecting marker detection by ExacTrac<sup>®</sup>. This allows on-line computer-assisted 6D control of the treatment couch from outside the treatment room. 48 patients are treated with frameless cranial Stereotactic RadioTherapy (SRT) on the Novalis<sup>®</sup> System (BrainLAB AG, Feldkirchen, Germany). The maximum 3D vector of the setup was 9.13mm (RMS 2.67mm) while rotations up to 5.95° of the patient inside the mask system have been observed. The intra-fraction motion evaluation indicated mean shifts of -0.14mm (SD 0.66mm); 0.19mm (SD 0.74mm) and -0.13mm (SD 0.41mm) for the lateral, longitudinal and vertical direction respectively. The rotations had a mean value of -0.13° (SD 0.45°); -0.02° (SD 0.34°) and 0.05° (SD 0.41°) for the rotations around the lateral, longitudinal and vertical axis respectively. The 3D vector of the intra-fraction motion had a maximum value of 3.62mm (RMS 1.11mm) and intra-fraction rotations up to 2.56° were detected. The shifts and rotations detected during setup indicate movement possibility of the patient inside the mask, but the high immobilization capability of the mask system and the highly accurate 6D setup correction allow the application of frameless image guided SRS as alternative for invasive frame based SRS. Patients referred for gated SBRT have a fiducial marker implanted as surrogate for the target during IGRT. Selected patients received a hypofractionation schedule of 4x15Gy or 3x20Gy for lung treatments and 3x15Gy for liver treatments. Video-glasses are used for visual feedback to guide the voluntary breath-hold with audio-coaching with video-glasses. 25 patients have been treated with the system: 9 patients were treated in free-breathing, 7 had assistance of visual feedback to perform voluntary breath-hold and the last 9 patients were coached through the audio-part of the video-glasses to assist them in performing a breath-hold close to the reference level. The introduction of the video-glasses showed a reduction of the average delivery time to 1.4min/100MU (SD 0.4min/100MU). The treatments with audio-coaching indicate a significant reduction ( $p=0.004$ ) of the delivery time to an average value of 0.9min/100MU (SD 0.2min/100MU). As the breathing of a patient will never be predictable, it is not possible to accurately predict the time for a gated treatment delivery. But the gated irradiations showed promising results. The system showed a stable performance and is found clinically applicable.

## Quality Assurance and dose verification paths in the delivery of Intensity Modulated Radiation Therapy fields

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**Introduction:** Intensity Modulation Radiation Therapy has become a common practice in many of the centres around the world. The beam modulation starting with simple usage of compensators in multiple static fields has evolved today with continuous dynamic modulation in the arc therapy. These new technology advancements introduced complexity in the quality assurance and the dose verification process of the treatment delivery units. Edinburgh Cancer Center started clinical delivery of modulated photon beams using dynamic MLC for prostate malignancies in May 2006 and today extending this technique to other sites. Though the beam modulation technology has evolved robustly, there is a need to perform regular quality assurance on the usage of these techniques using standard procedures. Also, importantly unlike conformal conventional techniques, it is a common practice to confirm individual patient's beam delivery accuracy due to the involved complexity. As every radiation therapy centre, Edinburgh Cancer centre has a quality assurance policy for all the treatment units on their characteristic performance. With dynamic MLC based IMRT, the dose delivery as well as the spatial accuracy of the MLCs are very important during the treatment delivery. **Materials & Methods:** The dose delivery accuracy is confirmed with standard sweeping fields with varying sweep gaps over 10 cm<sup>2</sup> area and the spatial accuracy is confirmed with the 'garden fencing' method on regular intervals. In addition one of the clinical IMRT field is kept as a reference field and is checked regularly for long-term performance confirmation. The dose delivery verifications for individual patients are performed using single point measurements in a water equivalent phantom at dmax and 5.0cms depth. The measured values are compared against the treatment planning system calculated values and in-house developed independent MU check algorithm. The planar dosimetry is performed using commercial diode based 2-d array system, Mapcheck (Sun Nuclear corp., U.S.A) at 5.0cms water equivalent depth for all the individual fields and compared against the dose matrix from the treatment planning system. Also, for more detailed planar study on selective patients, film dosimetry using EDR 2 radiographic film and the analysis software 'RIT' (Radiological Imaging Technology, U.S.A) is used commonly, which will be eventually replaced with the computed radiography (CR) based dosimetry. **Results:** The details of the dynamic MLC based quality assurance procedures, the dose verification methods and their tolerance levels will be discussed.

## Improvements in Radiation Oncology: from conventional 2D to 3D and the present status

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The clinical delivery of radiotherapy started in 1920s treating single field by cumbersome low-energy machines till 1950s. The megavoltage cobalt and linear accelerator machines greatly improved the radiotherapy dose delivery. Two-dimensional (2D) tumor coverage of most tumors of the human body could be successfully achieved by high-energy radiation beams with 2 or more fields. The 2-D parallel opposed fields for head and neck or four-field box for pelvis or thorax regions could deliver the desired dose to the tumor but surrounding non-tumor tissues and organs got substantial radiation dose. In the 1980s, the application of computer-graphics technology to CT scanning permitted the three-dimensional (3D) display of anatomical informations, delineating the normal tissues and organs-at-risk (OAR) and this enhanced the possibility of delivering higher dose to tumor. Blocking the OARs diminished both acute and radiation morbidities resulting in better loco-region control and reduced radiation effects on normal tissues. Intensity modulated radiation therapy (IMRT), as the name implies, allows to modulate the radiation beams and dose fluence, which can thus deliver differing dose levels within the anatomic region of interest. Sophisticated immobilization and blocking devices are utilized for delivering IMRT (typical duration of 15-30 minutes). The head and neck is an ideal site for IMRT due to the complex anatomy of this region and the severity of radiation associated toxicity. Salivary gland, optic area and inner ear can be protected within a few millimeters. Compared to 3D-CRT, improvements in dose distribution by IMRT are easily shown for several site-specific tumors; eg. brain, orbit, lung, esophagus, mediastinum, spine, retroperitoneum, upper abdomen, prostate, rectum and cervix.

The challenge of more accurate delivery of radiotherapy encouraged the need for improvement in image-guided strategies. Frequent imaging in the treatment room during a course of radiation therapy, with decisions made on the basis of imaging, is referred to as image-guided radiation therapy (IGRT). MVCT scans can acquire images online and the fourth dimension in this setting refers to the impact of time on the position and/or shape of the target volume. Hence, IGRT by its ability to overcome the voluntary patient positioning error or involuntary organ motion change on a real time basis is called the 4D radiotherapy. Currently cancers of head and neck, lung, esophagus, and prostate are considered as suitable indications for IGRT, when curative

approach is the goal. Biological imaging can show the functional aspect of tumor more precisely. Two imaging modalities have emerged viz. positron-emission tomography (PET) and magnetic resonance spectroscopy (MRS). PET imaging combined with CT scan is able to show highly active neoplasms (like lung carcinoma, lymphomas) more precisely. The PET-CT fusions of images are now used, in a limited manner, to design the target volume for radiotherapy delivery.

### Modern Radiotherapy Treatment Verification in CLINAC – DHX Linear accelerator with ion chamber array detectors

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**Introduction:** Radiotherapy demands stringent quality assurance and accurate dose determination for delivery of highly conformal dose to patients. The increased complexity of clinical treatments raises the need for more accurate dose verification systems and procedures. Generally 3D dose distributions obtained from a treatment planning system have to be verified by dosimetric methods. **Materials and methods:** A linear accelerator Clinac DHX, supplied by Varian Medical Systems, Inc., Palo Alto, CA, equipped with a 120-leaf MLC Millennium, 6 and 18 MV photons and five different electron energies (6, 9, 12, 16 & 20 MeV) was installed at our centre in December 2006. Initially we have carried out 3D-CRT and subsequently in June 2007 we started treating with dynamic IMRT. Virtual simulation and the 3D treatment - planning are carried out with Eclipse, and the inverse-planning system is by Helios. All these systems were interfaced with ARIA networking system. The I'matriXX ionization chamber array consists of 1020 single air-vented plane-parallel plate ion chambers arranged in 32 x 32 matrix. The each chamber consists of 4.5 mm diameter, 5 mm height and 0.08 cc of sensitive volume. The absolute dose was estimated using array detectors. To check the final dose delivered during IMRT planning fluence patterns such as field-in-field, pyramidal and chair tests were generated with the treatment planning system (TPS) and the same was executed in the accelerator and measured with the I'matriXX device. The matrix device can also be used to verify the flatness, symmetry, and penumbra and field width of photon and electron beams as routine QA procedure. **Results and Conclusion:** The absolute dose measured using I'matriXX device using  $K_{user}$  factor was found to be within 1%. The reproducibility of measurements was within 0.2%. The ion chamber array system was found to be linear in the dose range of 2- 500 cGy and the response of the detector

was found to be independent of dose rate between 100 MU / min to 600 MU / min. The estimated relative output factor with I'matriXX was found to match very well with the ion chamber measurements. The 2D intensity map at different depths ( $d_{max}$ , 10 cm and 20 cm) for physical and enhanced dynamic wedges were in good agreement for 15° 30° 45° and 60° wedge angles ( $\gamma \leq 1$ : 98%, criteria 3%, 3mm). The fluence pattern measured by the matrix device for field-in-field, pyramidal and chair test was found to be in good agreement with the calculated fluence by TPS both for 6 and 18 MV photons ( $\gamma \leq 1$ : 96%, criteria 3%, 3mm). The measurements and evaluation proves that I'matriXX can be used for quantifying absolute dose. Moreover, using I'matriXX as absolute dosimeter in IMRT field verification avoids the time-consuming procedure of making ionimetric measurement for absolute dose estimation and film for fluence verification. The I'matriXX can also be used for routine quality assurance checks like flatness, symmetry, field width and penumbra of the linear accelerator beam.

### Total Skin Electron Therapy (TSET) With And Without Beam Modifiers

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**Introduction:** The short range of low energy electrons from 2 to 9 MeV has made them useful for the treatment of superficial lesions covering large areas of the body, such as mycosis fungoides and other cutaneous lymphomas. At these electron energies, the beam penetration falls off rapidly beyond a shallow depth. Thus superficial lesions can be treated up to few millimeters without exceeding the tolerance of the bone marrow. **Materials & Methods:** The purpose of this study was to evaluate the effect of the beam modifiers on the characteristics of the Varian 2100C 6 MeV beam using high dose rate total skin electron mode (HDTSe). The technique developed in the study was a modified Stanford Technique. In this technique, the patient is treated with dual six fields using + 17.5° angle above and below the horizontal line at 350 cm SSD. The patient is rotated every 60° intervals so that the whole skin surface is covered with the beam. The scattering filter used in the study was two strips of non-exposed developed radiographic films. The filter was mounted on the HDTSe applicator. Cable irradiation effect was investigated. The cable effect was reduced by shielding the cable with a steel pipe of 1 cm thickness, and by using the two voltage technique. Absolute dosimetry was carried out with a new definition of B factor in this study.

**Results:** The dose uniformity within a rectangle of 160 cm x 60 cm using beam modifier was found to be  $\pm 3\%$  along the vertical direction and  $\pm 4\%$  along the horizontal direction compared to

$\pm 5\%$  along the vertical and  $\pm 4.2\%$  along the horizontal without beam modifier. The x-ray contamination from the six dual fields beyond 30 mm depth was increased from 1.0% without beam modifier to 1.5% of the maximum dose with beam modifier. The extracameral signal produced from cable irradiation was reduced from 2.4% to 0.5% by shielding the cable. **Conclusion:** The dual six fields technique with scattering filter investigated in this study has improved the desired beam characteristics required in the treatment of mycosis fungoides. The x-ray contamination was increased by the scattering filter to 1.5% of the dose which is within the recommendations of the AAPM report (23).

### Emerging Technologies in Radiation Oncology

**Rolf Staehelin**, Varian Medical Systems International AG, Zug, Switzerland.

Radiation Oncology has undergone dramatic technological changes through the last decade. Intensity Modulated Radiation Therapy (IMRT) and Image Guided Radio Therapy (IGRT) with advanced KV imaging tools has become mainstream, state-of-the-art radiation therapy practice. Within a very short time frame IGRT has been adopted by RT professionals and successfully introduced at many cancer centers around the globe. This trend is reflected by a huge demand in efficient and easy-to-use tools for IGRT. Today Varian Medical Systems has shipped more than 1000 On-Board Imager® systems, empowering clinicians with Dynamic Targeting™ tools for more accurate and better patient care.

However, the trend towards more accurate and faster tools to treat many different indications continues. This talk will therefore give an overview on the actual state-of-the-art tools and focus on new promising capabilities and tools, which – while still in an early stage – have already been widely accepted and introduced in the radiation oncology community. **RapidArc™** represents a revolutionary breakthrough in cancer treatment that radically reduces treatment time. It offers all the benefits of IMRT in dramatically shorter treatment times. Clinicians now deliver continuously modulated dose to the entire tumor volume while sparing normal, healthy tissue with a single rotation of the linear accelerator gantry. RapidArc treatment exploits many of the unique characteristics of the Varian Clinac®, Millennium™ MLC and the On-Board Imager. **Novalis Tx®** (picture 1) is a new tool dedicated to neurological and stereotactical applications. Its unmatched beam shaping capabilities utilizing a high-definition HD120™ MLC, versatile imaging tools consisting of the On-Board Imager and ExacTrac® X-ray, combined with a robotic couch for patient positioning and correction in 6D provide the basis for more specialized and unique treatments and SBRT applications.

### Dosimetric characteristics of Enhanced Dynamic Wedge

**S. Sowmya Narayanan**, Kavi Arasu and Geeta S. Narayanan  
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**Introduction:** Beam modification is an essential component in Radiotherapy to achieve uniform dose conformity in the target volume. In static conformal treatments, physical wedges are being used for this purpose. Use of these wedges has limitations owing to the fixed wedge angles and the beam attenuation from wedge material. Enhanced Dynamic Wedge (EDW) overcomes these limitations. Using EDW, the wedge dose profile is created by the sweeping action of the collimator (one of the Y jaws) from open to closed position while the beam is on. The possible wedge angles with EDW are: 10, 15, 20, 25, 30, 45 and 60 degrees for a maximum field size of 30 (-20,10) cm wide. Owing to jaw movements during treatment to get the desired wedge effect, it is essential to have quality assurance program, similar to any other dynamic treatments, which would satisfy the clinical implementation of EDW. **Materials & Methods:** We, at our Institute, have a multi modality modern linear accelerator, which is capable of delivering treatments with EDW. The dosimetric characteristics of EDW were performed using amorphous silicon EPID (aS1000) for profiles and 0.6cc ion chamber for wedge factor. The evaluation of the curves generated by EPID was done through Portal Dosimetry Review workspace under ARIA work environment<sup>®</sup>. Phantom verification of treatment plans for physical wedge and the corresponding EDW were carried out in Eclipse Treatment planning system (Varian Medical Systems, Inc. Palo Alto, CA). **Results:** The comparison of corresponding profiles between physical and EDW shows good agreement on the slope of the curve. The wedge factor generated using EDW for various wedge angles were found to be correlating with the reference value. The treatment plan verification using phantom were in good agreement for the profiles and the MU value was reduced upto 20-25% (mean) for EDW depending on the wedge angle and field size, as compared to the use of physical wedge for the same plan. This reduction in MU for EDW considerably reduces the whole body patient dose arising out of leakage through linac head. The treatment delivery through EDW is monitored by Segmented Treatment Table (STT) generated by Linac Computer. **Conclusion:** Treatment with EDW produces wedge-shaped dose distributions using computer-controlled dose delivery combined with upper jaw motion. Delivery of such high-end treatment requires validation of various relevant dosimetric parameters. EDW reduces the patient dose outside the treatment field during radiotherapy.

## **LINAC Plus mMLC based Stereotactic Radiotherapy - Initial Experience at National Oncology Center, Muscat**

*Namrata Satyapal, S.S.Sivakumar, S.Kannandhasan, Kamal El Ghamrawy, Department Of Radiation Oncology, National Oncology Center, Royal Hospital, Muscat, Oman.*

**Objective:** is to share our experience in establishing Stereotactic Radiotherapy facility at the National Oncology Center, Oman. The National Oncology Center (NOC) at Royal Hospital was inaugurated in December 2004. In December 2007 we treated our first case of stereotactic radiosurgery. To reach this goal several steps were initialized and achieved: preparation of technical specifications, processing the necessary hard and soft ware, development of quality assurance and clinical protocols, technical and clinical training, auditing of entire protocols by international professionals. The Stereotactic facility at NOC is Linac (6MV) based with M3-micromultileaf collimator from Brain lab with all associated accessories and Localizer devices. Dose computation is carried using I-Plan 3D workstation. We will be presenting the summary of the entire procedure as well as few clinical cases that have been treated so far.

## **Image Based HDR Brachytherapy – ICRU Recommendations**

*Salim Shaib Rassou, Department of Radiation Oncology, Tawam Hospital, Al-Ain, United Arab Emirates.*

The current clinical practice for cervical cancer intracavitary brachytherapy in most centers is to prescribe the dose to point A. However, this is an empirical point and does not necessarily reflect dose to the tumor. Although 3-dimensional image-based treatment planning is extensively used in prostate brachytherapy, only a few institutions have used it to shape the dose distribution in cervical brachytherapy. The European Gynaecological GEC-ESTRO Working Group have since 2005 proposed nomenclature for volume definition and recommendations for image-based intracavitary brachytherapy for cervical cancer, followed later on by the American Image-guided Brachytherapy Working Group. ICRU has recommended determining the tissue volume encompassed by the 60 Gy reference isodose surface (reference volume), however this recommendation is not enough. The main goal of Three-dimensional treatment planning is to allow and tailor the spatial dose distribution to the shape of the pre defined volume and reduce the rate of late complication by reducing the dose to normal tissues. Magnetic resonance imaging (MRI) provides superior soft-tissue resolution and is the best imaging modality for

depicting cervical tumour size and extent compared to computed tomography (CT) scans. MRI should be performed with image-compatible brachytherapy applicators in place for visualization of structures for proper delineation. Unfortunately, because these applicators are expensive and cumbersome, their use is limited to a few institutions. Because the tumor volume changes dramatically during the course of therapy, imaging should be performed before the start of external-beam radiation therapy (EBRT) and at each insertion with the image-compatible brachytherapy applicator in place. A 'high risk' CTV (HR CTV) carries a major risk of local recurrence because of residual macroscopic disease. The intent is to deliver a total dose as high as possible and appropriate to eradicate all residual macroscopic tumor. An 'intermediate risk' CTV (IR CTV) carries a major risk of local recurrence in areas that correspond to initial macroscopic extent of disease and residual microscopic disease at the time of brachytherapy. The intent is to deliver a total radiation dose appropriate to cure significant microscopic disease in cervix cancer, which corresponds to a dose of at least 60 Gy. For Organs at Risk (OAR) (bladder, rectum, and sigmoid) the minimum dose in the most irradiated tissue volume recommended for reporting is 0.1, 1, and 2 cm<sup>3</sup>; optional 5 and 10 cm<sup>3</sup>. The presentation will focus and detail all new aspects of modern 3D brachytherapy.

## **PET/CT imaging for Planning Radiotherapy in Head and Neck Cancers**

*Tejinder Kataria, Manoj Tayal, Janardhan N, Surya Potharaju, Department of Radiation Oncology, Artemis Health Institute, New Delhi, India.*

PET/CT scanning is one of the most powerful diagnostic tools available today enabling the determination of the precise location of a tumor. FDG-PET alone can provide up to 90% sensitivity and specificity in staging neck nodes<sup>1</sup> [1]. <sup>18</sup>F-FDG-PET has a major impact on the management of patients for radiotherapy, influencing both the staging and the management in 27% of patients<sup>2</sup> [2]. **Materials & Methods:** Eight head & neck cancer (HNC) patients including four with carcinoma larynx, three with carcinoma oropharynx, and one with carcinoma paranasal sinuses were custom fitted with head and neck immobilization devices. CT simulation was performed together with <sup>18</sup>F-FDG PET imaging. Gross target volume (GTV) and pathologic nodal volumes were first defined in the conventional manner based on CT. A coregistered <sup>18</sup>F-FDG PET and CT planning image dataset was then used for the contouring. <sup>18</sup>F-FDG PET GTVs were determined and displayed simultaneously with the CT contours. CT GTVs were then modified based on the PET data to form

final PET/CT treatment volumes. Intensity-modulated radiation therapy (IMRT) was used for dose planning to the CT GTV or the PET/CT GTV. Results: Three patients with laryngeal carcinoma had no change in the tumor volumes as they were PET-negative after microlaryngeal surgery, while in one patient there was FDG uptake in the anterior commissure with no visible lesion in the CT-scan and hence his target volumes were modified to include the cervical lymph nodes. The CT GTV was modified in all the three patients with oropharyngeal cancers based on  $^{18}\text{F}$ -FDG PET data; the resulting PET/CT GTV was larger than the original CT volume. In two cases of oropharyngeal cancer the pathologically enlarged CT lymph nodes were modified to create final lymph node volumes. In one of eight patients,  $^{18}\text{F}$ -FDG-avid lymph node was identified in the retropharyngeal region which was not identified as pathologic on CT. One patient with paranasal sinus tumor had complete excision and there was no PET avid disease and hence CTV was drawn with more confidence. Radiotherapy planning using IMRT demonstrated the capability of this technique to target anatomic or anatomic/physiologic target volumes. In this manner, metabolically active sites could be intensified to greater daily doses. Conclusion: Inclusion of  $^{18}\text{F}$ -FDG PET data resulted in modified target volumes in radiotherapy planning for HNC. PET and CT data acquired on dual-acquisition PET/CT systems reduces the need for re-registrations. It is possible to use IMRT to target dose to metabolically active sites based on co registered PET/CT data.

### Total Body Irradiation (TBI) with 6MV photons-Implementation procedures

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**Introduction:** Total body irradiation (TBI) with 6 MV x-rays from linear accelerators has been used in conjunction with high dose cytotoxic drugs and bone marrow transplantation (BMT) to destroy bone marrow and leukaemic cells. To start TBI treatments for this application there is need to acquire physics parameters for magna fields at long focus skin distances (FSD) sufficient to cover the size of an adult patient. For BMT purposes, the specifications for TBI treatments are more stringent which need important requisites viz. 1) the dose delivery should include skin to 100% dose and 2) the dose uniformity in the entire body should be within  $\pm 10\%$ . 3) There is need for clinical dosimetry to document the dose delivered to various parts of the body 4) Also there should be method for development of shields for critical organs such as lungs, kidneys etc. to keep their absorbed doses within permissible limits.

**Materials and Methods:** Clinac 600 CD linear accelerator with gantry at  $270^\circ$ , collimator at  $45^\circ$  provide magna field of diagonal dimension 224 cm at 4.0M FSD, provides dose rate 6.7cGy/min. An acrylic beam spoiler screen of  $2\text{M} \times 0.7\text{M} \times 0.015\text{M}$  dimensions, mounted on mobile stand was fabricated locally. Beam flatness was measured moving a with FC 65 chamber with suitable build up. A special beam flatness filter was fabricated with poly-vinyl chloride sheets (PVC), 1.5 mm thick  $\rho = 1.34 \text{ g/cc}$ . Percentage depth dose (CADD) and tissue maximum ratios (TMR) were measured using 0.6 cc chamber and a plane parallel chamber (PPC 40) with and without beam spoiler in position. Measurements were carried out with phantom dimensions 90cm x 30cm x 40cm and 200cm x 40cm x 50cm. Clinical dosimetry was performed with humanoid phantom using calibrated DPD dosimeters and Li Bo4 TLD chips. Lung shields were fabricated using simulator radiographs obtained at 1.0m applying proper minification factor to represent the true dimensions of shields at beam spoiler position. The accuracy of the shields is checked with portal radiography with 5 cGy dose at exit plane (EP) of the phantom. **Results:** Beam flatness using the locally fabricated beam flattener with acrylic beam spoiler improved beam flatness from  $101.6 \pm 1.5\%$  (open beam) to  $100.1 \pm 0.4\%$ . Beam spoiler and flattening filter effected beam attenuation by factors 0.962 and 0.970 respectively. The entrance skin dose is modified to 100% with beam spoiler compared to 79.3% without it. CADD values normalized to skin and 1.5 cm depth have shown reduction of %DD in the presence of beam spoiler. Mean output at dose maximum point in the phantom is 0.064 cGy/MU at 4.0M FSD requiring 1562 MU/ 100 cGy absorbed dose. Estimates of absorbed dose were within 3% using DPD and TL detectors in the treatments delivered with phantom patient. The shields prepared cover accurately the regions of the lung and the method of preparation of shielding is acceptable for treatment.

### Clinical use of stereoscopic x-ray positioning of head & neck cancer patients treated with three-dimensional radiotherapy: Our preliminary experience with BrainLab ExacTrac IGRT system.

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**Introduction:** Recent improvements in planning and delivery of complex radiotherapy treatments have led to increased opportunities for more precise treatments of cancer. With these new capabilities, greater emphasis is placed on the accuracy of patient

positioning ensuring patients are set-up with millimeter accuracy for each treatment fraction. Image Guided Radiotherapy (IGRT) techniques have given promising tool in this direction. **Materials & Methods** The ExacTrac IGRT (from M/s BrainLab) room based stereoscopic x-ray positioning system for on-line kV imaging and correction of the patient supported with Varian (6X) linear accelerator is installed, commissioned & clinically implemented at Father Muller Oncology Center, Mangalore in April 2008 which is first of its kind in India. X-ray images generated with the ExacTrac system are two orthogonal X-ray projections through isocenter. The system software then uses the treatment planning CT data to create digitally reconstructed radiographs (DRR) of the patient according to the projection angle of the X-ray tubes. Automatic 3D image fusion and its corresponding DRR projection quantifies patient alignment error. The IR tracking ensures that the suggested shifts are made correctly by the therapist and verified by the ExacTrac system. ExacTrac IR system is calibrated daily with the help of calibration isocenter phantom. A body phantom with IR markers is taken for planning CT & dummy plan is created with PTV in Eclipse planning system and exported to ExacTrac workstation for X-ray system repositioning verification. **Results:** A total of 345 measurements were taken in 20 patients undergoing head & neck treatments with IR markers (5nos) based positioning. Random errors with the x-ray positioning system before and after correction in the anteroposterior (AP), lateral and longitudinal direction were (average  $\pm$  1 SD)  $-13.85 \pm 1.17$  mm,  $-4.0 \pm 0.28$  mm;  $-1.27 \pm 2.12$  mm,  $-0.78 \pm 0.41$  mm;  $2.27 \pm 4.25$  mm,  $1.71 \pm 0.58$  mm respectively. Conventional & IR marker based positioning showed significantly larger systematic errors in AP and laterally; but longitudinally, the difference was not significant. The total Linac time for one treatment session was 12 min 28 sec  $\pm$  2.5 min 29 sec, half of which was used for the x-ray assisted positioning procedure. **Conclusion** X-ray – assisted patient positioning significantly improves setup accuracy.

### Complications of radiotherapy in the oral cavity - Minimizing the unavoidable

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Oral complications from cancer therapies including surgery, radiation, chemotherapy, immunotherapy and/or cell transplantation are common and can substantially impair the comfort and function of patients during and after treatment for cancer. These oral complications range from mild and transient to permanent and debilitating side effects depending on number of factors. During the course of the treatment, these complications

may sometimes have an impact on the patient's willingness to adhere or complete with the prescribed therapies. Current clinical researches and trials are targeted to minimize these complications and improve the multi-disciplinary management approach of lesions and symptoms, which occur in the oral cavity as side effect of cancer therapies. In this presentation, the etiology, incidence, preventive measures and the management approaches of radiation therapy related side effects in the oral cavity will be discussed from a dental and oral maxillofacial prospective.

### Consistency in Inter-Fraction Treatment Delivery during Imrt of Prostate Cancer

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**Background:** A protocol of EPI registration for verification of radiation treatment fields has been Implemented at our department. A template is generated using a reference image which is then registered with the EPI for treatment verification. This study examines consistency in the registration and verification of EBRT/IMRT patients with prostate cancer. **Material and methods:** Seven patients with prostate cancer undergoing IMRT were analyzed. Clinac-2300 C/D with Millennium Multileaf Collimator (MMLC 120, Varian), EPI system aS 500 (Amorphous Silicon detector type, Varian), RT Simulator (Acuity, Varian), Eclipse TPS System (varian), Varis networking information system, Anatomy matching software, were used in the present study. For these patients the daily EPI from initial 3 fractions followed by twice weekly EPI were registered. For each fraction, an antero-posterior (AP-PA) and left or right lateral EPI were generated and registered with the reference images. Two measures of displacement for the AP EPI in the superio-inferior (SI) and right left (RL) directions and two measures of displacement for the Lat EPI in the AP and SI directions were taken. The data for total of 189 images and 378 measurements were analyzed. Means and standard deviations, as well as systematic and random errors were calculated for each patient. If systematic errors are more than maximum limits, then EPI was repeated. Variance components analysis was used to evaluate how much variance is attributed to the patients. Time and trends were estimated using repeated measures analysis. **Result:** The mean and standard deviation of the 7 patients' measurements were within the maximum limits, for APLR, APSI, LatAP and LatSI mean values are  $\pm 1.0$ ,  $1.0$ ,  $0.7$  and  $1.1$  respectively. These are 14% for APLR and APSI, 10% for LatAP, and 16% for LatSI.

Results are discussed and compared with the values of earlier studies. The observed variations are well within limits and their magnitude was small. **Conclusion:** These findings are useful in the documentations of consistency and reliability in the quality assurance of treatment verification of IMRT for prostate cancer in our center. The observed variations are well within limits. If radiolucent markers like (gold seeds) are present in the simulator radiographs, the quantifications in prostate movements and shifts in EPI images could be well documented.

### **“To Err is Human”: Lessons Learned from Accidents in Radiation Therapy**

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**Objectives:** 1) To provide a review of previously reported errors in medicine and specifically in radiation therapy. 2) To see what lessons can be learnt from previous reports on errors in radiation therapy. 3) To provide guidance on minimizing the occurrence of errors in radiation therapy.

The overall process of radiation therapy contains multiple steps, uses complex radiation technologies, and involves multiple professional disciplines including Radiation Oncologists, Medical Physicists and Radiation Therapists (Radiographers). In general, the aim is to deliver the prescribed radiation dose with an accuracy of 5%. It is also well recognized that errors (adverse events) do occur in all areas of medicine. Thus, quality assurance (QA) programs in radiation therapy are developed to ensure an accurate dose delivery while at the same time minimizing the probability of the occurrence of medically related errors. Multiple reports demonstrate that about 10% of people who receive health care in the industrialized world will suffer as a result of preventable harm and adverse events. It is also recognized that these statistics are significantly worse in the developing world. In radiation therapy, there are now an increasing number of reports that describe radiation related medical errors both in the peer-reviewed literature as well as through international organizations. In 2004, the World Health Organization (WHO) launched the World Alliance for Patient Safety in response to the recognition that “to tackle patient safety internationally, a comprehensive, multifaceted approach involving cultural change, system development and technical expertise was necessary”. In 2007, the WHO had its first meeting specifically addressing patient safety in radiation therapy. A major purpose of these reports and committee activities is to review these medical accidents in detail to see what lessons can be learned to

mitigate their occurrence. While there are multiple aspects to the occurrence of adverse events, there are some broad conclusions and guiding principles that evolve out of the review of past accidents. Four key components to quality assurance programs are best summarized by the following words: *education, documentation, verification* and *communication*. Adequate implementation of each of these components will provide a significant impact on minimizing medically related errors.

### **Quality Assurance Procedures of External Beam Radiotherapy: Evaluation of Errors in Various Types of 3d-Conformal Treatments.**

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**Introduction:** Comprehensive Quality Assurance program improves the quality of treatment delivered to patients. The investigation of treatment errors can facilitate introduction of QA procedures to overcome the occurrence of them. The QA procedures developed for such 3DCRT, IMRT, SRS/SRT are highlighted in the present paper. **Materials & Methods:** The following equipments were used for the QA program. Clinac 2300CD and Clinac 600EX-Linear Accelerators with MLC, micro MLC and EPIDs. Eclipse-3D TPS & Brainlab I-Plan system with Inverse planning software. VARiS-Networking system. DPD-12 Invivo dosimetry. Rando Phantom and OmniPro-ImRT Phantom with ImRT software. Three 3DCRT plans were created for Breast, Head & Neck and Pelvis sites. Two IMRT plans were created for Head & Neck and Pelvis sites. Finally one SRS and one SRT plan was created for the cranial site. For all the above cases, verification plans were created on ImRT Phantom. The QA was done for 3DCRT/IMRT/SRS/SRT treatments using the 1) Absolute dosimetry, 2) Film dosimetry, 3) Invivo dosimetry, 4) EPID for setup verification, 5) Diamond software for mu calculations, 6) Irreg software for mu calculations. **Results & Discussion:** Various guidelines given by various organizations on the QA aspects of RT equipment and dose delivery verifications are discussed. QA aspects of the CT/MRI/RT-Simulator, Linear accelerator and RTPS were discussed. Examples of various useful published materials are presented. Up-to-date references related to the QA procedures and evaluated errors are presented. In the absolute dosimetry for all the 3DCRT plans the dose errors were <1%, for IMRT the errors were <3% and in SRS/SRT cases the errors were <6%. The increase in the % of errors in IMRT and SRS/SRT compared to the 3DCRT were attributed to the complex nature

of dose delivery and small field sizes involved in the IMRT and SRS/SRT treatments. In the film dosimetry of IMRT plans, 95% of data were having errors <3% and 5% of data were having errors <5%. The irregular calculations, dynalog file verifications and in vivo dosimetric results were also evaluated and found that all of them were well within the acceptable limits. **Conclusions:** Careful implementation of QA protocols confirms integrity of hardware, software and data of all radiotherapy equipments and also helps to understand their features. The QA reduces uncertainties and errors in dose delivery and ensures the accuracy of the treatment delivery to the patients, helps to inter-compare the results and collaborate with other centers. It helps the staff involved to update their knowledge in QA procedures and develop new ideas/methods in QA. Finally the QA improves the work practices of the department.

### Dosimetry evaluation of One-Dose plus – Mosfet based commercial in-vivo dosimeter

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**Introduction:** In-vivo Dosimetry in radiation therapy is the final part in the quality assurance chain of dose delivery verification process. Various detector systems like TLDs and semiconductor diodes are commonly used and some centres have used gafchromic films for specific treatment techniques. Recently mosfet based detectors are getting widespread usage for in-vivo dosimetry especially because of its smaller dimension. **Material & Methods:** One dose plus, designed by Sixel Technologies, U.S.A., evaluate dose at the depth of maximum ionization (dmax) for megavoltage photon therapy beams. The shift in the threshold voltage due to the irradiation is quantified against the absolute dose delivery. The novel design of this system enables to store the patient identification, treatment related information and the measured dose as a permanent record on the inbuilt EEPROM. The dosimeters are available in batches (32 in each batch) and are associated with a calibration certificate, which gives all the required dependency correction factors such as: energy, dose-rate (MU/min), wedge, SSD, field size, and dose linearity. In Edinburgh Cancer Centre, we have evaluated these dosimeters for the specified dosimetric factors and also estimated the angular dependency on a water equivalent phantom. Two simulated treatments on Rando, anthropomorphic phantom and two sets of measurements on actual patients were also performed. **Results & Discussion:** The studies performed on the water equivalent phantom showed good agreements for energy and field size dependency. SSD dependency showed good agreement for values lesser than 100.0 cms for 6MV, 10MV &

18MV energies. At 130.0cms, 10MV & 18MV showed larger variations (< 5%). Dosimeter response was found to be overall better through not applying the manufacturer's wedge correction factor and brought all dosimeter values within 5% of the expected value. Linearity with dose was found to be high, with an  $r^2=0.999$ . Angular response readings up to 45 degrees for all energies were found to be within tolerance. However, measurements indicate there may be a reduced dosimeter response at increased angle for higher energies. The results of the simulated treatments on the anthropomorphic phantom showed good agreement with the treatment planning dose values, if the wedge dependency factor is not applied. Similar results were observed for the measurements performed on two prostate patients treated with 3field conformal technique. With these encouraging early results, several patient measurements are planned for selected H&N and Gynaecological treatments and their results will also be presented.

### Comparison of Conformity Indices for Quantitative Evaluation of Dose Homogeneity for Imrt Treatments of Head and Neck Cancers

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**Introduction:** Dose homogeneity within the planning target volume (PTV) needs to be ensured in IMRT treatment delivery. In IMRT of head and neck cancers, dose distributions of various plans are much more heterogeneous. Therefore in addition to traditional dose volume histograms various conformity indices have been proposed for the quantitative comparison of rival treatment plans. This study evaluates the efficacy of available conformity indices viz. H-index, HI index and S-index. **Materials and Methods:** 22 head and neck cancer patients treated by 6 MV dynamic IMRT with 5-7 fields in Clinac-DHX are studied. Homogeneity index (H-index) is defined as the ratio of the maximum dose ( $D_{max}$ ) in the PTV to the prescribed dose ( $D_p$ )<sup>1</sup>. Another homogeneity index called as HI index has been defined<sup>3</sup> as

$$HI = (D_2 - D_{98}) / D_p \times 100\% \dots\dots\dots(1)$$

Here  $D_2$  and  $D_{98}$  represents the doses to 2% and 98% of the PTV respectively. The new homogeneity index called as 'S' index (Sigma index) proposed by Yoon (2007) is defined as the standard deviation of the normalized differential curve<sup>4</sup>.

$$S \text{ index} = D_{SD} = \sqrt{[\sum (D_i - D_{mean})^2 \times v_i / V] \dots\dots\dots(2)}$$

Where  $D_{SD}$  represents the standard deviation of the dose,  $v_i$  is the  $i^{th}$  volume element receiving a dose of at least ( $D_i$ ) and V is the total

volume. Dmean is the mean dose. **Results & Discussion:** The H-index, HI index and S index values varied between 1.024 to 1.112, 4.03 to 16.9 and 0.94 to 3.43 respectively (Table.1). Fig 1.(a) shows cases in which the DVH curves are quite different, but H indices are identical ( $H=1.06$ ). The dose homogeneity for the patient 5 is better than for patient 10 (S index 1.36 vs 2.01). Fig 2.(a) shows that the HI values for the DVHs of patients 11 and 16 do not accurately represent the dose homogeneity. Fig 2.(b) indicates that, based on the S index, the dose homogeneity of the DVHs is better for patient 11 than for patient 16 (S index 2.06 vs 2.34). These results indicate that H and HI indices do not provide the accurate dose homogeneity information, but the S indices uniquely provide quantitative information about the dose homogeneity. **Conclusion:** The conformity index ('S' index) is better than the conventional H and HI indices in providing the quantitative information on the dose homogeneity in IMRT of head and neck cancer patients.

## UK Model for Cancer Control Programme Applied to Oman

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Cancer places a heavy burden of disease in the community. One in three people will get the disease and one in four will die from it. Its multiple sites, presentations and complications and the complexity of its treatment present a major challenge to the health care. In addition, the individual consequences of the diagnosis of a malignant disease for patient are far reaching and profound. Cancer is still regarded by the public as an especially threatening disease and one which to some extent is still a taboo subject. There are huge economic consequences resulting from cancer. In 1995, the Department of Health in UK acknowledge that survival data for cancer patients UK are among the lowest in Europe and a committee has been asked to look at that and to create a network of care in UK which will enable a patient, whenever he or she lives to be sure that the treatment and care received is of a uniformly high standard. This report was published and a strategic framework has been established with introduction of cancer units and increasing input from palliative care as well as defining guidance for patient care. The National Cancer Research Network (NCRN) was established in April 2001, and aims to provide the National Health Service (NHS) in UK with an infrastructure to support the high quality cancer clinical studies and to improve the speed, quality and integration of research resulting in improved patient care. The National Institute for Health and Clinical Excellence (NICE) has also started an independent organization responsible for providing national guidance on the promotion of good health

and the prevention and treatment of ill health. A cancer reform strategy has been published in 2007 going into detail targets about treatment time as well as quality. More recently a Drazzi report in 2008 has put further guidance and recommendations to move on with health service. Definitely this has been reflected positively on the cancer outcome in UK. As Oman has started to have its first cancer center recently, it was thought to bring the UK experience to Oman and to make a guidance framework about how to benefit from the UK model in improving cancer care in Oman.

## Dosimetric characteristics of Enhanced Dynamic Wedge

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**Introduction:** Beam modification is an essential component in Radiotherapy to achieve uniform dose conformity in the target volume. In static conformal treatments, physical wedges are being used for this purpose. Use of these wedges has limitations owing to the fixed wedge angles and the beam attenuation from wedge material. Enhanced Dynamic Wedge (EDW) overcomes these limitations. Using EDW, the wedge dose profile is created by the sweeping action of the collimator (one of the Y jaws) from open to closed position while the beam is on. The possible wedge angles with EDW are: 10, 15, 20, 25, 30, 45 and 60 degrees for a maximum field size of 30 (-20,10) cm wide. Owing to the jaw movement during treatment to get the desired wedge effect, it is essential to have quality assurance program, similar to any other dynamic treatments, which would satisfy the clinical implementation of EDW. **Materials & Methods:** We, at our Institute, have a multi modality modern linear accelerator<sup>§</sup>, which is capable of delivering treatments with EDW. The dosimetric characteristics of EDW were performed using amorphous silicon EPID (aSi1000) for profiles and 0.6cc ion chamber for wedge factor. The evaluation of the curves generated by EPID was done through Portal Dosimetry Review workspace under ARIA work environment<sup>§</sup>. Phantom verification of treatment plans for physical wedge and the corresponding EDW were carried out in Eclipse Treatment planning system<sup>§</sup> (Varian Medical Systems, Inc. Palo Alto, CA). **Results:** The comparison of corresponding profiles between physical and EDW shows good agreement on the slope of the curve. The wedge factor generated using EDW for various wedge angles were found to be correlating with the reference value. The treatment plan verification using phantom was in good agreement for the profiles and the MU value was reduced upto 20-25% (mean) for EDW depending on the wedge angle and field size, as compared to the use of physical

wedge for the same plan. This reduction in MU for EDW considerably reduces the whole body patient dose arising out of leakage through linac head. The treatment delivery through EDW is monitored by Segmented Treatment Table (STT) generated by Linac Computer. **Conclusion:** Treatment with EDW produces wedge-shaped dose distributions using computer-controlled dose delivery combined with upper jaw motion. Delivery of such high end treatment requires validation of various relevant dosimetric parameters. EDW reduces the patient dose outside the treatment field during radiotherapy.

### Brachytherapy in oral cancer

*Presented by Dr.D.V.L.N.Sastry.M.D, D.M.R.T (Toronto)*

Oral Cancer is a common cancer in this part of the country. Over seventy percent are in advanced stage and treated with the combination of external RT and chemotherapy. Early disease at accessible sites in oral cavity is treated with interstitial brachytherapy. The experiences using Radium, Iridium wires and HDR Brachytherapy using Iridium sources is presented. With Radium 65 % were disease free for more than five years. With Iridium wires 78 % in carcinoma cheek and 84 % in carcinoma of anterior 2/3 tongue achieved complete response. With HDR Brachytherapy CR was achieved in 93% of the 118 patients treated for carcinoma of the anterior 2/3 tongue. Surgery was done for residue or recurrent disease. Elective neck dissection was done in 34 patients and neck dissection was also done for another 34 patients who had metastatic lymph nodes. Overall 90/110 were disease free for more than 3 to 5 years.

### Clinical use of helical tomotherapy

*Florian Sterzing, M.D and Klaus Herfarth, M.D.*

**Background and Purpose:** Helical tomotherapy was introduced into clinical routine at the department of radiation oncology in the University hospital of Heidelberg in July 2006. We describe the experience of 550 patients treated with helical tomotherapy. Patient selection, time effort, handling of daily image guidance with megavoltage CT and quality of radiation plans shall be assessed.

**Material and Methods:** Between July 2006 and February 2009 550 patients were treated with helical tomotherapy in the University hospital of Heidelberg. This very heterogenous group of patients was composed of the following tumor entities: head-and-neck tumors (n=80), prostate cancer (n=130), gastrointestinal tumors (n=60), breast cancer (n=48), multiple metastases (n=11), spinal reirradiation (n=20), thoracic tumors (other than lung

(n=60), radiosurgery (n=20), malignant pleural mesothelioma (n=10), sarcoma (n=60), whole abdominal irradiation for ovarian cancer (n=13), skin malignancies (n=3), craniospinal axis treatment (n=20), others (n=15). In 98% of the fractions a pretreatment megavoltage ct scan was performed. After matching with the kilovoltage planning ct scan corrections for translations and roll were done. **Results:** Helical tomotherapy was able to treat very small, very big or multiple targets. Image-guidance with MV-CT allowed fast position correction and safe and precise treatment application. For the described tumor entities average time on table was 22 minutes, average treatment time 9.6 minutes. Excellent dose distributions with homogeneous target coverage and sparing of organs at risk could be achieved for all the described tumors. **Conclusions:** Helical tomotherapy and daily image-guidance with megavoltage ct could be introduced fast and successfully into daily clinical routine. This method is suited to treat standard IMRT cases or patients with very big and complex shaped targets.