Increase in Superficial Dose in Whole-Breast Irradiation with Halcyon™ Straight-through Linac Compared to Traditional C-arm Linac with Flattening Filter: In-vivo Dosimetry and Planning Study

Fionnbarr O'Grady PhD[1], Andrew R. Barsky MD[1], Shibu Anamalayil MS[1], Gary M. Freedman MD[1], Christopher Kennedy PhD[1], Bin Cai PhD[2], Eric Laugeman MS[2], Lei Dong PhD[1], Geoffrey D. Hugo PhD[2], James M. Metz MD[1], Sasa Mutic PhD[2], Neil K. Taunk MD MS[1], Taoran Li PhD[1]

[1]Perelman School of Medicine of the University of Pennsylvania, [2]Washington University School of Medicine in St Louis

Introduction

Purpose: To assess the need for bolus when treating breast cancer patients with Halcyon given the higher superficial dose associated with the beam.

Motivation: Bolus is often applied in treating breast cancer to increase superficial dose to reduce the risk of local recurrence. This is particularly important with PMRT where recurrences often involve the scar, subcutaneous tissue or the dermis itself[1].

Halcyon (Varian Medical Systems, Palo Alto USA) is a novel medical accelerator, that features a straight-through linac with a single 6 MV flattening filter free (FFF) beam within an enclosed bore geometry. The mean energy of the beam is lower than a flattened beam of the same nominal energy in a conventional C-arm linac. This is primarily due to the removal of the flattening filter and may be compounded by the straight-through linac design and electron contamination from the bore cover acting as a spoiler. The lower mean energy of the beam leads to higher superficial dose.

Proposal: Superficial dose must be studied for breast and chest wall patients treated with Halcyon to determine the appropriate treatment techniques, in particular the need for bolus, for management of skin coverage and toxicity.

Fig. 1 Rando phantom Setup showing OSLD placement

Methods and Materials

In-vivo Study: OSLD measurements were made on 11 breast patients treated with Halcyon. Two OSLDs were placed in each section of a 3x3 grid across the surface of the breast.

Phantom Study: To study the difference in superficial dose in a controlled setting, measurements were made of the Halcyon 6 MV FFF beam and a TrueBeam 6 MV FF beam delivered to an anthropomorphic Rando™ phantom (Imaging Solutions, Brisbane, Australia) with a 2cm layer of bolus underneath to simulate breast tissue. Measurements were made on the TrueBeam with and without an 1cm layer of bolus above the OSLDs to mimic clinical practice. The OSLDs were placed in the same configuration as described for the in-vivo study (Fig.1).

All in-vivo and phantom measurements used Landauer nanodot OSLDs which have an intrinsic buildup of 0.04 g/cm^2[2].

Planning Study: 16 patients treated on Halcyon were re-planned with a conventional linac (Clinac or TrueBeam) to determine the difference in superficial dose predicted by the TPS (Eclipse v15.5). Measures were taken to increase the accuracy of the TPS surface dose.

Patient Characteristics	In-Vivo (11 pts)	Planning (16 pts)
Laterality		
Right	8 (72.7 %)	8 (50 %)
Left	3 (27.3 %)	8 (50 %)
Position		
Supine	9 (81.8 %)	13 (81.3 %)
Prone	2 (18.18 %)	3 (18.7 %)
Target		
Whole Breast	6 (54.6 %)	14 (87.5 %)
Whole Breast + LNs	5 (45.4 %)	2 (12.5 %)
Surgery		
Intact Breast	7 (63.6 %)	14 (87.5 %)
Mastectomy w/ recon	3 (27.3 %)	2 (12.5 %)
Mastectomy no recon	1 (9.1 %)	0 (0 %)

Table 1. Patient characteristics for the in-vivo and planning studies

Results

In-vivo and Phantom Measurements

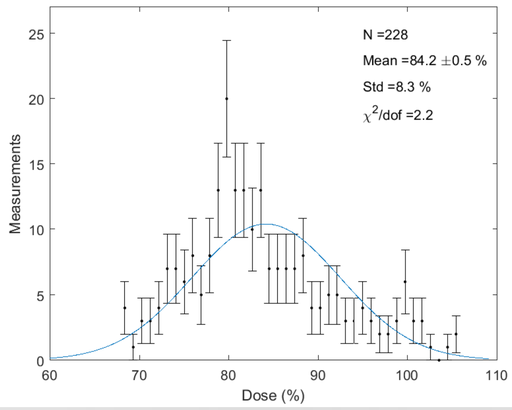

Fig 2. Histogram of in-vivo and phantom superficial dose measurements

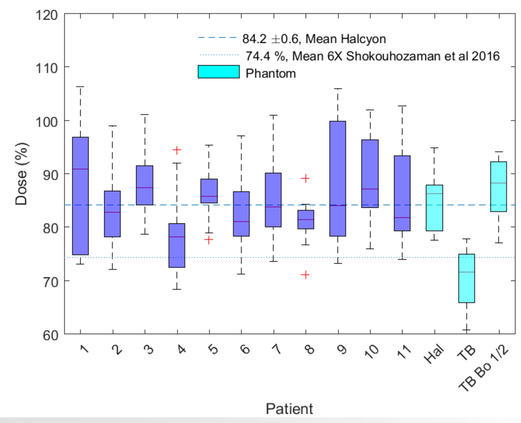

Fig 3. Superficial dose measurements vs patient and phantom measurements for Halcyon, TrueBeam and an average of TrueBeam with and without bolus. Average value for 6 MV FF shown for comparison[3]

Planning Study

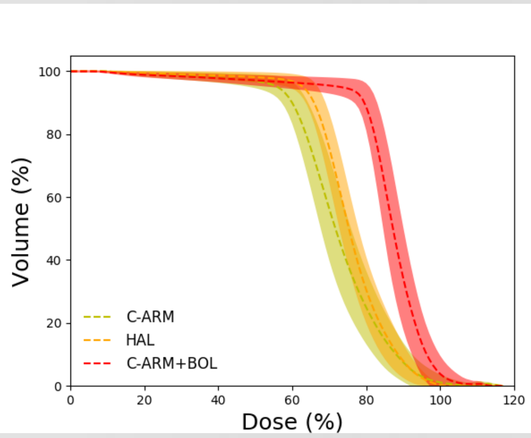

Fig 4. Comparison of breast skin DVH for C-arm linac (yellow), Halcyon (orange) and C-arm linac w/ bolus every other day (red). The dashed curve and bands represent the mean and 1 sigma variation

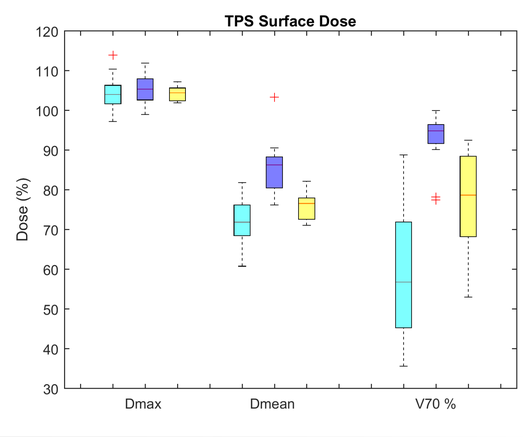

Fig 5. Comparison of Dmax, Dmean and V70% for breast skin structure calculated in Eclipse for C-arm FF linac (cyan), C-arm FF linac + bolus every other day (blue) and Halcyon (yellow)

Conclusions

- In-vivo and phantom measurements demonstrate 10-15% increase in superficial dose for Halcyon 6 MV FFF compared with 6 MV FF
- TPS superficial dose comparison also shows an increase for Halcyon, however it does not reflect the full magnitude of the increase observed in the in-vivo and phantom measurements.

References

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3. Soleymanifard et al, Wspolczesna Onkol. 2016:20(2): 137-40

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