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BHPA-symposium 2022

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Scientific Session

Topic: Radiotherapy Patient positioning/SGRT/IGRT

Chair: Koen Tournel (Jessa, Hasselt)

Saturday 30/04/2022 10h40-11h55

Auditorium 2000

In-bore surface guided DIBH breast VMAT treatments in a closed-bore linac

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ABSTRACT – This study presents preliminary results on a fully surface guided deep-inspiration workflow for left-sided breast cancer patients.

KEY WORDS – VMAT, deep-inspiration breath-hold (DIBH), surface scanning, intrafraction motion monitoring

Introduction

An in-bore surface scanning system to monitor patients in the closed-bore linac Halcyon (Varian Medical Systems) has recently become available, AlignRT InBore (VisionRT Ltd.). We treated 4 patients in deep-inspiration breath-hold (DIBH) and assessed inter and intra fraction motion and workflow efficiency.

Materials and methods

Four left-sided breast cancer patients were treated in DIBH on Halcyon using a triple partial arc VMAT technique with simultaneous integrated boost (SIB) for 21 fractions. Setup was performed with the ceiling mounted AlignRT system and patients were shifted into the Halcyon bore. A manual switch to the AlignRT InBore system was required for our research system. At the treatment isocenter, AlignRT InBore monitored the breast surface and patients performed video-coached breath-holds, figure 1. Delivery was manually interrupted when the patients left the breath-hold window (± 3mm, 3°). Portal images were acquired during delivery using framegrabber hardware and software (iTools, Varian Medical Systems) at gantry angle 130°. Inter fraction, intra fraction and intra-breath-hold motion were extracted from surface, CBCT and portal image data. The efficiency of the surface guided workflow was assessed by collecting setup time, time at the isocenter and total fraction duration from both AlignRT as Record and Verify timestamp information.

Results

A total of 64 complete fractions were available for analysis. Inter fraction systematic (Σ) and random (σ) setup errors were Σ =1.0mm, σ =1.2 mm for the AP, Σ =1.3mm, σ =1.8 mm for the SI and Σ =1.1mm, σ =1.7 mm for the LR axis. The mean intra fraction errors were 0.0 ± 1.0 mm for the "AP" axis (linear combination of the AP and LR component) and 0.4 ± 1.0 mm for the SI axis as detected on portal images, see figure 2. Intra-breath-hold motion was limited to median 1 mm for the AP, 1.3mm for the SI and 0.6 mm for the LR axis. Median total fraction duration was 10 min 1 sec which includes a mean 2 minutes of idle time (figure 1) to switch from the patient setup to the InBore AlignRT system. A median 5 min 15 sec was spent at the treatment isocenter (including CBCT acquisition, position verification and VMAT delivery). 92% of all fractions were completed in 4 breath-holds of mean 25 sec duration.

Conclusion

Full surface guided DIBH workflows using both AlignRT for patient setup as AlignRT InBore on the Halcyon linac proved efficient with good inter and intra fraction reproducibility.

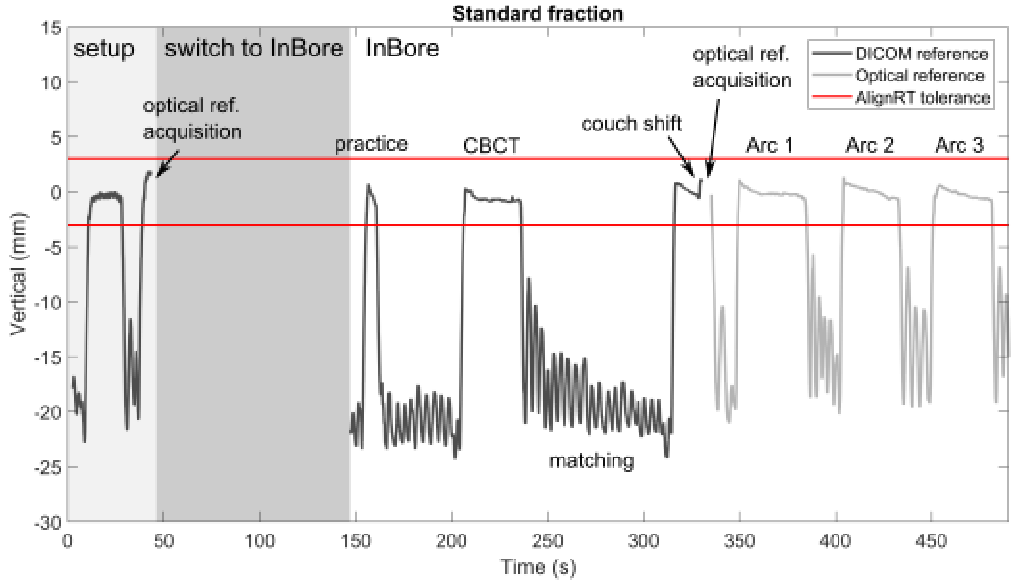

Figure 1: The vertical (AP) deviation of the breast monitored for an entire treatment fraction after initial setup in free breathing. After patient setup RTTs acquire an optical reference and switch to the InBore system (which takes 100 seconds as the patient file has to be closed and re-opened on a different computer). Patients are shifted to the treatment isocenter after which another practice breath-hold is performed. A CBCT is acquired within one breath-hold after which RTTs perform a 3D online matching to the planning CT. Patients are instructed to perform a breath-hold and couch corrections are performed followed by the acquisition of a new optical reference. The treatment is delivered in 3 breath-holds.

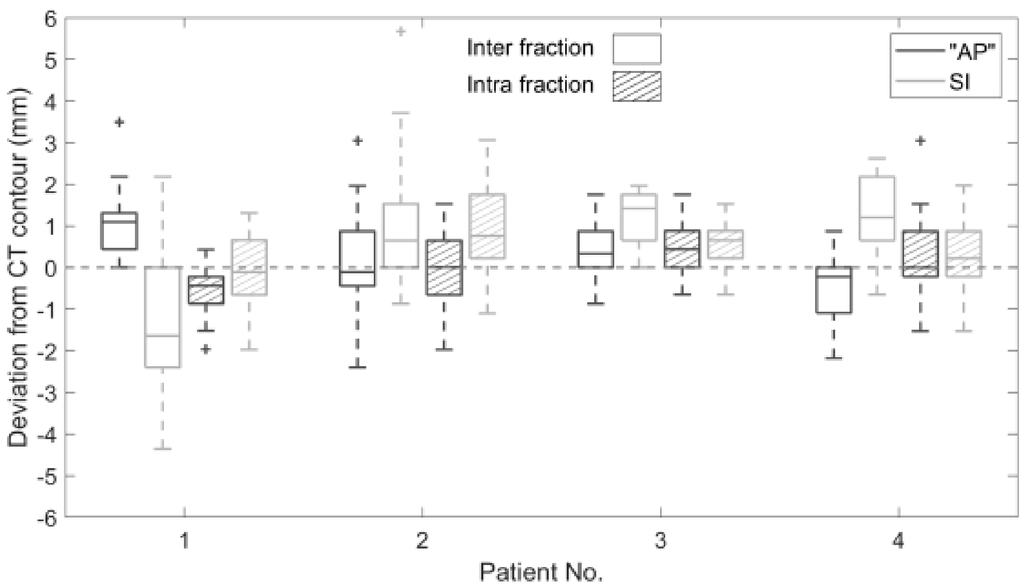

Figure 2: Residual inter and intra fraction error as detected on portal images (PI). Images were registered to the body contour and lung-chest wall interface. As PIs are acquired at 130° gantry angle the "AP" deviation is a linear combination of the AP and LR error.

Implementation of a class solution protocol for breast cancer treatment

D. Dechambre[1], L. Gofflot[1], E. Sterpin[1]
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ABSTRACT – The purpose of this work was to define a protocol of class solution to help standardize the treatment planning, specifically for breast cancer treated with DMLC. 30 plans were designed and verified to ensure the stability of the system. The plans showed a better CTV coverage compared to the original ones and a controlled complexity. Based on the results, a proposition was made to replace some of the QA process by computerized verifications.

KEY WORDS – IMRT, Breast cancer, Class solution

Introduction

Due to the recent increasing complexity of radiotherapy techniques, quality assurance processes (QA) are now becoming more and more important in the treatment process to manage uncertainties and to ensure a good concordance between the planned dose and the delivered dose. However, these verifications are time consuming. For a defined set of patients, a class solution protocol consists in guidelines for the planification and the verification of treatment plans. This could allow physicists to obtain a controlled complexity and ensure a relative similarity between the plans created. It ultimately allows the physics team to let go a part of the QA process. This work aimed to build a class solution protocol, following the NCS22 guidelines[1]. It focused on the treatment of breast cancer by means of DMLC technique at the Cliniques Universitaires Saint-Luc (CUSL).

Materials and methods

The class solution protocol was created over 30 patient cases, all previously treated at CUSL for breast cancer. 30 plans were created using treatment planning system RayStation v.9B, each consisting of 2 tangential beams. The protocol was established using 20 patients (group A), then validated over 10 patients (group B). The dosimetric properties of plans created for the group A were compared to the original plans, and group A and group B were also compared to ensure stability of the class solution. Usual DQA were performed for each plan on a 2D ion chamber matrix, as well as a secondary dose calculation (SunCheck), by means of a gamma evaluation. This secondary calculation acts as a computerized verification, which is evaluated as a replacement to the physical tests. 5 more plans were submitted to thorough testing using ionization chamber and film dosimetry in a cheese phantom.

Results

Two optimization volumes were defined and a planification organigram was created to guide the user, associated to a template of dose constraints. Wilcoxon tests showed that the CTV coverage (V95%) is increased for the new plans (p= 0,019) and that mean dose to ipsilateral lung is decreased (p=0,0036). Regarding the other results, no statistical difference was observed, proving the plans created were at least as good as the original plans. The comparison between group A and group B showed similar plan quality and complexity. All DQAs and secondary dose calculations successfully passed the gamma evaluation (γ3%/2mm). The secondary dose calculation proved to be in good concordance with the measures in the cheese phantom, with even better results than the TPS.

Conclusion

Thanks to the guidelines provided to the user, the class solution protocol helps to standardize the planification so that we expect less sub-optimal plans. The measures and computations performed proved the stability of the class solution. Considering those results, we proposed a simplification of the QA process, replacing the “physical” tests by computerized verifications with SunCheck, therefore reducing the team workload and sparing machine time use, while ensuring the quality of the treatment.

References

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Gantry triggered x-ray verification of patient positioning during single-isocenter stereotactic radiosurgery using ExacTrac Dynamic: increasing certainty of lesion localization.

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ABSTRACT - Gantry triggered stereoscopic x-rays are used to position, verify and monitor patients during single-isocenter stereotactic radiosurgery. Positioning errors during beam delivery from 24 treatments were analyzed. Mean errors across all patients were 0.18 mm, 0.07 mm and 0.16 mm for longitudinal, lateral and vertical displacements, and 0.13°, 0.12° and 0.11° for roll, pitch and yaw rotations. A beam-off strategy is to be considered when measured intra-arc errors are out of tolerance.

KEY WORDS – Stereotactic radiosurgery, intra-fraction monitoring, brain metastases, patient positioning, stereoscopic x-rays.

Introduction

Single-isocenter linac-based stereotactic radiosurgery (SRS) has emerged as a dedicated treatment option for multiple brain metastases. To do so, image-guidance for patient positioning and motion management is becoming very important. The purpose of this study was to analyze the translational and rotational intra-fraction errors during SRS, by applying surface-guidance coupled with gantry triggered stereoscopic x-ray verifications during the arc delivery. The benefits of such a positioning system were also assessed.

Materials and methods

Treatments were planned with non- coplanar dynamic conformal arcs for 24 patients corresponding to 93 brain lesions. Intra-arc positioning errors were measured using stereoscopic x-rays (ExacTrac Dynamic, BrainLAB, Munchen, Germany), triggered in the middle of every treatment arc (234 arcs in total). Couch corrections above 0.7 mm and 0.5° are always applied. Intra-arc positioning data was analyzed and compared to those of a previous study in our department, where intra-fraction stereoscopic x-rays were only taken after each couch rotation.

Results

Intra-arc errors ranged between 0 mm and 1.64 mm for translations and 0° and 0.88° for rotations (Figure 1). Total 3D displacement ranged between 0.03 mm and 1.64 mm. 95th percentiles of errors across all arcs delivered were 0.58 mm, 0.47 mm and 0.32 mm for longitudinal, lateral and vertical displacements, and 0.46°, 0.27° and 0.43° for roll, pitch and yaw rotations respectively. Mean errors across all patients were 0.18 mm, 0.07 mm and 0.16 mm for longitudinal, lateral and vertical displacements, and 0.13°, 0.12° and 0.11° for roll, pitch and yaw rotations (Table 1). 6 out of 24 patients showed at least one arc above the correction thresholds (0.7 mm for translations, 0.5° for rotations), corresponding to 17 treatment arcs (7% of delivered beams). When compared to inter-beam errors measured after table rotation, the mean errors measured were considerably smaller (Figure 2), ranging from 38.2% (lateral) to 80% (longitudinal) reduction.

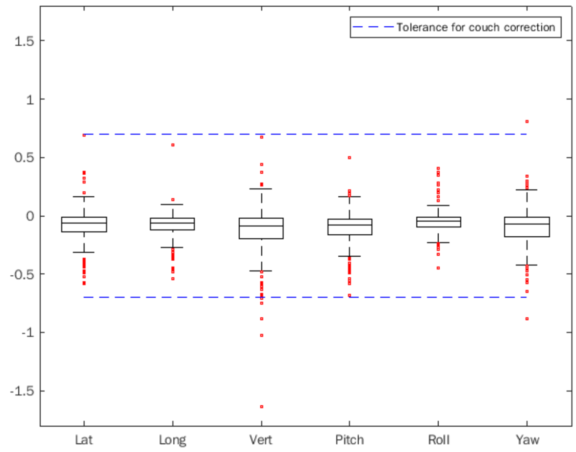

Figure 1 – Intra-arc translational (mm) and rotational (°) errors.

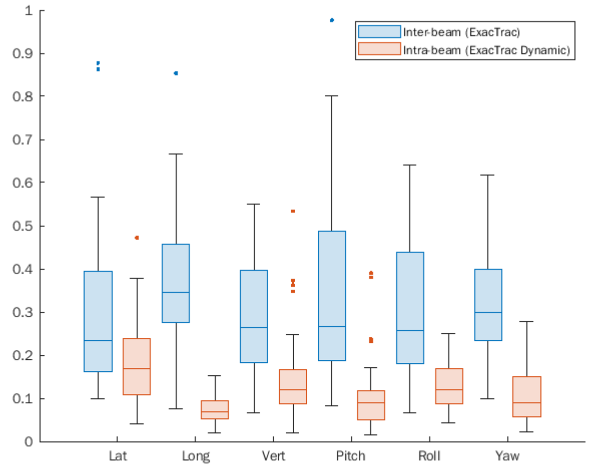

Figure 2- Mean absolute intra-arc errors per treatment (mm and °)

	Mean	SD	Median	90th percentile	95th percentile	99th percentile	Max
Lateral	0,18	0,10	0,17	0,317	0,47	0,57	0,69
Longitudinal	0,07	0,03	0,07	0,404	0,59	0,87	1,64
Vertical	0,16	0,12	0,12	0,219	0,32	0,48	0,61
Pitch	0,12	0,10	0,09	0,347	0,46	0,56	0,68
Roll	0,13	0,05	0,12	0,18	0,27	0,37	0,45

Table 1 – Absolute intra-arc errors (mm)

Conclusion

Gantry triggered x-ray verification provides information of the real position of the patient during irradiation and allows verification of the couch corrections performed before every arc. When comparing inter-arc and intra-arc positioning errors, we could identify table rotation as an important source of patient motion. A beam-off strategy is to be considered when measured intra-arc errors are out of tolerance, as the frequency of corrections would not increase treatment times considerably. Intra-arc monitoring and correction with stereoscopic x-rays increases the certainty of lesion localization, making a 0 mm margin strategy possible.

Functionality-optimised radiotherapy for lung cancer patients using 4DCT

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ABSTRACT – This retrospective study investigated the implementation of functional planning for lung cancer patients using 4DCT Jacobian percentile-based ventilation to reduce RILI risks related to the mean dose and functional lung receiving at least 20 Gy. Ventilation maps were generated using peak respiration images from 4DCT scans and deformable image registration. Ventilation was inserted into the planning process using percentile-based contours. Anatomical and functional planning were compared through 20 plans, showing significant dose endpoints reduction without major drawback. (Maximum 80 words)

KEY WORDS – 4DCT, Ventilation, Lung, Functional Planning, FLART

Introduction

The risk of Radiation-Induced Lung Injuries (RILI) is directly related to the volume of functional lung receiving at least 20 Gy (V_{20Gy}) and to its mean dose (D_{mean})[1-7]. Reducing these doses by implementing functional lung imaging in radiotherapy (RT) treatment planning could reduce the risks of RILI [8,9]. The aim of this study is to retrospectively investigate the feasibility of 4DCT-based functional RT treatment planning for thoracic tumors using available clinical tools.

Materials and methods

Twenty selected patients underwent a 4DCT (Aquilion LB, Canon Medical Systems Europe B.V., Zoetermeer, The Netherlands) for a thoracic RT treatment between July and October 2020. Peak Inhalation (PI) and Peak Exhalation (PE) 4DCT images were used to calculate ventilation via the Jacobian method using the default intensity-based free-form deformable image registration on MIM Maestro (v7.0.6, MIM Software Inc., Cleveland, USA). Functional lung contours FL75, FL60, FL50 and FL25 were segmented by thresholding the ventilation distribution at the 25th, 40th, 50th and 75th percentiles, respectively, then transferred on the initial planning CT with a rigid registration of the PI image. Two Monaco (v5.51, Elekta AB., Stockholm, Sweden) VMAT plans were optimized for each patient with a 33x2 Gy prescription: one anatomical plan using classical constraints and one functional plan with ALARA constraints on V_{20Gy} and D_{mean} for FL60 and FL25. Intra-method difference between functional volumes was assessed using a Kruskal-Wallis test. Dose improvements were assessed using a paired Wilcoxon double-tailed signed-rank test. Functional volumes and dose differences were compared with our previous work based on SPECT. A $p<0.05$ significance level was used for each test.

Results

The Jacobian method provided 4 distinct ($p<0.001$) volumes (Figure 1) larger than their perfusion SPECT counterparts ($p<0.00001$). DVHs showed a reduction in almost all doses for functional lung contours, anatomical lung and the body, with no substantial change in the dose to the target and organs at risk. Results (Figure 2) show a reduction of median V_{5Gy}, V_{20Gy} and D_{mean} in all lung volumes ($p<0.01$). However, median V_{40Gy} increased in FL75, anatomical lungs and body ($p<0.01$). Small changes were found for the PTV dose coverage, although all constraints were met. No significant changes were observed in doses to the heart, esophagus, and spinal canal. Good agreement was found with our SPECT-based study regarding the impact of functional planning.

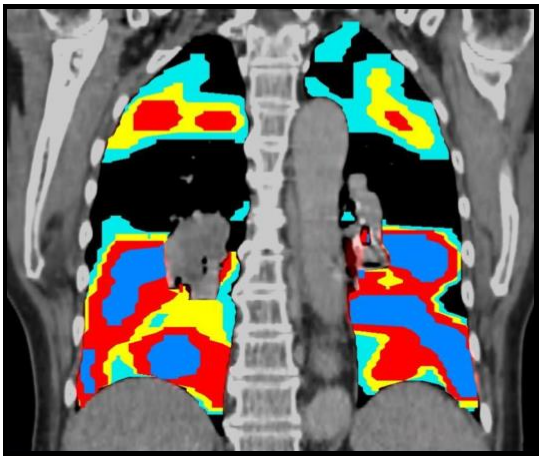

Figure 1: Example of segmented functional contours FL75 (cyan), FL60 (yellow), FL50 (red), FL25 (blue).

Table 1: Median dose improvements (green) and drawbacks (red) in volumes of interest. The p-value is obtained with a paired Wilcoxon double-tailed signed-rank test.

VOI	Dose Parameter	Anatomical Plan	Functional Plan	Median Difference	p-value
PTV	V95% (%)	95.85	95.17	-0.68	p<0.01
	D50% (Gy)	66.05	66.38	0.33	p<0.001
FL25	V5Gy (%)	27.67	22.82	-4.85	p<0.01
	V20Gy (%)	5.77	4.78	-0.99	p<0.001
	V40Gy (%)	1.45	0.68	-0.77	P<0.01
	Dmean (Gy)	5.74	4.48	-1.26	p<0.001
	Dmax (Gy)	66.43	67.28	0.85	n.s.
FL50	V5Gy (%)	37.13	31.16	-5.97	p<0.0001
	V20Gy (%)	8.52	8.21	-0.31	p<0.00001
	V40Gy (%)	4.38	4.02	-0.36	p<0.001
	Dmean (Gy)	7.58	6.88	-0.70	p<0.001
	Dmax (Gy)	68.15	68.95	0.80	p<0.05
FL60	V5Gy (%)	35.77	34.03	-1.74	p<0.0001
	V20Gy (%)	11.64	10.44	-1.20	p<0.00001
	V40Gy (%)	4.99	4.44	-0.55	p<0.001
	Dmean (Gy)	8.32	7.79	-0.53	p<0.00001
	Dmax (Gy)	68.63	69.18	0.55	p<0.05
FL75	V5Gy (%)	38.87	31.78	-7.09	p<0.0001
	V20Gy (%)	12.32	10.55	-1.77	p<0.00001
	V40Gy (%)	5.76	5.99	0.23	p<0.01
	Dmean (Gy)	9.02	8.12	-0.90	p<0.0001
	Dmax (Gy)	69.05	69.35	0.30	p<0.01
Lungs	V5Gy (%)	36.89	30.57	-6.32	p<0.0001
	V20Gy (%)	11.38	9.92	-1.46	p<0.00001
	V40Gy (%)	5.96	6.35	0.39	p<0.01
	Dmean (Gy)	8.56	7.50	-1.06	p<0.0001
	Dmax (Gy)	69.68	69.80	0.12	n.s.
Heart	Dmean (Gy)	1.85	1.92	0.07	n.s.
	Dmax (Gy)	11.20	13.53	2.33	n.s.
Oesophagus	Dmax (Gy)	26.08	26.03	-0.05	n.s.
Spinal Canal	Dmax (Gy)	32.33	32.38	0.05	n.s.
Body	V5Gy (%)	33.63	32.58	-1.05	p<0.01
	V20Gy (%)	12.87	12.89	0.02	n.s.
	V40Gy (%)	3.91	3.99	0.09	n.s.
	Dmean (Gy)	3.90	4.02	0.12	p<0.01
	Dmax (Gy)	70.10	70.38	0.28	n.s.

Conclusion

The 4DCT-based Jacobian ventilation method was successfully implemented using clinical tools while delivering promising results regarding functional lung avoidance to mitigate RILI. All results were consistent with the literature. Future work should concentrate on improving the implementation of 4DCT ventilation in the RT planning workflow and investigating functional planning at a larger scale. This opens the way for prospective functional lung avoidance studies.

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