

quantify the reproducibility of the eye immobilization system CT scans were co-registered using rigid 6D skull registration. With the scans co-registered x, y and z displacement of the lens/optic nerve insertion were measured manually. From these displacements, a 3D vector was calculated.

**Results:** Thirty-four patients were identified, having been treated from October 2010 to September 2015. Thirty-nine co-registrations were performed using 75 scans (2-3 scans per patient). The mean displacements of lens and optic nerve insertion were 0.1 mm and 0.0 mm – confirming that there was no systemic shift from planning to treatment. The median 3D displacements (absolute value) of lens and nerve insertion were 0.8 and 0.7 mm (SD 0.5 and 0.6 mm). Ninety-eight percent of 3D displacements were below 2 mm (maximum 2.4 mm). Following this analysis, we have not changed our GTV to PTV margin of 2-3 mm as it is also meant to account for uncertainties in planning MRI to CT registration, skull tracking as well as contouring variability.

**Conclusions:** We have found our stereotactic eye immobilization system to be highly accurate (< 1 mm) and free of systematic error.

185

#### ROLE OF VOLUMETRIC MODULATED ARC THERAPY WITH FLATTENING FILTER FREE DELIVERY IN LUNG STEREOTACTIC BODY RADIOTHERAPY

Hongwei Liu<sup>1</sup>, Ivo Olivotto<sup>2</sup>, Harold Lau<sup>2</sup>, Zoann Nugent<sup>3</sup>, Rao Khan<sup>2</sup>

<sup>1</sup>Central Alberta Cancer Centre, Red Deer, AB

<sup>2</sup>Tom Baker Cancer Centre, Calgary, AB

<sup>3</sup>CancerCare Manitoba, Winnipeg, MB

**Purpose:** To evaluate the role of volumetric modulated arc therapy (VMAT) combined with flattening filter free (FFF) beam delivery in lung stereotactic body radiotherapy (SBRT).

**Methods and Materials:** Ninety-eight Stage I lung cancer cases treated with SBRT were included. Retrospectively, single arc, 6 MV VMAT with FFF and flattened filed (FF) beam plans were generated using the identical optimization criteria with Acuros XB dose computation algorithm. Optimization constraints included target dose ratio of 50% prescription isodose volume to target (R50%) and maximal dose at 2 cm from the target (D2cm). Study parameters including the number of monitor units (MUs), mean target dose, conformality number (CN) and heterogeneity index (HI) of the target, R50%, D2cm, and mean dose to normal tissues were determined and compared for the two delivery modes. A paired matched t-test was used to compare the difference. The effect of tumour, patient and treatment mode (FFF versus FF) on the difference of MUs obtained from the two delivery systems was statistically determined using linear regression analyses.

**Results:** FFF beams required 6.9% (range -3.4 to 15.6%) more MUs and resulted in slightly higher values for mean target dose, R50% and D2cm (all  $p < 0.0001$ ) compared to FF beams. CN, HI of target and mean dose to the normal body were similar between the two plans. Logistic regression analysis confirmed that VMAT with FFF mode, not the tumour or patient specific parameters, caused the increase in MUs compared to FF beam delivery ( $p = 0.043$ ).

**Conclusions:** In lung SBRT, using VMAT with FFF beam required 7% more MUs compared to a VMAT with FF beam plan and provided similar target coverage. The low leakage dose advantage of FFF delivery is offset by the increased number of MU. The only advantage available to the FFF beams is their estimated faster delivery.

186

#### PROCESS STREAMLINING TO REDUCE RESPIRATORY VARIATION IN VISUALLY MONITORED DEEP INSPIRATION BREATH HOLD RADIATION THERAPY FOR BREAST CANCER PATIENTS

Gillian Ecclestone<sup>1</sup>, Leigh Conroy<sup>2</sup>, Roseanne Moore<sup>3</sup>, Tracey Lundstrom<sup>3</sup>, Karen Long<sup>2</sup>, Nancy Beauchemin<sup>3</sup>, Mary Loi<sup>2</sup>, Colleen Schinkel<sup>3</sup>

<sup>1</sup>Tom Baker Cancer Centre, Calgary, AB

<sup>2</sup>University of Calgary, Calgary, AB

<sup>3</sup>Tom Baker Cancer Centre, Calgary, AB

**Purpose:** Deep inspiration breath hold (DIBH) is an established technique to reduce heart and lung dose during radiation therapy for left-sided breast cancer. The visually monitored DIBH method (VM-DIBH) is a low-cost technique that employs coincident in-room lasers and skin marks to reproduce the breath hold level (BHL) achieved at CT simulation. The purpose of this study was to quantify inter-fraction BHL variability, and to perform a process review and revision to streamline and improve the current VM-DIBH process at our cancer centre. Specific guidelines, workflows, and tolerances were established to improve daily treatment accuracy, reduce systematic errors and inter-fractional respiratory variability, and mitigate potential breath hold reproducibility issues prior to treatment.

**Methods and Materials:** BH measurements were collected for 55 left-sided breast patients at the time of simulation and treatment; to determine population inter-fraction BHL differences. The BHL was determined by measuring the anterior-posterior displacement of the lateral tattoo on the affected side between free breathing and BH. Inter-fraction BHL differences were quantified to establish a baseline for improvement and a BHL tolerance for treatment to reduce the respiratory variation within the VM-DIBH technique. Respiratory reproducibility assessment guidelines to be applied during simulation were developed and validated on a cohort of 12 left-sided breast patients to determine their candidacy for VM-DIBH. This cohort of patients was treated using the new BHL tolerance and was compared to 12 patients treated using the original DIBH process. To assess acceptability of the process change, a 12 question survey was completed by Radiation Therapists prior to and following implementation.

**Results:** A 3 mm BHL tolerance was chosen for this pilot study as an achievable goal with respiratory coaching based on the population data collected ( $n = 55$ ). Sixty percent of patients had a BHL variability of  $\leq 5$  mm with 36% of patients  $\leq 3$  mm. The mean and standard deviation was 5 mm and 3 mm respectively. Tolerances greater than 3 mm were deemed too large when combined with setup errors. One hundred percent of patients treated with the new DIBH process in place ( $n = 12$ ) were able to achieve a breath hold within the 3 mm tolerance. The increased respiratory reproducibility achieved with the BHL tolerance yielded decreased setup variation in the motion vectors influenced by respiration (longitudinal and vertical directions). When localizing the isocentre on day 1 of treatment, the frequency of required couch shifts decreased by 17% in both the anterior-posterior and superior-inferior directions. The new process was well received based on the radiation therapists surveyed.

**Conclusions:** The new streamlined DIBH process improved workflows, decreased BHL variability and received positive feedback from staff. Respiratory inter-fractional errors were reduced, which may lead to reduced systematic setup errors.

187

#### DETERMINING OPTIMAL VOLUMETRIC IMAGE GUIDANCE STRATEGIES FOR BREAST BOOST RADIATION THERAPY

Winnie Li, Susanne Lofgren, Grace Lee, Paul Kwan, Robert Dinniwel, Douglas Moseley

Princess Margaret Cancer Centre, Toronto, ON

**Purpose:** Breast boost to the tumour bed following whole breast radiotherapy (RT) in breast-conserving therapy can reduce local recurrence. The aim of this study was to identify appropriate and reliable surrogates to optimize cone beam computed tomography (CBCT) image registration for breast boost patients to reduce inter-user variability.

**Methods and Materials:** Daily localization CBCT images are acquired and any positional discrepancies corrected prior to three-field conformal breast boost treatment delivery. Under ethics approval, patients receiving breast boost RT between October and December 2014 were included in this retrospective

analysis. Patients were categorized into three groups based on their cavity visibility on CT: C1 (indistinct or no visible cavity); C2 (moderately visible cavity with indistinct borders); and C3 (highly visible cavity). Three observers manually registered the CBCTs for each patient utilizing two methods and materials: matching the ipsilateral breast/chest wall and lung interface as the target surrogate, and direct registration to the cavity. Krippendorff's alpha was used to assess agreement between the two methods. Root mean square (RMS) was calculated to assess the difference between observers.

**Results:** Thirty breast boost patients, 10 in each cavity visualization category, were included for analysis. A total of 150 CBCT images were analyzed by each observer. Registration to the ipsilateral chestwall/breast reported a median RMS error of 0.1989 between observers. Direct registration to the cavity resulted in a median RMS error of 0.1784 between observers. The Krippendorff's alpha for ipsilateral chestwall/breast registration in C1, C2 and C3 patients in the left-right (LR), cranio-caudal (CC), and anterior-posterior (AP) directions were: 0.8, 0.84, 0.9; 0.81, 0.72, 0.55; and 0.78, 0.6, 0.52, respectively. The Krippendorff's alpha for direct cavity registration in C1, C2 and C3 patients in the LR, CC, and AP directions were: 0.72, 0.64, 0.84; 0.86, 0.72, 0.62; and 0.75, 0.6, 0.58, respectively. The ranksum difference between registration methods was  $p = 0.1538$ , with variation reported between cavity visualization categories (C1,  $p = 0.8903$ , C2,  $p = 0.0257$ , C3,  $p = 0.9450$ ).

**Conclusions:** Image registration to the ipsilateral breast/chest wall and lung interface for breast boost RT was more consistent than direct registration to the cavity, resulting in lower inter-observer variability for breast boost IGRT. Varying visibility of the post-operative tumour bed on CBCT images limits direct registration to the breast cavity.

188

## VOLUMETRIC WHOLE BRAIN IRRADIATION EVALUATION

Sheila Sze, Matthew Follwell, Muoi N Tran

Simcoe Muskoka Regional Cancer Centre, Barrie, ON

**Purpose:** Whole brain radiotherapy (WBRT) has been effectively used for palliative treatment of brain metastases, and for prophylactic treatment in cancers shown to commonly metastasize to the brain. A retrospective investigation was completed to compare the traditional whole brain osseous-based field placement technique to a volumetric based technique with respect to clinical target volume (CTV) coverage, planning target volume (PTV) coverage, and the optic lens Dmax.

**Methods and Materials:** This study included 47 patients treated with field-based WBRT in an aqua plastic mask at the Simcoe Muskoka Regional Cancer Program between July 2012 and July 2013. On the 3D CT image, the CTV (brain) was contoured with a 5 mm PTV margin, a contour-based plan was generated using the Multileaf Collimators to conform to the PTV with a 7 mm penumbra margin and 5 mm shielding around the optic lens. The plan was then normalized using  $V95\% \geq 99\%$  to PTV with a Dmax point dose  $\leq 115\%$ . This contour-based plan was then compared to the original field-based plan. Descriptive statistics was used for analysis.

**Results:** The mean values for the field based plans and the contour based plans are as follows. CTV  $V95\%$ : 99.55%, SD = 0.47% compared to 99.96%, SD = 0.08%; PTV  $V95\%$ : 98.62%, SD = 0.82% compared to 99.73%, SD = 0.21%, optic lens Dmax: 3.66 Gy, SD = 3.09Gy compared to 3.68 Gy, SD = 0.78 Gy.

**Conclusions:** This study demonstrates an increase in CTV  $V95\%$  of 0.41% and PTV  $V95\%$  of 1.11% with the volumetric based WBRT planning technique compared to the traditional osseous field-based technique. A contour-based WBRT approach ensures standardization in generating a plan and eliminates the inter-operator variability amongst the radiation oncologists, while maintaining comparable optic lens Dmax dose.

189

## VAGINAL SPARING WITH VOLUMETRIC MODULATED ARC THERAPY (VMAT) FOR RECTAL CANCER

Scott Boulet, Bashir Bashir, Oliver Bucher, Eric VanUytven, John Ioculano

University of Manitoba, Winnipeg, MB

**Purpose:** Compare dosimetric differences between VMAT plans with and without an objective to spare the vagina, to determine whether the volume of the vagina that receives 20 (V20 Gy), 30, 40, 45, or 50 Gy could be reduced. Secondary objectives included whether the maximum dose (Dmax) delivered, and the mean dose (Dmean) delivered are significantly different between the two treatment plans

**Methods and Materials:** Ten patients with rectal cancer previously treated with 3D conformal radiotherapy were selected for this study. All patients received 50.4 Gy in 28 fractions of radical neoadjuvant RT for T3, N1-2, low rectal cancers. Two VMAT plans were created for each patient; one with an objective to spare the vagina and one without. Target coverage and sparing of other organs at risk were not compromised between the two VMAT plans. Differences in vaginal dose was determined using Wilcoxon signed-rank tests. The selected threshold for significance was  $p$ -value  $\leq 0.05/7$  using a Bonferroni correction for multiple comparisons.

**Results:** Significant differences were observed for the median Dmax and Dmean doses delivered, and the median V50Gy volumes; 52.6 versus 49.6 Gy ( $p = 0.0051$ ), 49.9 versus 47.8 Gy ( $p = 0.0051$ ), and 47.6 versus 0% ( $p = 0.0051$ ) respectively. V45 Gy volumes also appeared different between the two treatment plans and would be considered significant at the  $p$ -value  $\leq 0.05$  threshold, but because the threshold  $p$ -value was adjusted using the Bonferroni correction, it was no longer significant. The dosimetric differences between V20 Gy, V30 Gy, and V40 Gy were not significant.

**Conclusions:** VMAT planning using an objective to spare the vagina can significantly reduce the volume of vagina receiving 50 Gy, as well as the Dmax and Dmean, without compromising target coverage or adjacent organs at risk dose constraints.

190

## REDUCING RADIATION THERAPY READY-TO-TREAT TO TREATMENT START TIMES

Cynthia Stulp<sup>1</sup>, Andrew Chacko<sup>2</sup>, Karen Long<sup>1</sup>, Coline Dirkse<sup>1</sup>, Tien Phan<sup>1</sup>, Ivo Olivotto<sup>1</sup>, Raman Dhoot<sup>1</sup>, Colleen Schinkel<sup>1</sup>, Alison Gourley<sup>1</sup>, Victoria Hladka<sup>1</sup>, Darren Graham<sup>1</sup><sup>1</sup>Tom Baker Cancer Centre, Calgary, AB<sup>2</sup>Alberta Health Services, Calgary, AB

**Purpose:** To determine the impact of a process improvement project on the Ready-to-Treat to Treatment (RTT-to-RTx) target which had been reduced from 90% within four weeks to 90% within 2.6 weeks in a nine-linac cancer centre with a pre-project RTT-to-Tx interval of 90% within 3.8 weeks.

**Methods and Materials:** Using a process improvement methodology based on LEAN and Six Sigma principles, the defined opportunity goal, was to reduce the RTT-RTx for patients receiving RT for breast cancer (25% of the centre's RT courses) by 30% from 3.8 weeks to 2.6 weeks (27 days reduced to 18 days), within six months, without negatively impacting other tumour groups. The RTT-to-RTx data was reported as three monthly rolling averages. The improvement process was structured along six components: Define Opportunity, Build Understanding, Manage Change, Act to Improve, Sustain Results, and Share Learning. To define the opportunity, a six-hour, current state process mapping occurred. This demonstrated that the existing process had many steps/hand-offs/interruptions/waits without much continuous flow. The value stream map showed that there was inconsistent use of the RTT date, an average lead time from Booking to Treatment of 12-13 working days (18 calendar days), and only five to eight hours of value added time. Building understanding included presentations to radiation oncology, therapist and clerical groups.