

INTRODUCTION

- Accelerated Partial Breast Irradiation (APBI) is a radiation therapy given only to the part of the breast that has cancer in it or where the tumor was removed after lumpectomy and is to deliver higher dose over a shorter period than standard whole breast treatment.
- Current standard for APBI is 3D conformal radiation therapy (3D-CRT) by utilizing multiple fields with different gantry, collimator, wedges, and couch angle and follows RTOG 0413 protocol.
- Varian Halcyon is a ring mounted LINAC that is designed to deliver modulated ARC treatments and only has 6MV flattening filter free (FFF) beam will target better and lower the dose spillage on normal breast tissue.
- Halcyon LINAC also has four times faster gantry speed and two times faster MLC speed than Truebeam LINAC could decrease treatment time and decrease patient movement error.

AIM

Overall Aim

Evaluate whether 3D-CRT APBI plan is replicable on Halcyon LINAC with better dose sparing on normal breast tissue and shorter treatment time.

Aim #1: Re-plan APBI clinical plans from University of Kentucky (UK) on Halcyon LINAC.

Aim #2: Evaluate and determine the clinical feasibility of the treatment plan.

Aim #3: Check quality assurance of delivery accuracy.

METHOD

- Ten randomly selected APBI patients who has been treated in UK clinic using mixed energy flattened beams (6-18 MV) were re-planned on Halcyon with VMAT using avoidance sector with same fractions and dose prescription.
- Halcyon plan angles were chosen to cover the planning target volume (PTV) and avoidance sectors were utilized to minimize dose to lung and heart.
- Final dose calculations were performed with advanced AcurosXB algorithm.
- PTV conformity and OAR doses were compared to each other as well as to constraints listed in the RTOG 0413 protocol¹.
- Out of field dose (e.g. $V_{50\%}$, $V_{80\%}$, and $V_{100\%}$) and delivery efficiency (total MU, treatment time) were evaluated for all plans.
 - Treatment time was calculated by dividing MU from dose rate for each method.
 - 3D-CRT: 400 MU/min, Halcyon: 800 MU/min

RESULTS

Table 1. Comparison of doses on 3D-CRT(6-18MV) and Halcyon(6MV-FFF) plan to RTOG 0413 protocol¹ for 10 APBI patients treated in UK. Mean \pm Standard Deviation values reported. All plans met with RTOG 0413 constraints. Halcyon plans had greater conformity compared to the 3D-CRT plans with better CI ($p < 0.001$). Doses to ipsilateral breast also decreased by 5.74% for $V_{100\%}$ ($p < 0.001$) and 9.3% for $V_{50\%}$ ($p < 0.001$). Dose to heart when treating left breast increased by 16.92% ($p = 0.001$) but still within RTOG 0413 dose limits.

Structures	RTOG 0413 ¹	3D-CRT	Halcyon
PTV _{eval}	$V_{90\%} > 90\%$	$99.83 \pm 0.17\%$	$99.88 \pm 0.28\%$
	Max < 120%	$105.88 \pm 1.79\%$	$108.34 \pm 0.4\%$
	Conformity Index	1.39 ± 0.23	0.99 ± 0.02
Ipsilateral Breast	$V_{100\%} < 35\%$	$26.23 \pm 8.32\%$	$20.49 \pm 6.56\%$
	$V_{50\%} < 60\%$	$54.75 \pm 9.89\%$	$45.45 \pm 9.13\%$
Contralateral Breast	$D_{max} < 3\%$ of Rx	$1.8 \pm 0.64\%$	$2.47 \pm 0.57\%$
Ipsilateral Lung	$V_{30\%} < 15\%$	$5.48 \pm 3.63\%$	$7.05 \pm 4.78\%$
Contralateral Lung	$V_{5\%} < 15\%$	$0.0 \pm 0.0\%$	$0.90 \pm 1.83\%$
Heart (Left)	$V_{5\%} < 40\%$	$2.23 \pm 1.10\%$	$19.15 \pm 10.3\%$
Heart (Right)	$V_{5\%} < 5\%$	$0.0055 \pm 0.0077\%$	$0.90 \pm 0.47\%$
Thyroid	$D_{max} < 3\%$ of Rx	0.20%	0.50%

Table 2. Comparison of isodose volume and treatment time on 3D-CRT(6-18MV) and Halcyon(6MV-FFF) plan for 10 APBI patients treated in UK. Mean \pm Standard Deviation values reported. The normal breast $V_{50\%}$ ($p = 0.002$), $V_{80\%}$ ($p = 0.001$), and $V_{100\%}$ ($p = 0.009$) were significantly lower with all the Halcyon plans. Total MU for 3D-CRT and Halcyon was 400.1 ± 77.45 and 664.88 ± 145.85 , respectively. Treatment time was calculated by using total MU and dose rate (3D-CRT: 400 MU/min, Halcyon: 800 MU/min). Halcyon plan showed shorter treatment time than 3D-CRT ($p < 0.001$).

Structures		3D-CRT	Halcyon
Isodose Volume [cm ²]	$V_{50\%}$	936.8 ± 536.5	745.1 ± 422.8
	$V_{80\%}$	697.9 ± 409.1	427.7 ± 246.2
	$V_{100\%}$	394.5 ± 263.9	257.7 ± 156.4
Treatment Time [min]		1.00 ± 0.19	0.84 ± 0.18

Figure 1. Dose distributions of 3D-CRT original clinical plan using 18MV beam (left), and Halcyon plan using 6MV-FFF beam (right). Halcyon plan showed better dose conformity ($p < 0.001$) around PTV than 3D-CRT plan. Better normal breast tissue dose sparing is also shown for Halcyon plan with reduced $V_{50\%}$ ($p = 0.002$), $V_{80\%}$ ($p = 0.001$), and $V_{100\%}$ ($p = 0.009$)

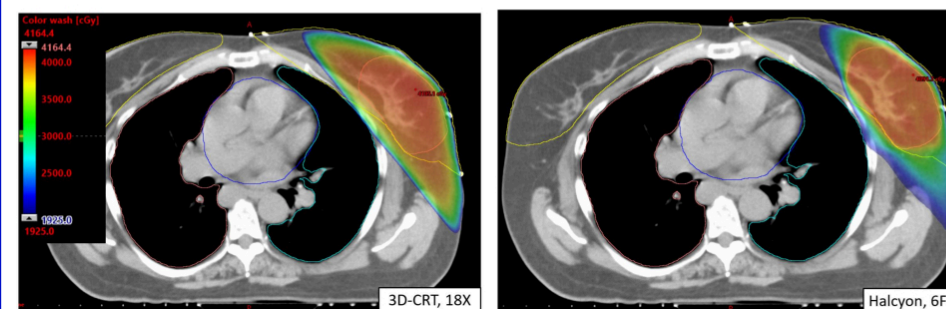


Figure 2. Dose Volume Histogram (DVH) comparing 3D-CRT plan (triangle) to Halcyon plan (square). DVH of PTV_{eval} (pink) of the Halcyon plan drops faster than the 3D-CRT plan after 97% coverage. Ipsilateral breast DVH (yellow) on Halcyon plan is much lower compared to the 3D-CRT plan.

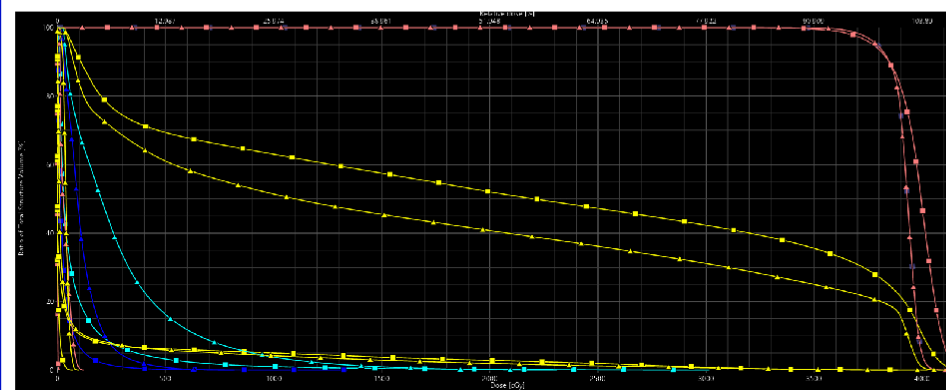
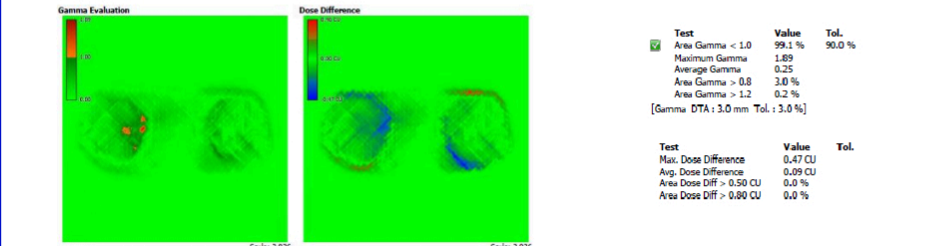


Figure 3. Quality Assurance (QA) done using portal dosimetry with 3%/3mm gamma analysis passing rate. Three arcs were used for this plan and the pass rates for each arcs were 99.3, 99.4%, and 98.1%.



CONCLUSIONS

- All re-planned Halcyon plans were met with RTOG 0413 constraints
- Halcyon produced more conformal dose around the target than 3D-CRT with the average CI of 0.99 ± 0.02 ($0.96-1.02$) and 1.39 ± 0.23 ($1.17-1.86$), for Halcyon and 3D-CRT respectively
- $V_{50\%}$, $V_{80\%}$, and $V_{100\%}$ decreased significantly on Halcyon plan compared to 3D-CRT plan
- Treatment time was shorter on Halcyon than 3D-CRT. If considering all the gantry, collimator, wedges, and couch angle rotation between each fields, this will be more significant.
- Dose to the OARs increased but all within RTOG 0413 dose limits
- For left breast treatment, heart dose increased significantly but still within RTOG 0413 dose limits
- Future work will include further optimizing APBI Halcyon plans to lower dose to heart and using Halcyon APBI technique with Deep Inspiration Breath Hold (DIBH)

SUMMARY

- Halcyon plan produced better conformity around the target and reduced doses to normal breast tissue than 3D-CRT.
- Doses to the OARs increased on Halcyon plan but still followed RTOG 0413 protocol.
- Using DIBH could help with decreasing doses to the OARs

REFERENCES

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