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Volumetric Modulated Arc Therapy Vs. IMRT: a Treatment Planning Comparison for Larynx, Oro- and Hypopharynx Carcinomas

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Background: Volumetric intensity-modulated arc therapy (VMAT) is an emerging radiation therapy technique allowing for rapid delivery of highly conformal treatments. In this study, the treatment plans for VMAT and static-field intensity-modulated radiation therapy (IMRT) for head and neck cancer patients were compared.
Material and Methods: The last 10 patients who underwent static-field IMRT for larynx, oro- and hypopharynx carcinomas treatment were replanned using VMAT with two dynamic arcs. Both plans were prescribed to deliver 70 Gy to the gross tumour, 60−64 Gy to intermediate-risk areas and 56 Gy to low-risk areas. Dose to the planning target volume (PTV) and organs at risk (OAR) were evaluated according to ICRU recommendations and compared. For the PTV we evaluated the V95%, near-maximum (D2%), near-minimum (D98%) and median (D50%) doses received by the target volumes. Homogeneity indexes (HI) and conformity indexes (CI) were calculated. D2%, maximum dose (Dmax), mean dose (Dmean) or volume receiving a relevant dose were used for OAR. Monitor units (MU) were also documented.
Results: Both IMRT and VMAT can provide good PTV coverage (D98% >95%, V95=100%). The dose to the 70 Gy PTV tends to be more homogeneous for the IMRT plans (HI = 0.08 for IMRT vs. 0.1 for VMAT, $p = 0.068$). The HI indices are similar for the 60−64 Gy PTV (0.12 vs. 0.13) and the 56 Gy PTV (0.15 vs. 0.16). CI was similar for both techniques: 1.62 (1.28–3.28) for IMRT vs. 1.81 (1.24–3.07) for VMAT. Spinal cord Dmax <45 Gy in most cases, with D2% lower for IMRT (41 vs. 42.25 Gy, $p = 0.025$). Brainstem Dmax <54 Gy for all patients with both techniques (median Dmax=49.9 vs. 49.25 Gy, $p > 0.05$). Dmean was higher for IMRT vs. VMAT for both right (30.15 vs. 29.37 Gy) and left (42.45 vs. 40.8 Gy) parotids, as was D50% for right (26.44 vs. 26.25 Gy) and left (38.95 vs. 37.8 Gy) parotid glands. VMAT allowed for a reduction in Dmax (73.2 vs. 75.75 Gy) and D2% (69.86 vs. 72.2 Gy) for the mandible. Both techniques give comparable oral cavity Dmax and D2%. Esophagus Dmean <45 Gy in most cases. MU for VMAT were significantly lower (494 vs. 1472, $p < 0.001$).
Conclusions: This planning study shows that both IMRT and VMAT provide comparable PTV coverage. While IMRT can achieve better target dose homogeneity, VMAT is better at sparing doses to OAR in some cases. Overall, both techniques seemed to be equivalent. MU were considerably lower for VMAT, resulting in a shorter delivery time that can benefit patients and department logistics.

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A Dosimetric Comparison Between Single Arc and Double Arc Technique Using Volumetric Modulated Arc Therapy for Brain Metastases

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Purpose: Volumetric modulated arc therapy (VMAT) is a technique allowing for highly conformal intensity-modulated dose distributions by delivering with gantry rotation. We compared the difference VMAT plans between using single arc (SA) technique and double arc (DA) technique.
Methods and Materials: We selected the 7 patients with brain metastases who had been treated with whole brain radiotherapy followed by VMAT boost. For each patient, two VMAT plans consisting of SA and DA technique were generated to brain metastases. These all plans were optimized according to VMAT technique with same optimized condition. Dose prescription was 3 Gy in 10 fractions without normalization. For comparison, we used the quality of coverage (QOC), homogeneity index (HI) and conformity index (CI), which was defined by the Radiation Therapy Oncology Group (RTOG). The dose volume histograms (DVH) also were evaluated.
Results: Summated planning target volumes (PTV) were 7.2 to 122.3 cc (median 44.7cc). The DA technique showed significantly better averaged HI (1.14) compared with the SA (1.19) and the VMAT plans using DA technique showed much steeper PTV dose gradients than SA technique on DVH. The sparing of OAR (brain, lens, and brain stem) was not significantly different between the double arc VMAT and single arc VMAT.
Conclusions: Compared with VMAT plan using SA technique, DA technique provided significantly more homogeneous PTV coverage and similar sparing of OAR.

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A Dose-volume Analysis of Magnetic Resonance Imaging-aided High-dose Rate Image-based Interstitial Brachytherapy for Previously Untreated Uterine Cervical Cancer

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Background: To investigate the feasibility of our novel image-based high-dose rate interstitial brachytherapy (HDR-ISBT) for uterine cervical cancer, we evaluated the dose-volume histogram (DVH) according to the recommendations of the Gynecological GEC-ESTRO Working Group for image-based intracavitary brachytherapy (ICBT).
Materials and Methods: Between June 2005 and April 2009, 31 previously untreated cervical cancer patients were treated (median age, 56 years; range, 34−79 years). The eligibility criteria for undergoing ISBT were determined based on ABS recommendations (bulky lesion, narrow vagina, inability to enter the cervical os, extension to the lateral parametria or pelvic side wall, and lower vaginal extension). The survivors were followed up for a minimum of 2 year (median; 42 months, range; 24−69 months). Histological findings showed 28 squamous cell carcinomas, one adenosquamous carcinoma, and 2 adenocarcinomas. Using the UICC classification of 2002, 2 T2b, 23 T3, and 6 T4 were identified. There were 15 N0 and 16 N1 patients, and 5 patients were classified as M1 (para-aortic lymph node metastasis alone).
We implanted magnetic resonance imaging (MRI)-available plastic applicators by our unique ambulatory technique. Total treatment doses were 30−36 Gy (6 Gy per fraction) combined with external radiotherapy (ERT). Treatment plans were created based on planning computed tomography with MRI as a reference. DVHs of the high-risk clinical target volume (HR CTV), intermediate-risk CTV (IR CTV), and the bladder and rectum were calculated. Dose values were biologically normalized to equivalent doses in 2 Gy fractions (EQD_2).
Applicator displacement was evaluated by daily CT images and we compared the distance between applicator tips and center of the gravity of three marker seeds implanted in the edge of the CTV.
Results: The median D90 (HR CTV) and D90 (IR CTV) per fraction were 6.8 Gy (range, 5.5−7.5) and 5.5 Gy (4.2−6.4), respectively. The median V100 (HR CTV) and V100 (IR CTV) were 99% (83–100) and 82% (64–96.2), respectively. When the dose of ERT was added, the median D90 and D100 of HR CTV were 81.6 Gy (65.5–96.6) and 64.7 Gy (49–83.2). D_{2cc} of the bladder was 70 Gy (52.8–119) and of the rectum was 67.7 Gy (48.9–86.8). The 3-year local control rates were 100%, 92% and 67% for T2b, T3 and T4 lesions. The 3-year disease free survivals were 100%, 77% and 67% for T2b, T3 and T4 lesions. The 3-year local control rates were 93% and 81% for N0 and N1 lesions. The 3-year disease free survivals were 70% and 81% for N0 and N1 lesions. Severe late complications (Grade 3−4 in CTCAE Ver.3) were observed for 2 patients.
Conclusions: Although the tumours were advanced and difficult to treat effectively by ICBT, MRI-aided image-based ISBT showed favorable results.

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Is RapidArc Superior to 3D Conformal Radiotherapy for Radical Radiation of Primary Esophageal Carcinoma − A Dosimetric Study

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Background: Oesophageal carcinomas are traditionally treated with 3D conformal radiotherapy (3DCRT). The application of RapidArc (RA) for this site has not been previously investigated. RA has the potential to offer more conformal treatment without compromising normal tissue toxicity given that stringent dose constraints are applied. However, there is also concern that RA may produce higher V5 and mean lung doses which correlate with an increased risk of radiation pneumonitis. This current pilot study examines the feasibility of RapidArc for oesophageal radiation and lung sparing compared to 3DCRT.
Materials and Methods: 12 patients, who were treated radically between 2006–2008 to a dose of 50 Gy/25 fractions, were randomly selected from our electronic patient records. These cases equally represented upper, mid and lower oesophageal tumours. Archived patient CT simulation scans were anonymized and planned using RA and 3DCRT with the following dose constraints: PTV covered by 47.5 Gy to at least 98% volume with acceptable hotspot <110%, spinal cord Dmax <45 Gy, V20 lung <30%, mean lung dose (MLD) <20 Gy. Results were analyzed with two-tailed Wilcoxon matched pair analysis.

Results: RapidArc produced superiorly conformal plans compared to 3DCRT (conformality index 1.37 (1.17–1.64) 3DCRT and 1.06 (0.93–1.19) RA; p = 0.003). The hotspot within the PTV was greater for RA plans when comparing identical PTV volume coverage (106.4% (103.4–109.9) 3DCRT and 109% (106.0–113.6) RA). RA produced greater sparing of lung volumes with significant differences in V13 (31.1% (6.6–80.9) 3CDRT and 27.4% (4.3–82.7) RA; p = 0.015), V20 (23.1% (5.3–65.7) 3DCRT and 13.3% (1.7–51.3) RA; p = 0.022), and MLD (10.9 Gy (3.1–27.7) 3DCRT and 9.2 Gy (2.5–22.8); p = 0.0022). The V5 was not statistically different (p = 0.071). RA also provided lower mean heart doses (16 Gy (1.1–33.9) 3DCRT and 13.5 Gy (1.0–30.3) RA; p = 0.0058).
Conclusion: RA is a feasible modality for primary radiation of oesophageal carcinoma. Compared to 3DCRT, RA provided better sparing of lung and heart volumes. Further study is required to validate this finding especially with respect to normal tissue complication probability modeling.

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Combined Whole Brain Radiotherapy and Simultaneous Integrated Boost for Multiple Brain Metastases Using the Volumetric Modulated Arc Therapy Technique

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Background: Using the Volumetric modulated Arc therapy (VMAT) technique, we performed this study to evaluate the effects of the whole brain radiotherapy (WBRT) with a simultaneous integrated boost in patients with multiple brain metastases.
Materials and Methods: For five patients with multiple brain metastases, two RT plans for each patient were generated: (1) an integrated VMAT (iVMAT) plan consisting of WBRT with a simultaneous integrated VMAT boost and (2) a sequential 2-Dimensional WBRT followed by a VMAT boost (2DVMAT) plan. In iVMAT plan, dose prescription was 5 Gy in 10 fractions without normalization. For the comparison, we evaluated the averaged quality of coverage (QOC), homogeneity index (HI) and conformity index (CI). Doses to organ at risk (OAR), a mean dose (D_{mean}) to the brain and a maximum dose (D_{max}) to the lens were evaluated by use of dose-volume histograms (DVHs).
Results: The average of monitor units (MUs) of iVMATand 2DVMAT plan were 1,118 and 1,012 respectively. The iVMAT plan showed better HI (1.12) and CI (1.30) compared with 2DVMAT plan (HI 1.26 and CI 1.67). However target coverage result (QOC) improved with 2DVMAT plan (0.95) compared with iVMAT plan (0.90). For the sparing of OAR, the D_{mean} to scalp was on average 5.7 Gy lower with iVMAT plan (9.1 Gy) compared with 2DVMAT plan (14.8 Gy). Whereas, the D_{max} to lens were on average 7.4 Gy with iVMAT plan and 7.1 Gy with 2DVMAT plan.
Conclusions: In patients with multiple brain metastases, iVMAT plan showed more conformal and homogenous target coverage and an improvement in scalp sparing compared with 2DVMAT plan. The future studies enrolling more patients will be necessary to draw the conclusive results.

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Feasibility of Frameless Cranial Radiosurgery With Infrared Markers Fixed to an Immobilization Mask That is Monitored Under X-ray and Infrared Image Guidance System

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Purpose: In frameless radiosurgery using the NovalisTX and ExacTrac system, stereotactic localization is achieved using a infrared (IR) camera system combined with an array of passive IR markers that has a 1:1 relationship to the localizer array used in CT which is then fixed above a thermoplastic mask. After positioning with the camera, changes in the patients position with respect to the mask system are then corrected using stereoscopic imaging with 6D automatic fusion. For larger patients, due to contact of the array with the patient's chest, localization accuracy can be compromised due to an inability to fit the array over the patient. The goal of this study is determine the feasibility of performing frameless radiosurgery by replacing the array with IR markers fixed directly to the immobilization mask.
Methods and Materials: An anthropomorphic head phantom with 5 hidden targets was used for the study. A mask was fabricated to which several IR markers were fixed. The phantom was scanned with the standard array and then with IR markers placed directly on the mask. Plans were generated for each target and phantom positioning was tested first with the default array and then with the IR markers fixed on the mask. Initial positioning by ExacTrac was verified with cone-beam CT and orthogonal kV/MV planar images. The differences in phantom shifts found by ExacTrac for positioning with the array vs. with IR markers on the mask were recorded for each target at 5 table angles typically used in clinical practice. Each target was tested twice for a total of 50 shift comparisons.
Results and Discussion: The mean absolute differences in translational shifts between positioning with the array vs. with IR markers on the mask in the vertical, longitudinal and lateral directions was 0.19 ± 0.14 mm, 0.19 ± 0.18 mm and 0.26 ± 0.27 mm respectively. The mean absolute differences in rotational shifts in the vertical, longitudinal and lateral directions was 0.20 ± 0.17^{o}, 0.11 ± 0.08^{o}, and 0.01 ± 0.08^{o} respectively.
The differences observed for both translation and rotation between the two methods used were small. Using a tolerance level of 0.7 mm/1º, no additional shift would be required at the 95% confidence level with the exception of lateral translations which slightly exceeds tolerance.
Conclusion: This phantom study shows that using IR markers fixed directly to the mask when patient geometry does not allow for the use of default IR marker array allows for sub millimeter localization.

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Comparing the Outcome of Treatment With Different Techniques and Dosages of Radiotherapy in Hodgkin Lymphoma

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Introduction: There are approximately 7,500 new cases of Hodgkin lymphoma diagnosed each year in the United States. Men are more susceptible than women (1.4:1). The role of radiotherapy in the treatment of Hodgkin's disease and non-Hodgkin's lymphoma has changed considerably in the last few decades so in this study we try to compare the outcome of using different technique of radiotherapy in treatment of Hodgkin lymphoma.
Material and Method: In this retrospective study, one hundred six patients aged 20 to 50 years who had documented Hodgkin lymphoma which were admitted in Emam Khomeini hospital were assessed. They were treated with three different technics of radiotherapy, the first one is Mantle, the second is inverted and the third one is Tonsil, three ranges of dosages were used, the first is under 2500CGy, the second 2500–4000CGy and the third one is more than 4000CGy and their response to the treatment were evaluated.
Results: 74 (69.82%) patients were male and 32 (30.18%) were female. 64 patients after treatment, they had positive response and they did not have recurrence, from this number of patients, 38 (59.37%) were male and 26 (40.62%) were female. These patients were divided into three groups from the aspect of pathology, the first group had Nodular sclerosis (NS), the second is Mixed cells (MC) and third group is Lymphocyte predominant (LP). 34 patients had NS which 16 (47.1%) of them were male and 18 (52.9%) were female. 20 (58.8%) had a positive response to the treatment but 14 (41.2%) patients had recurrence and did not respond to the treatment. 58 had MC which 48 (82.8%) were male and 10 (17.2%) patients were female, 40 (69%) patients answered to treatment but 18 (31%) did not answer and 14 had LP, 10 (71.4%) were male and 4 (28.6%) were female, in this group 12 (85.7%) patients, unfortunately did not respond to the treatment but 2 (14.3%) of them did answer to the treatment. The effective radiotherapy dosages which is used for the treatment of Hodgkin Lymphoma is 2500–4000CGy, in this study, we used three ranges of radiotherapy doses, the first group consisted of 8 patients got under 2500CGy and 2 (25%) of them had positive response to this dosage but 6 (75%) had negative response, the second group which is consisted of 64 patients got 2500–4000CGy that 40 (69.5%) of them had positive response but 24 (37.5%) did not answer and 34 patients which were in the third group got more than 4000CGy that 20 (58.8%) of them had positive answer to the treatment but 34 (41.2%) of this group did not answer and had recurrence. Finally, we used three techniques of radiotherapy as a main treatment in our Hodgkin lymphoma patients, the first one is Mantle, the second technique is Inverted and the third one is Tonsil but Para Aortic and Pelvic techniques were not used. Among 62 patients which answered to our treatment, the Mantle technique was used for 56 (90.3%) of them, Inverted is used for 4 (6.5%) and lateral face is used for 5 (3.2%) of patients.
Conclusion: The most common technique which is used for Hodgkin lymphoma is the Mantle and the number of patients which answered to Mantle technique is more than the other techniques of radiotherapy and the most effective dosages which can be used are 2500–4000CGy.