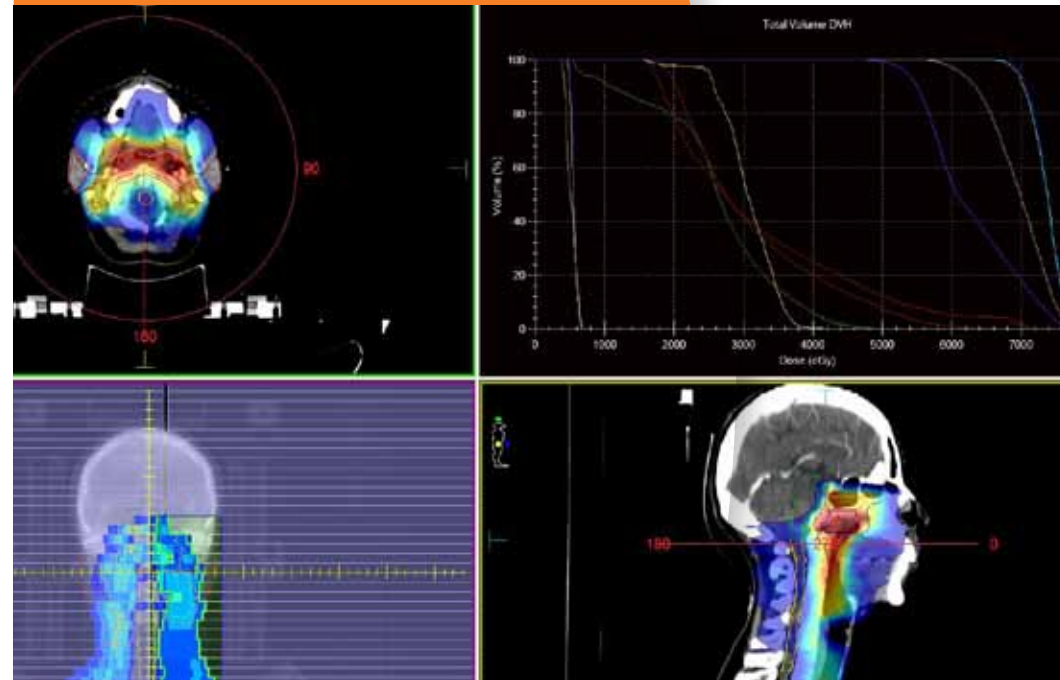


# VMAT

Volumetric Modulated Arc Therapy



## ASTRO 2010 Abstracts

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### CLINICAL APPLICATION OF APERTURE-BASED VMAT WITH RING-SHAPED REGION OF INTEREST FOR PLANNING IN LOCALIZED PROSTATE CANCER

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#### Purpose/Objective(s)

We previously reported an efficient VMAT planning procedure for prostate cancer, using a ring-shaped region of interest (ROI). We thereafter evaluated our initial clinical experience including planning, verification and early toxicities, of VMAT optimized by using the ring-shaped ROI for localized prostate cancer.

#### Materials/Methods

Single-arc VMAT plans for 10 localized prostate cancer patients were generated using the ERGO++ treatment planning system, which afforded a simplified aperture-based VMAT planning capability. The clinical target volume was defined as the entire prostate for the low-risk group, whereas for the intermediate-risk group it was defined as the entire prostate and the proximal seminal vesicles. The prescription dose was 74 Gy in 37 fractions. Dose constraints for VMAT planning were prescribed only for the planning target volume (PTV) and the ring-shaped ROI surrounding the PTV. Reference step and shoot IMRT plans were also created, with five coplanar equidistant fields.

Cumulative dose volume histogram parameters for the PTV and the organs at risk (OAR) were calculated for the VMAT and IMRT plans. Total monitor units (MU) and treatment time were also compared between the VMAT and IMRT plans. The VMAT plans were transferred to a linac controller, and dose distributions were verified using films positioned inside a phantom on axial, coronal, and sagittal planes. Subsequently, the VMAT beams were delivered to the patients. Acute toxicities were scored with the National Cancer Institute - Common Toxicity Criteria version 4.0.

#### Results

Using ring-shaped ROI for optimization, VMAT resulted in concentric dose distribution characterized by dynamic arc therapy. Although this optimization employed dose constraints only for the PTV and the ring-shaped ROI, VMAT provided satisfactory target conformity and OAR sparing comparable to IMRT. Isocenter dose discrepancy between measurement and calculation in the 10 VMAT plans was  $0.69 \pm 0.34\%$ . The pass rates of the gamma indices with 3 % and 3 mm criteria and dose threshold of 50 % of the prescribed dose on the axial, coronal and sagittal planes were  $99.1 \pm 0.7\%$ ,  $98.5 \pm 0.8\%$  and  $98.4 \pm 0.4\%$ , respectively. VMAT required fewer MU than IMRT (relative reduction of 19%;  $p = 0.006$ ). Mean treatment time was 133 seconds for VMAT, versus 358 seconds for IMRT ( $p = 0.006$ ). Grade 3 or worse acute toxicities were not seen.

### Conclusions

We have successfully treated 10 localized prostate cancer patients using aperture-based VMAT plans, each with a ring-shaped ROI. VMAT provided plan quality similar to IMRT with reduced MUs and total treatment time. The delivered dose by VMAT agreed with the planned dose under 3%-3 mm criteria.

### Author Disclosure

K. Ishii, None; M.N. Hosono, None; D. Tatsumi, None; R. Nakada, None; S. Tsutsumi, None; R. Ogino, None; T. Maekado, None; Y. Takada, None; T. Tada, None; Y. Miki, None.

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### EVALUATION OF THE DOSIMETRIC IMPACT OF INTRAFRACTION MOTION AND MLC LEAF INTERPLAY IN HYPOFRACTIONATED PROSTATE IMRT AND VMAT TREATMENT

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### Purpose/Objective(s)

Daily target localization can improve the radiotherapy treatment accuracy. However, the intrafraction tumor motion generally is not corrected. Using the tracking data acquired with a 4D electromagnetic localization system, we evaluated the impact of the MLC leaf interplay and the target motion during the hypofractionated prostate IMRT and VMAT treatment.

### Materials /Methods

Three transponders (Calypso Medical, Seattle) were implanted inside the prostate for daily target localization and real-time tracking. IMRT and VMAT plans were generated to deliver 70 Gy in 28 fractions to the PTV, which was expanded from GTV by 4 mm margin. For 5 patients and a total of 140 fractions of treatment, the intrafraction translation and rotation of the tumor were derived from the beacon coordinates extracted from the daily tracking records. The time and duration of the MLC segment for each control point in the IMRT and VMAT plans were calculated based on the speed of gantry rotation and MLC leaf motion. To determine the MLC leaf interplay effect on each fractional dose, we applied the calculated rotation and translation to the 3D dose map of each corresponding MLC segment. The summation of the daily fractional doses resulted in the accumulated dose for the entire treatment. Dose to the rectum and bladder as well as GTV coverage and dose uniformity (defined as D1/D99) were analyzed.

### Results

For all 140 treatments, 99% of the intrafraction translation was within 4 mm, 50% of the pitch and 90% of the yaw were within 5 $\sigma$ , and 90% of the roll was within 3 $\sigma$ . The mean (SD) of pitch, yaw and roll were 2.7 $\sigma$  (6.1 $\sigma$ ), -1.5 $\sigma$  (2.4 $\sigma$ ) and -0.8 $\sigma$  (1.7 $\sigma$ ) respectively. Pitch of larger than 10 $\sigma$  were observed for 20% of the treatment time. Although the cumulative GTV coverage remained 100% for both IMRT and VMAT, for

some fractions the volume of GTV that received prescription dose could decrease by as much as 7.5% for IMRT and 2.3% for VMAT. As the result of the significantly shorter delivery time, VMAT plans had smaller variation in daily GTV coverage (1.9 % for VMAT vs. 5.3% for IMRT) and dose uniformity (1.4 to 5.5% for VMAT vs. 2.7 to 9.1% for IMRT) (p<0.05). Minor changes in bladder V60 (-5 to 1%) and rectum V70 and V60 (12%) were shown on the accumulative plans. However, mainly due to the large average pitch rotation in some fractions, the daily bladder V60 varied by -7.3 to 3.4%, and rectum V70 and V60 changed by -4.0 to 3.3%.

### Conclusions

The MLC leaf interplay has negligible impact on the total dose. However, large consistent rotation during the treatment can affect fractional dose to GTV, rectum and bladder. The intrafraction motion has less effect on VMAT due to the shorter treatment time. In addition patient bowel preparation and dietary instruction can reduce the variation in fractional dose.

### Author Disclosure

J. Ye, None; M. Rao, None; F. Chen, None; D. Cao, None; S. Eulau, None; T. Mate, None; R. Takamiya, None.

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### ASSESSING THE ROLE OF VMAT RELATIVE TO IMRT AND HELICAL TOMOTHERAPY IN THE MANAGEMENT OF LOCALIZED,

### LOCALLY ADVANCED, AND POST-OPERATIVE PROSTATE CANCER

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### Purpose /Objective(s)

To quantitatively compare advanced radiotherapy (RT) techniques with regards to treatment delivery efficiency and dosimetric quality in the treatment of prostate cancers eligible to receive RT. Current state-of-the-art techniques considered here are step and shoot intensity modulated radiation therapy (IMRT), volumetric intensity modulated arc therapy (VMAT) and helical tomotherapy (HT).

### Materials/Methods

Twenty-five prostate cancer patients were included in this retrospective planning study. We evaluated VMAT, IMRT and HT for the treatment of intact prostate: prostate alone (n = 5), prostate + seminal vesicles (n = 5), prostate + seminal vesicles + pelvic lymph nodes (n = 5), and in the post-prostatectomy setting: prostate bed (n = 5), prostate bed + pelvic lymph nodes (n = 5). The same planning system was used to generate IMRT and VMAT plans using identical optimization objectives, while the HT plans were generated with a different

planning system using comparable dose-volume objectives. A dosimetric evaluation was done to compare target coverage, integral dose and sparing of organs at risk (OAR) including the bladder, rectum and femurs between treatment plans. The times required to deliver each plan were also measured using a stopwatch for each case. The times measured for IMRT and VMAT include both the beam on time and the gantry rotation time between subsequent beams or arcs.

### Results

The dosimetric quality of IMRT, VMAT and HT plans were comparable in terms of both target coverage (PTV V95% and CTVV100%all.98.7%) and sparing of theOARexamined for all prostate treatment groups.Of note,HT resulted in a slightly higher integral dose and mean doses to the OAR but did yield a lower maximum dose to all OAR examined. The delivery of VMAT plans resulted in reduced overall treatment times over IMRT by 75% on average (range, 70-86% across all groups) and HT by 70% on average (range, 62-80% across all groups). VMAT also resulted in a 15-38% reduction in monitor units (MU) over IMRT. The MU reduction per fraction ranged from an average of 100 MU in the prostate only group (range, 16-202) up to an average of 423 MU in the prostate group with lymph nodes (range, 320-610). MU for HT cannot be compared in a meaningful way to Linac-based MU.

### Conclusions

VMAT improved the efficiency of

delivery in all cases, reducing treatment time and monitor units for equivalent dosimetric quality compared to IMRT and HT across various volumes involved in prostate cancer radiotherapy both in the intact prostate and post-operative setting.

### Author Disclosure

M.T. Davidson, None; S. Blake, None; D.L. Batchelar, None; P. Cheung, None; K. Mah, research collaborations with Philips Medical Systems and Elekta, Inc (although no financial relationship), G. Other.

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### ESTABLISHING THE ROLE OF VMAT IN TREATING COMPLEX PRIMARY BRAIN CANCERS

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### Purpose/Objective(s)

To determine if volumetric modulated arc therapy (VMAT) offers advantages over step and shoot intensity modulated radiotherapy (IMRT) for complex brain gliomas.

### Materials/Methods

Twelve patients were selected retrospectively for this planning study

where 6 had brainstem glioma (BG) and 6 had high grade glioma (HGG) involving critical organs at risk (OAR). BGs were prescribed 54 Gy/30 fractions (frx). HGGs were prescribed 50 Gy/30 frx to the PTV that included a 1.5 cm CTV (PTV50), with a simultaneous boost to a total dose of 60 Gy/30 frx to the GTV + 5 mm (PTV60). Identical objectives were used during optimization for the 7 beam IMRT and VMAT planning techniques including (1) a full single arc (VMAT1) and (2) one full arc plus one coplanar partial arc (spanning 90 degrees), delivered anteriorly (VMAT2). Priority was given to OAR with strict dose constraints at the expense of target coverage. We compared the percent volume of the PTV encompassed by 95% of the prescribed dose (V95), conformity index (CI), homogeneity index (HI), mean and maximum OAR doses, integral dose (ID) to normal brain, monitor units (MU), and duration of treatment delivery that included both beam on and gantry rotation time (between beams for IMRT or arcs for VMAT2).

### Results

The BG PTV and HGG PTV60 achieved a V95.96% regardless of technique (1% variation between all plans). Coverage of PTV50 for HGG cases was similar, with both VMAT techniques improving the V95 by an average of 2% over IMRT. VMAT2 plans were the most homogeneous and resulted in slightly better conformality. Typically, VMAT2 resulted in a lower maximum dose to the brainstem and spinal cord. There

was no significant difference in ID to the normal brain between techniques. VMAT1 yielded the fastest treatment times (averaging 86 s) and fewestMUas compared to IMRT and VMAT2. Delivery times for VMAT1 and VMAT 2 were reduced by 81-85% and 72-77%, respectively, compared to IMRT. Over 30 frx, average MU reductions for VMAT1 and VMAT2 vs. IMRT were 13% and 15% for BG and 23% and 5.4% for HGG.

### Conclusions

VMAT offers improved treatment delivery efficiency in complex brain tumors while maintaining similar dosimetric quality to IMRT. A second arc can improve dose homogeneity and sculpting around OAR, at a small cost of greaterMUand time as compared to a single arc.

### Author Disclosure

M. Tsao, None; S. Blake, None; M.T.M. Davidson, None; M. Follwell, None; W. Xu, None; D. Moseley, None; A. Sahgal, None.

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### VERIFICATION OF ELEKTA MLC LEAF POSITIONS BY CUSTOM MADE SLIDING WINDOW QA PLAN AND PICKET FENCE TEST WITH VARIABLE GANTRY ANGLES

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**Purpose/Objective(s)**

We have evaluated Elekta MLC leaf positions required for volumetric modulated arc therapy (VMAT) delivery.

**Materials/Methods**

A step and shoot plan was created by ERGO++ treatment planning system (TPS) with varying gantry angles and varying MLC 1-cm gap positions, each being set at an equal spacing. This plan was converted to a dynamic VMAT sequence and then transferred to an Elekta linac controller, RT Desktop 7. Subsequently, the gantry angle range was reduced to -0.1 to 0.1 degrees in total so that it is practically regarded as a sliding window QA plan. All the leaf positions were intentionally shifted to obtain a leaf error to dose variation plot. Using this plan, dose output was measured by an ion chamber placed in a plastic phantom while changing the leaf velocities. Using the same sliding window QA plan, an isocenter dose was measured by an ion chamber with a build-up cap, and the dependences of gantry angles and leaf moving directions were evaluated. Next, an X-OmatV film was placed on a shadow tray attached to the linac head. Using the sliding window QA plan, dose variations were measured on the leaf gap positions of 40 leaf pairs for various static and rotating gantry angles. Again the leaf position was purposely shifted to obtain a position error to dose variation plot. Finally, a picket fence QA plan with varied gantry angles from -130 to 130 degrees was created using ERGO++ TPS. Again, the beam was delivered to a film on the shadow tray. The positional accuracy of each leaf

was analyzed by a film scanner system.

**Results**

The dose output varied linearly with the leaf positional error, and 0.1 mm positional error led to approximately 1% dose error. The dose output error exceeded 2% when the leaf velocity went beyond the calibrated maximum velocity of 2.2 cm/sec. The dose output errors were always less than 2% independent of gantry angles and leaf moving directions. Film reading resulted in maximum leaf position discrepancy of 0.4 mm between a gantry angle of zero and various static or rotating gantry angle ranges. The picket fence test with varying gantry angles from -130 to 130 degrees led to maximum leaf position error of 0.5 mm among 40 leaf pairs.

**Conclusions**

We have proposed a method for verifying Elekta MLC leaf positions required for VMAT delivery by using a custom made sliding window QA plan and a picket fence test with variable gantry angles.

**Author Disclosure**

D. Tatsumi, None; K. Ishii, None; R. Nakada, None; S. Tsutsumi, None; R. Ogino, None; M. Inoue, None; T. Ichida, None; Y. Takada, None; M.N. Hosono, None; Y. Miki, None.

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**OF DOSE CALCULATION ACCURACY IN VMAT PLANNING FOR SBRT LUNG TREATMENT**

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**Purpose/Objective(s)**

Recent studies have demonstrated that the use of volumetric modulated arc therapy (VMAT) can significantly improve the delivery efficiency of stereotactic body radiation therapy (SBRT). The potential application of VMAT in the delivery of lung SBRT, however, raises concerns regarding the impact of intrafraction organ motion due to breathing and the degree to which this motion can lead to discrepancies between the planned and delivered doses. To address these concerns, we have utilized four-dimensional (4D) dose calculations to investigate the influence of intrafractional organ motion on the delivered dose in lung SBRT cases treated using VMAT.

**Materials/Methods**

For 12 patients with Stage I/II non-small-cell pulmonary tumors, a respiratory-correlated 4D computed tomography (4D-CT) study was acquired. The internal target volume was determined based on the maximum intensity projection 4DCT dataset, and a 5 mm margin was added to create the planning target volume. VMAT plans were generated using the Pinnacle3 SmartArc module with a

dose prescription of 3 x 20 Gy. All plans were generated for an Elekta Synergy linear accelerator using 6 MV photons. A model was developed to simulate the interplay between the MLC leaf sequences and the target movement during the delivery of VMAT. The 4D dose distributions were calculated using a non-rigid deformable image registration algorithm. Target volume coverage and doses to critical structures were calculated using a 4D methodology and were compared with those calculated using a 3D methodology.

**Results**

As a result of tumor motion, the GTV dose was slightly decreased on average (1% of the prescribed dose) in the 4D calculation as compared with the 3D calculation. For all 12 patients, the mean difference between 3D and 4D calculation for D<sub>min</sub> of GTV was 0.58 Gy, with a maximum difference of 1.43 Gy. The impact of intrafraction motion on target dose homogeneity (defined as D<sub>1</sub>/D<sub>99</sub>, where D<sub>1</sub> and D<sub>99</sub> represent the dose covering 1% and 99% of target volume, respectively) was patient dependent and relatively small (13%). For all patients included in this study, the interplay effect was found to have a limited impact on the target dose distribution with the variation of daily GTV coverage equal to less than 0.3% of the daily prescription. Negligible effects were observed on the doses to critical structures.

**Conclusions**

The interplay effects between the MLC leaf sequence and tumor motion is

negligible when VMAT is used in lung SBRT. The 3D dose calculation slightly underestimated the delivered dose to GTV. Generally, the 3D doses to critical structures provided good approximations of the 4D dose calculations.

#### Author Disclosure

M. Rao, None; J. Wu, None; D. Cao, None; J. Ye, None; F. Chen, None; T. Wong, None; V. Mehta, None; D. Shepard, None.

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### STEREOTACTIC RADIATION TREATMENT PLANNING WITH VOLUMETRIC MODULATED ARC THERAPY (VMAT): IMPACT OF DUODENAL SPARING

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#### Purpose/Objective(s)

Volumetric modulated arc therapy (VMAT) allows for intensity-modulated radiation delivery during gantry rotation with dynamic MLC motion, variable dose rates and gantry speed modulation. The dose limiting structure for pancreatic stereotactic body radiation therapy (SBRT) is the duodenum. Herein we evaluate VMAT dose distribution, delivery times, and determine the effect of duodenal sparing (DS).

#### Materials/Methods

Plans from fifteen patients with unresectable pancreatic cancer (14

head/1 tail) were selected. VMAT treatment planning with the "SmartArc" function of Pinnacle v. 8.9 was used to plan a single fraction of 25 Gy to the PTV (GTV plus a 2mm expansion). Two VMAT SBRT plans were conducted for each case; the first did not account for duodenal toxicity while the second did. In each case one 360° coplanar arc was used with 4 degree spacing between control points. Prescriptions were set for 25 Gy in a single fraction normalized to the 80% isodose line. Constraints used during planning included: stomach/duodenum any point max 30 Gy (for DS plan), liver D50 5 Gy, ipsilateral kidney D25 5 Gy, cord Dmax 5 Gy and stomach D4 22.5 Gy.

#### Results

The pancreatic tumor volume ranged from 58.4 cm<sup>3</sup> to 320.3 cm<sup>3</sup> and the average overlap volume between the PTV and the duodenum was 8.4 cm<sup>3</sup>. In 10/15 original non-sparing plans the duodenal Dmax exceeded 30 Gy. With DS optimization, only 1/15 plans exceeded the 30 Gy threshold. These differences were statistically significant (p<0.001). Typical number of MU and delivery times, as calculated by the planning software were: 5494 MU and 775 secs vs. 5296 MU and 703 secs for the DS and non-DS plans, respectively. Though the difference in delivery times was significant (p = 0.01), it averages only 1.2 minutes. In the initial non DS plan, the average duodenal Dmax = 30.4 Gy, and over 4% of the duodenum received at least 23.4 Gy. However, after adding a max dose objective for the duodenum, the average Dmax = 28.1 Gy and 4% of

the duodenum volume received less than 19.7 Gy (p<0.001). As expected VMAT plans with a larger proportion of overlap between the duodenum and PTV had a higher duodenal Dmax.

#### Conclusions

This study demonstrates the feasibility of newly available VMAT for high-dose SBRT treatment of pancreatic cancer. VMAT planning for pancreatic cancer should incorporate duodenal constraints in an attempt to limit the risk of duodenal toxicity. Future studies will also evaluate whether VMAT with fractionated SBRT may result in improved duodenal sparing.

#### Author Disclosure

J.M. Herman, None; J. Kang, None; R. Tuli, None; C. Wolfgang, None; T.M. Pawlik, None; E. Tryggestad, None; K. Smith, None; T.L. DeWeese, None; J. Wong, None; E.C. Ford, None.

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### STEREOTACTIC BODY RADIOTHERAPY (SBRT) TREATMENT OF LUNG LESIONS USING VOLUMETRIC MODULATED ARC THERAPY (VMAT)

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#### Purpose/Objective(s)

SBRT is an effective treatment method for selected lung tumors. Efficient treatment delivery can help limit intra-fraction motion, particularly for high dose per fraction regimens. In this study we investigate the feasibility to deliver

SBRT using VMAT to improve delivery efficiency.

#### Materials/Methods

Eight patients who underwent SBRT of lung lesions with traditional IMRT were re-planned with VMAT. Respiratory-correlate 4D-CTs were performed for all patients and ITVs. were drawn for tumor motion greater than 8 mm. The PTV volumes range from 19cc to 69cc with an average of 47cc. Both IMRT and VMAT plans prescribed 12Gy x 4 fractions to the PTV, normalized to 80%-90% isodose line. These plans were performed using Pinnacle 9.0 with the SmartArc module. For IMRT plans, 6-8 coplanar beams were used. The number of segments for each beam was limited (average 5 segments per beam) to reduce interplay effect between leaf segmentation and tumor motion. For VMAT plans, a single 200 degree arc with 4 degrees per segment was used. The same set of planning objectives was used for both IMRT and VMAT plans. The goal of VMAT planning is to achieve the same organ at risk (OAR) sparing, after which PTV coverage, conformal index, mean lung dose were compared with those of the IMRT plans. Both IMRT and VMAT were delivered with a Synergy-S machine (Elekta Inc). Patient specific QAs were done using MapCHECK for IMRT and MapPHAN for VMAT. As fair comparison of delivery time, IMRT beams were delivered using consolidated field sequencing to allow all beam delivered with a single beam-on command.

### Results

Both IMRT and VMAT plans passed our 95% QA criteria (5% and 5 mm). Both plans have, on average, 96% of the PTV covered by the prescription dose. Comparing mean IMRT and VMAT plan parameters for the 8 patients respectively, the minimum PTV dose was  $42.7 \pm 2.7$  ( $\pm$ SD) Gy vs.  $43.9 \pm 2.0$  Gy; the conformity index was  $1.09 \pm 0.12$  vs.  $1.06 \pm 0.04$ ; mean lung dose was  $3.7 \pm 1.2$  Gy vs.  $3.8 \pm 1.3$  Gy; the MUs per fx was  $2959 \pm 660$  vs.  $2587 \pm 380$ ; and delivery time per fx was  $9.4 \pm 2.1$  min vs.  $6.6 \pm 2.1$  min. The differences in the dosimetric parameters were statistically insignificant ( $p=0.06$ ), while the difference in delivery time with an average  $30\% \pm 12\%$  time reduction in VMAT delivery is statistically significant ( $p = 0.0001$ ).

### Conclusions

With VMAT, the delivery of hypo-fractionated SBRT treatment of lung lesions is faster comparing with traditional IMRT delivery while keeping similar OARs sparing, PTV coverage and mean lung dose. The shorter treatment time not only improves patient comfort but also reduces the possibility of intra-fraction motion. The aperture of each segment of VMAT plans changes gradually due to leaf speed constraint and would reduce the interplay effect of segment and breathing motions. Such interplay effects need further quantitative study.

### Author Disclosure

Y. Le, None; D. Song, None; E. Ford, None; J. Kang, None; J. Wong, None.

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### DOSIMETRIC COMPARISON OF VMAT, IMRT AND PROTON THERAPY FOR POST-PROSTATECTOMY RADIATION THERAPY FOR PROSTATE CANCER

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### Purpose/Objective(s)

Radiation therapy (RT) for the treatment of prostate cancer after radical prostatectomy (RP) is widely accepted. With technological advances, radiation treatment technique and dosimetry may vary. The purpose of this study is to quantify dosimetric difference of proton therapy vs. VMAT and IMRT focusing on bladder and rectal dose sparing and target coverage.

### Materials/Methods

This study analyzes a subset of twenty patients who received post-RP RT at our institution and builds on initial work comparing 3DRT to IMRT for these patients. All volumes were delineated by a single observer in accordance with EORTC consensus guidelines. A CTV expansion of 7 mm (5 mm posteriorly) was used to determine the PTV. All plans met a minimum of 95% target coverage to a prescription dose of 68.4 Gy. Optimal beam arrangement for IMRT was previously studied at our institution, leading to selection of a 9-field technique. The VMAT planning utilized either 1 or 2 full arcs depending upon optimizer performance. The

proton arrangement was opposed laterals and utilized active scanning. As this was a strict dosimetric analysis density corrections were not employed. Five patients were analyzed for this initial study. Differences of DVH values between plans were evaluated using 2-tailed paired t-tests.

### Results

Planning with all three treatment techniques demonstrated comparable PTV coverage. Difference in dose sparing of bladder or rectum between 9-field IMRT and VMAT planning was not significant. Improvement in rectal doses, proton vs. VMAT and IMRT was significant when comparing V40Gy, V34.2Gy (28%, vs. 48.16% and 45.33%,  $p = 0.016$  and  $p = 0.0004$ ). Bladder doses showed significance at V30Gy, V17.1Gy (32.58% vs. 57.27% and 62.76%,  $p = 0.045$  and  $p = 0.04$ ). Differences for VD when D.40Gy for rectum and VD when D.30Gy for bladder across all planning techniques were not significant.

### Conclusions

Proton planning resulted in greater sparing of normal tissues at lower doses with equivalent planned target coverage. Further research is necessary to determine the significance of better planned doses with protons compared to photon treatment with regard to toxicity and proven efficacy of photon therapy. The delivery efficiency with VMAT may prove a viable advantage. Cost effectiveness research is necessary to determine if the increased cost of proton therapy is outweighed by benefit to the patient if these dosimetric improvements

translate into improved clinical outcomes for PC patients.

### Author Disclosure

L.A. Doyle, None; M. Studenski, None; A. Harvey, None; A.P. Dicker, None; Y. Xiao, None; Y. Yu, None; T.N. Showalter, None; A.S. Harrison, None.

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### QUALITY CONTROL COMPARISON OF INTENSITY AND VOLUMETRIC MODULATED ARC RADIOTHERAPY (IMRT AND VMAT) FOR SPINE STEREOTACTIC BODY RADIOTHERAPY (SBRT): IMPACT OF ARC DISCRETIZATION

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### Purpose/Objective(s)

Ideally, the application of VMAT to spine SBRT should reduce the long delivery time associated with this hypo-fractionated IMRT technique. However, maintaining the stringent IMRT threshold of dose delivery accuracy should not be compromised. Our objective was to assess planned-to-delivered dose agreement using a 3D detector array for dosimetrically equivalent IMRT and VMAT spine SBRT plans, and the impact of arc discretization in the treatment planning system (TPS).

### Materials/Methods

VMAT plans with 90 control points (CPs) over 360° of gantry angle were generated using a commercially available TPS (Pinnacle3, version 8.9, Philips Medical Systems) for 15 spine metastases patients previously treated with a nine-field IMRT technique. The VMAT plans matched or exceeded IMRT plans in terms of both target coverage and organ at risk sparing. To assess the impact of arc discretization in the TPS, the 90 CP-VMAT plans were modified by doubling (180) the number of CPs using linear interpolation without plan re-optimization (gantry angular spacing reduced from 4° to 2°). The IMRT, 90 CP-VMAT, and 180 CP-VMAT plans were delivered to a hollow cylindrical 3D detector array, and the number of measurement points (pass rate) satisfying 3% of dose difference and 2 mm of distance-to-agreement tolerance were measured in addition to delivery time. Difference in the maximum spinal cord dose (D<sub>max</sub>) and target volume receiving 95% of prescribed dose (V<sub>95</sub>) were also calculated between the 90 and 180 CP-VMAT plans.

### Results

The mean detector pass rate (±SD) for the IMRT, 90 CP-VMAT and 180 CP-VMAT plans were 93.4% ± 2.9%, 87.5% ± 5.3% and 93.9% ± 2.8%, respectively. The comparison of the measured dose for the 90 CP-VMAT plans to the calculated dose for the 180 CP-VMAT plans (mean pass rate of 93.5% ± 2.9%) confirmed that the improvement in planned-to-delivered dose agreement for the 180 CP-VMAT plans was due to

a more accurate simulation of the dose distribution in the TPS with a 2° gantry angular spacing. Doubling the number of VMATCPs resulted in a small effect on the V<sub>95</sub> (maximum reduction of 3.3%). However, for one patient, the use of 180 CPs resulted in a clinically unacceptable increase in D<sub>max</sub> of 248 cGy as compared to the 90 CP-VMAT plans. As compared to IMRT, on average, treatment times were reduced by 63% and 53% for the 90 and 180 CP-VMAT plans.

### Conclusions

For spine SBRT, the 90 CP-VMAT plans provide the shortest delivery time but recomputation is recommended with a 2° gantry angular spacing for plan evaluation, and to achieve a similar planned-to-delivered dose agreement as compared to IMRT. Alternatively, VMAT plans should be optimized from the start with 180 CPs.

### Author Disclosure

D. Letourneau, None; E. Marchand, None; M.B. Sharpe, None; A. Sahgal, None.

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### VOLUMETRIC MODULATED ARC RADIOTHERAPY FOR NASOPHARYNGEAL CARCINOMA: A DOSIMETRIC COMPARISON WITH TOMOTHERAPY AND STEP-AND-SHOOT IMRT

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### Purpose/Objective(s)

Volumetric modulated arc therapy (VMAT) has been recently investigated in prostate cancer therapy because of its highly conformal dose distribution with shorter treatment time. The goal of this study was to compare VMAT with helical tomotherapy and step-and-shoot intensity-modulated radiation therapy (IMRT) for nasopharyngeal carcinoma (NPC) patients with regard to the sparing effect on organs at risk (OARs) and efficiency of delivery.

### Materials/Methods

Seventeen patients with NPC treated by helical tomotherapy were re-planned by VMAT (two arcs) and IMRT (seven to nine fields) for dosimetric comparison. The treatment planning used for VMAT and IMRT was Pinnacle3 -version 9.0. A dosimetric comparisons between VMAT, tomotherapy, and IMRT plans were analyzed to evaluate (1) coverage of planning target volume (PTV), (2) sparing of OARs, (3) delivery time, and (4) monitor units (MU).

### Results

The VMAT, tomotherapy, and IMRT plans had similar PTV coverage with an average of 96%. The homogeneity indices of VMAT (1.063) and

tomotherapy (1.058) were better than IMRT plans (1.072, p<0.001). There was no significant difference between VMAT and tomotherapy in homogeneity. Tomotherapy plans provided a better conformity index (1.17) than VMAT (1.26, p = 0.014) and IMRT (1.36, p = 0.016). The average maximum doses to spinal cord/brainstem for VMAT, tomotherapy, and IMRT were 31.4/ 49.0, 31.6/ 48.7, and 35.7/52.4, respectively. When compared with IMRT, VMAT and tomotherapy had a better sparing effect on brainstem and spinal cord (p < 0.05). The effect of parotid sparing was similar between VMAT (mean = 26.5 ± 3.3Gy) and tomotherapy (mean = 27.4 ± 2.0Gy), but better than IMRT (mean = 31.5 ± 2.4Gy, p < 0.001). The average delivery times for VMAT, tomotherapy, IMRT were 5.5 ± 1.1, 9.3 ± 0.8, and 9.1 ± 2.0 minutes. The monitor units per fraction for VMAT were much lower than for tomotherapy: 666.4 ± 45.7, and 8133.9 ± 635.6, respectively.

### Conclusions

There were no significant differences between VMAT, tomotherapy, and IMRT in the coverage of PTV; however, VMAT provided better sparing of normal tissue, homogeneity, and conformity than IMRT, and shorter delivery time and fewer monitor units than tomotherapy.

### Author Disclosure

S. Lu, None; C. Wang, None; L. Chen, None; J. Lee, None; S. Wen, None; J. Wu, None; Y. Lin, None; J. Cheng, None.

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### PARTIAL BRAIN VMAT PLANNING USING SIMULTANEOUS COUCH AND GANTRY ARCS

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#### Purpose/Objective(s)

To evaluate simultaneous gantry and couch rotation for partial brain planning using volumetric modulated arc therapy.

#### Materials/Methods

Ten patients previously treated with Step-and-Shoot IMRT for partial brain treatment were re-planned using a novel VMAT technique where both gantry and couch position was simultaneously varied. The hypothesis of this study was that simultaneous gantry and couch rotation would provide additional degrees of freedom that can further improve target coverage and spare normal structures. The treatment planning was performed using the Pinnacle3 treatment planning system and plans were developed for Elekta Synergy machine using 6MV photon beam. Pinnacle's Direct Machine Parameter Optimization module was used to optimize the aperture shapes after an initial fluence optimization. Typical prescription involved delivering 60 Gy in 2 Gy fractions. Partial single and dual arcs with a 120 degree gantry-couch span were used for VMAT planning, depending on the location

of the tumor. An optimal gantry and couch trajectory was obtained for the final plan. Dosimetric comparison was performed between VMAT plans and the original IMRT plan in terms of various dose-volume parameters such as normalized D95 for PTV and mean and max dose for the organs at risk. Total plan monitor units were also compared for these patients.

#### Results

Mean D95 to PTV was comparable to IMRT ( $99.0 \pm 1.3\%$  vs.  $98.0 \pm 0.7\%$ ) for all patients. For normal structures such as brainstem and optic chiasm the max dose was comparable between IMRT and VMAT plan. However, the mean dose to these structures was significantly reduced. Average% difference in mean doses to brainstem and optic chiasm was  $15.9 \pm 24.1$  and  $2.7 \pm 17.9\%$  respectively. For optic nerve, the% reduction in max dose and mean doses was  $14.4 \pm 15.9$  and  $32.3 \pm 19.3\%$ . Mean reduction in total planned monitor units compared to IMRT was  $29 \pm 15\%$ .

#### Conclusions

Plans based on gantry and couch simultaneous rotation showed that single and dual partial arc VMAT plans satisfied all the re-planning objectives and significantly reduced monitor units and mean doses to normal structures. Simultaneous gantry and couch rotation generates additional degrees of freedom therefore, improving target coverage and normal tissue sparing when compared to IMRT and standard VMAT plans.

#### Author Disclosure

L. Burgess, None; N. Tyagi, None; D. Ionascu, None; K. Yang, None; D. Yan, None.

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### IN VIVO DOSIMETRIC VERIFICATION OF VOLUMETRIC MODULATED ARC THERAPY FOR PROSTATE CANCER USING A RECTAL BALLOON

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#### Purpose/Objective(s)

The use of volumetric modulated arc therapy (VMAT) for prostate cancer is increasing rapidly. As part of patient-specific quality assurance, VMAT plans are verified in phantoms under the assumption that the surrogate geometry appropriately represents the scatter characteristics of the patient. However, for emerging, highly complex treatment delivery techniques, it is desirable to verify treatment delivery in the patient geometry. In this study, we examined an approach for verifying the dose delivered to the high dose volume of prostate patients during VMAT delivery using dosimeters affixed to a rectal balloon.

#### Materials/Methods

Patient selection was limited to subjects with clinical disease profiles T1-3N0M0. Patients received irradiation to the prostate volume with or without concurrent nodal irradiation. All patients received prostate immobilization during simulation and treatment delivery using the Radiadyne

water-filled rectal balloon system. VMAT plans consisting of 1 or 2 350-degree arcs were constructed using the Philips Pinnacle treatment planning system. VMAT plans were delivered using an Elekta Infinity accelerator. Prior to patient positioning, an LiF thermoluminescent dosimeter (TLD) was affixed to the exterior of the rectal balloon. Localization markers were placed 1-cm above and below the TLD along the long axis of the balloon. The balloon was encased in an ultrasound probe cover and inserted into the rectum such that the TLD was oriented along the anterior rectal wall. A daily cone beam CT (CBCT) was acquired and registered to the planning CT. Following treatment, absorbed dose measured by the TLD was compared to the planned dose at the TLD position, which was determined by correlating the position of the localization markers in the CBCT with the planning CT.

#### Results

VMAT plans provided better than 95% coverage of the planning target coverage for all patients with equal or better sparing of the rectum and bladder compared with a 7-field fixed-beam IMRT plan. The average delivery time for the VMAT plans was  $1.8 \pm 0.4$  minutes. The average measured TLD dose was  $191 \pm 19$  cGy, compared to an average planned dose at the TLD position of  $193 \pm 15$  cGy. The average percent difference between the measured and planned doses was  $-1.0 \pm 5\%$  and did not exceed 7%. Repeat TLD measurements showed intra-patient variations of less than 5%. A subsequent

sensitivity analysis revealed that dosimetric results were not sensitive to uncertainties in TLD localization.

### Conclusions

Clinical delivery of VMAT for prostate cancer has been verified in vivo using TLDs placed along the anterior rectal wall via immobilization balloon and localized on CBCT. The measurement procedure was valuable clinical tool appropriate for verification of a complex radiation therapy technology.

### Author Disclosure

J.D. Fontenot, None; M. Price, None; M. King, None.

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### DOSIMETRIC BENEFIT OF NON-COPLANAR VMAT DELIVERY

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### Purpose/Objective(s)

A key feature of VMAT is the ability to deliver non-coplanar arcs. Although the current implementations of VMAT have focused on axial coplanar delivery, non-coplanar arcs may bring additional dosimetric benefits for specific treatment sites. This work was carried out to study non-coplanar VMAT delivery for both intra-cranial and extra-cranial targets in terms of plan quality and delivery efficiency.

### Materials/Methods

Three GBM cases were selected for this study as examples for intra-cranial targets. Three extra-cranial cases with treatment sites of lung, prostate and head-and-neck were also included in this study. The Pinnacle3 SmartArc inverse planning algorithm was used to generate all the VMAT plans. A single arc was used in the axial coplanar VMAT plan for the five relatively simple cases, while two arcs were used for the H&N case. While for the non-coplanar VMAT plans, 3 to 4 arcs were used for each case with different couch angles and arc paths. Plan quality was compared between the two sets of data in terms of target dose coverage and OAR sparing. VMAT deliveries on an Elekta Synergy linac were also performed to compare the delivery efficiency.

### Results

For all six cases, the target dose coverage in both coplanar and non-coplanar VMAT plans remained essentially unchanged. As to the OAR sparing, the non-coplanar plans showed significant improvement for the cases with intra-cranial targets. For example, on average, the maximum and mean doses to brainstem were reduced from 3277 and 1016 cGy to 2524 and 668 cGy in the non-coplanar plans. These correspond to a 23% and 34% reduction. The average maximum dose to the chiasm was also reduced from 876 cGy to 346 cGy in the non-coplanar plan, a 61% reduction. For extra-cranial cases, however, there are no consistent improvements in OAR sparing for the non-coplanar plans. For the lung case, the maximum cord

dose was reduced from 926 to 579 cGy in the non-coplanar plan at the cost of the mean esophageal dose increasing from 484 to 521 cGy. For the prostate case, mean dose to the femoral heads decreased from 3389 to 2304 cGy in the non-coplanar plan, which was the only significant difference between the two plans. For the H&N case, the max dose to the cord and brainstem were reduced by 8.3% at the cost of the mean dose to these two structures increasing by 14.3% in the non-coplanar plan. The average treatment delivery time increased from 1.9 to 4.5 minutes for the non-coplanar plans.

### Conclusions

For intra-cranial cases, the use of non-coplanar VMAT can significantly improve the OAR sparing while maintaining the target dose coverage. For extra-cranial cases, only modest gains in OAR sparing were observed particularly for structures that are in close proximity to the targets. For all cases, these dosimetric benefits come at the cost of a prolonged treatment delivery time.

### Author Disclosure

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### VOLUMETRIC MODULATED ARC THERAPY FOR PROSTATE RADIOTHERAPY

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### Purpose/Objective(s)

Intensity modulated radiotherapy (IMRT) is an effective treatment modality for prostate carcinoma. A new technology, Volumetric Modulated Arc Therapy (VMAT), allows the radiation dose to be delivered continuously in a single gantry rotation. This technology promises to shorten delivery time as well as reduce the total MUs. This retrospective treatment planning study compares dosimetric quality and delivery efficiency of VMAT plans to clinically delivered IMRT plans.

### Materials/Methods

A cohort of 14 low-to-intermediate risk prostate patients (Stage T1/T2) were randomly chosen for replanning with a single VMAT arc. These patients were treated clinically with a 7-field IMRT technique (78 Gy in 39Fx). The following criteria were used to compare the plans: Conformity Index (V95/VPTV), PTV (D99, Dmax), rectum wall (D50, Dmax) and bladder wall (D50, Dmax). In addition, patient

specific QA measurements of both plan types were performed with a volumetric dosimeter to assess delivery accuracy (Gamma 2%/2 mm) as well as delivery efficiency (MUs and time). All metrics are reported as mean +/- 1 S.D. and were compared for significance with a Wilcoxon signed rank sum test statistic.

### Results

All plans met treatment planning criteria for plan acceptability as evaluated by a GU physician. The planning metrics with a statistically significant difference ( $p < 0.05$ ) were the bladder wall D50 (IMRT 39.6 +/- 3.9 Gy vs. VMAT 38.0 +/- 4.4 Gy), bladder wall Dmax (IMRT 77.8 +/- 1.0 Gy vs. VMAT 78.31 +/- 1.2 Gy) and the rectum wall D50 (IMRT 35.1 +/- 5.1 Gy vs. VMAT 38.4 +/- 3.7 Gy). In terms of delivery both the required MU's (IMRT 388.9 MUs vs. VMAT 355.4 MUs) and time (IMRT 9.5 +/- 2.7 [min] vs. VMAT 1.7 +/- 0.2 [min]) showed statistically significant difference. The Gamma analysis with 2%/2 mm (IMRT 97.1 +/- 1.7% vs. VMAT 98.0 +/- 2.0%) showed no significant difference.

### Conclusions

Equivalent target coverage and dose conformity was observed with VMAT plans. Due to the beam arrangements, VMAT offers slightly lower doses to anterior structures (bladder wall) but slightly higher doses to posterior structures (rectum wall). The key benefits for VMAT are reduced treatment delivery time and reduced MUs.

### Author Disclosure

D.J. Moseley, None; B. Zhang, None; E. Barnett, None; C. McCann, None; A. Abbas, None; L. Fenkell, None; I. Yeung, None.

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### EVALUATION OF ELEKTA VMAT FOR STEREOTACTIC BODY RADIOTHERAPY (SBRT): COMPARISON WITH HELICAL TOMOTHERAPY (HT), BRAINLAB DYNAMIC CONFORMAL ARC THERAPY (DCAT), AND FIXED FIELD THERAPY

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### Purpose/Objective(s)

The objective of this study is to report our initial evaluation of SBRT using VMAT on plan quality, dose delivery efficiency and accuracy compared with other arc therapy modalities, including HT, DCAT and CMS XiO planned fixed field therapy.

### Materials/Methods

Ten SBRT cases were investigated retrospectively for various tumor sites, including lung, liver, spine, kidney and prostate with fraction doses ranging from 6 to 15 Gy. Single-arc (full-arc or partial arc) and/or two-arc VMAT plans were generated on CMS Monaco TPS (Version 2.03.01, CMS Inc., MO) using biologically based optimization with Monte Carlo dose calculation. HT plans were created on TomoTherapy Hi?ART planning station (Version 3.2.3.2,

TomoTherapy Inc., WI) using a jaw size of 2.5 cm. DCAT plans were generated on BrainLAB radiotherapy treatment planning software (BrainSCAN, Version 5.31, Germany). Fixed field IMRT/conformal plans were developed on CMS XiO TPS (Version 4.4, CMS Inc., MO). Metrics used to evaluate the dosimetric plan quality include target coverage, heterogeneity index (HI), target mean/maximum/minimum doses, DVHs and patient mean dose. Evaluation of dose delivery efficiency and accuracy were performed using a cylindrical diode array detector system ArcCHECK (Sun Nuclear Corp., FL).

### Results

Both VMAT and HT are capable of providing more uniform target dose and better normal structure sparing compared to fixed field and DCAT plans. For lung SBRT, the PTV coverages are 95.9, 97 and 98.3% with HIs of 1.09, 1.08 and 1.13 respectively for the VMAT, HT and DCAT plans. For liver SBRT, the HI for HT plan is the lowest (1.04) compared to VMAT (1.06) and XiO (1.24). The target coverage of VMAT (99.6%) is slightly higher than the HT plan (97%). VMAT offers more efficient dose delivery than HT. Compared to HT treatment durations of 25, 17.9 and 7 min for the lung, liver and prostate cases, a reduction of 74%, 66% and 17% treatment times is measured for the VMAT plans. The estimated treatment time of DCAT for spine is reduced by 24.7% compared to VMAT plan, while for lung, liver and kidney cases, the treatment times of DCAT are comparable or shorter. The total MUs

are 1594, 6100 and 857 for the VMAT, HT and DCAT plans for the lung SBRT; 2368, 5985 and 2921 MUs for prostate and 2864, 15360 and 1464 MUs for liver for the VMAT, HT and XiO plans respectively. Plan delivery accuracy for all the modalities was comparable with average passing rates greater than 95%.

### Conclusions

Single-arc VMAT improved target uniformity and normal tissue sparing compared to CMS XiO fixed field and BrainLAB DCAT plans for SBRT. In comparison to HT, VMAT demonstrates significantly reduced treatment time and fewer MUs to achieve comparable dosimetric plans.

### Author Disclosure

X. Qi, None; A. Hu, None; W. Dzingle, None; K. Stuhr, None; H. Rice, None; Q. Diot, None; F. Newman, None.

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### INTENSITY MODULATED OR VOLUMETRIC MODULATED RADIATION THERAPY (IMRT OR VMAT) TO REDUCE ALOPECIA, XEROSTOMIA, AND OTITIS AFTER WHOLE BRAIN RADIATION THERAPY FOR BRAIN METASTASES: A PLANNING ANALYSIS

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### Purpose/Objective(s)

To investigate potential for reducing scalp, parotid, and ear dose via IMRT

(IM) or VMAT (VM) vs. standard opposed lateral (OL) beam setup to decrease incidence and severity of alopecia, xerostomia, and otitis after WBRT for brain metastases.

### Materials/Methods

Nine patients with brain metastases previously treated with standard OLWBRT using CT-planning were studied. 4 new plans were created for each patient: 1) 4-beam IM, 2) 7-beam IM, 3) 13-beam IM and 4) VM (single arc technique) and compared to the OLplan with respect to multiple normal tissue doses. IM plans included a mixture of coplanar and vertex beams set to avoid entry or exit through eyes, ears and mouth when possible. The PTV was defined as whole brain plus a 0.5cm uniform 3D expansion and prescribed 37.5Gy in 15 fractions, volumetrically for IM or VM or to midplane for OL. All plans were optimized to achieve equivalent uniform PTVcoverage and dose to lens, globe, brainstem, optic apparatus and cochlea while limiting dose to scalp (skin + 0.5cm depth), parotids and ears. Cochlear dose could not be reduced in this setting due to inclusion in the PTV(brain + 0.5cm). Multiple dose-volume histogram (DVH) parameters for PTV and organs at risk (OAR) were compared.

### Results

All multi-beam IM or VM plans significantly reduced dose to scalp, ears and parotids without increasing dose to optic n, lens, cochlea or brainstem, while maintaining homogeneity in the whole brain (WB) PTV compared to OL

plans. Exceptions were increased scalp low dose using VM (V5 +30%, V10 +10%) and increased mean lens dose with VM (7.4Gy v 4.8Gy OL). Mean PTV dose ranged from 39-40Gy for IM/VM plans vs. 38Gy for OL; PTV max dose was moderately higher for IM/VM (46-50Gy) vs. OL (42Gy). Mean dose to optic n, lens, and cochlea were 27Gy, 3.6Gy, and 33Gy and similar across plans. Improved scalp sparing was seen for low, intermediate, and high doses (V5, V10, V20, and V30) with 4- and 13-beam IM; intermediate and high doses with 7-beam IM (V10, V20, and V30) and only high doses with VM (V20 and V30) compared to OL. Depending on the DVH parameter, IM/VM reduced scalp dose 10-70%, ear dose 2-96%, parotid dose 3-31%. Across all plans, 13-beam IM achieved the largest dose reduction for scalp (V10 -10%, V20 -30%, V30 -70%), ear (V5 -10%, V10 -32%, V20 -28%, V30 -96%), and parotid (-31% mean dose).

### Conclusions

IMRT or VMAT provided sparing of scalp, ear and parotids compared to standard OL beams for WBRT. Such improvement is promising and may decrease non-cognitive WBRT toxicities (alopecia, otitis, xerostomia). 13-beam IMRT plans were superior while VMAT increased low-dose scalp and lens dose. Future planning will attempt to reduce cochlear dose to avoid hearing loss but may require WB PTV modification.

### Author Disclosure

B.R. Mancini, None; L.H. Kim, None;

S.F. Shaitelman, None; D. Yan, None; L.L. Kestin, None; I.S. Grills, None.

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### COMPARISON OF VMAT AND FIXED FIELD IMRT DELIVERY TIMES: CLINICAL RESULTS FROM AN IMPLEMENTATION STUDY

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### Purpose/Objective(s)

VMAT has been suggested to improve the efficiency of radiation delivery. We initiated a clinical study in a community cancer center to evaluate the gains in delivery efficiency for a fairly standard population of patients receiving radiotherapy.

### Materials/Methods

Patients were enrolled in an IRB approved clinical study and consented to having both fixed field IMRT and VMAT plans prepared. IMRT plans were first generated in CMS XiO. VMAT plans were then created in Pinnacle3 SmartArc to match the quality of the IMRT plans. All plans were reviewed by the treating physician. QA was performed on an Elekta Synergy linac for both sets of plans. If the VMAT plan matched all the parameters of the IMRT plan, than 20% of the prescribed fractions were treated with VMAT (in most instances one fraction per week was VMAT while the remaining 4 treatments were IMRT).

### Results

Since each patient was treated on the same machine using both an IMRT and VMAT plan, the delivery efficiency could be reported against an internal control. The 17 patients enrolled in this study included 3 brain, 2 head and neck, 10 abdomen, and 3 pelvic cases. The number of IMRT fields varied from 6 to 9 depending on the complexity of the treatment site. The delivery time for the IMRT plans were primary determined by the number of control points. VMAT plans had different numbers of arcs, for instance, 1 arc for the brain, abdomen, and pelvic cases, and 2 to 3 arcs for the head and neck cases. For brain, head and neck, abdominal, and pelvic cases respectively, the average IMRT treatment times were 14, 18, 17, and 18 minutes, while the average VMAT treatment times were 2.1, 5.4, 2.3, and 2.8 minutes.

### Conclusions

VMAT plans were delivered on average 13.6 minutes faster than fixed field IMRT.

### Author Disclosure

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### VMAT IN PROSTATE AND HEAD AND NECK (H&N) CANCER: NO MAJOR EFFECT OF MULTILEAF COLLIMATOR (MLC) LEAF WIDTH ON DOSE DISTRIBUTION

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#### Purpose/Objective(s)

We investigated the influence of two MLC on dose distribution for prostate and H&N cancer treated by VMAT.

#### Materials/Methods

Twenty cases were planned: 10 prostate cases for a total dose of 80 Gy and 10 H&N cases for a total dose of 66 to 70 Gy. All cases were planned with two different MLC (Elekta): the MLCi2 with a leaf width of 10 mm and the BeamModulator (BM) with a leaf width of 4 mm. VMAT plans were calculated with the SmartArc inverse planning algorithm of the Pinnacle system (Philips). The goal of the dose optimization was to obtain the best compromise between tumor coverage and organ at risk sparing (OAR) following standard recommendations. Qualitative analysis of isodoses distribution and exhaustive quantitative evaluation was done. Some of the

parameters used to evaluate the quality of the PTV dose distribution were minimum (Dmin) and maximum (Dmax) doses, and percentage volume receiving more than 95% of prescribed dose (V95%). Conformality was evaluated by the conformation number (CN) and the conformal index (COIN). For H&N plans we analyzed Dmax for spinal cord and brainstem, and mean dose ( $D_{mean}$ ) for parotids. For prostate plans we analyzed  $D_{max}$  and  $D_{mean}$  for rectum and bladder walls, and the dose received by 5% of femoral heads (D5%). To evaluate dose distribution on healthy tissues we used V25%, V50% and V95%.

#### Results

For PTV, with BMMLC V95% increased on average of 3.5% and 4.1% for prostate and H&N cases respectively. For PTV, Dmin increased of 0.5 Gy and 1.1 Gy for prostate and H&N cases respectively whereas Dmax varied on average of 0.4 Gy for prostate and H&N cases. Conformality was higher with MLCi2 collimator: CN values were 0.760 and 0.734 for prostate cases, and 0.671 and 0.666 for H&N cases with MLCi2 and BM collimator respectively; COIN values were 0.649 and 0.612 for prostate cases, and 0.639 and 0.613 for H&N cases with MLCi2 and BM collimator respectively. For main OAR, there were no major differences on dose distribution. For healthy tissues, with BM collimator V25% and V50% decreased of 2.8% and 10.7% for prostate cases, and 3.8% and 6.6% for H&N cases respectively whereas V95% increased of 23.9% and 9.8% for prostate and H&N cases. Plans with BM collimator required about over 10%

more monitors units. For head and neck cases, two arcs were more frequently needed using BM collimator (6/10) than with MLCi2 collimator (3/10) to obtain an acceptable dose distribution, due to more complex fluence patterns. The main disadvantage of more arcs was the increase of the delivery time. More details about quantitative and qualitative analysis will be presented.

#### Conclusions

For prostate and head and neck cancer, there was no major advantage on dose distribution using a 10mm (MLCi2) or 4 mm (BeamModulator) leaf width MLC.

#### Author Disclosure

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