Breast LN 40.05Gy/15Fx: Modal Description, Structures and Scorecards

Purpose
This document provides instructions on how to apply the ***"RNSH_Breast_LN_SIB_40.05_15_v1.0"*** Model and ***"RNSH_LT_Breast_LN_SIB_40.05_15 v1.0"*** and ***"RNSH_RT_Breast_LN_SIB_40.05_15 v1.0"*** Scorecard for clinical use within your institution.

Please refer to the following manuscript for additional information if required:
Comprehensive nodal breast VMAT: solving the low-dose wash dilemma using an iterative knowledge-based radiotherapy planning solution
https://pubmed.ncbi.nlm.nih.gov/34387031/

Overview
A knowledge-based planning (KBP) model is designed to provide a simple and robust comprehensive VMAT solution for intact breast and post mastectomy comprehensive lymph node (CLN) radiotherapy treatments without increase in low dose wash.

The dose prescription which the model is compatible with is 40.05Gy in 15 Fractions with the addition of a 48Gy simultaneous integrated boost (SiB) as required.

This model was created using three 6FFF arc Halcyon plans calculated on ARIA Eclipse (Version 16.1.4) with Acuros External Beam (Version 15.6.06) and Photon Optimiser (Version 16.1.0) but is also compatible on TrueBeam with Acuros External Beam (Version 15.6.06) and jaw tracking.

Overshoot was used via "SkinFlash-Bolus" of at least 0.5cm and is included into the function of model and planning process.

The "**Automatic Intermediate Dose**" function of the Photon Optimizer was utilized with **MR3** level of restart and **convergence mode** and/or **convergence mode: extended** selected in the calculation options. These **settings should be changed prior to starting the optimization or plan quality will be compromised. Plan normalisation is for all plans to account for skin flash in the optimisation.**

The model estimates the DVH for Breast_Contra, Heart, Humeral_Head, LADCA, Larynx, Liver, Lung_Contra, Lung_Ipsilat, Oesophagus, Spinal_Cord, Thyroid and Trachea. Additional derived structures such as zzAnt_Tune, zzBrst_sub_Bst, zzLung_Crop and zzNTO also receive DVH estimates.

The Breast_LN_40.05Gy/15Fx model was created using the following process/guidelines.

CT Simulation
Every patient must have simulation planning CT in the desired treatment position being Head first Supine with both arms raised above head. The CT scan length must include superior border of Mid Mandible to 5cm INF of infra mammary fold ensuring the entire lungs are captured.

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Target and OAR Contouring Guidelines

Delineation of the target volumes is performed by the Radiation Oncologist (RO) in accordance with ESTRO consensus guidelines. Structure names **must** follow the ESTRO nomenclature and TG-263 naming conventions. OAR contouring is to follow the below table.

Target Contouring Guideline

Name	Guideline
CTVp_Br/CW	CTV Breast (off pec major & 5mm under skin), CTV Chest Wall (off pec major & 2mm under skin **or** cropped 0mm for inflammatory disease)
CTVp_TB	CTV Boost (5mm margin to TB, cropped inside CTVp_Br/CW)
CTVn_L1	CTV Axilla Level 1
CTVn_L2	CTV Axilla Level 2 (includes interpectoral lymph nodes)
CTVn_L3	CTV Infraclavicular Level 3
CTVn_L4	CTV SCF Level 4
CTVn_IMN	CTV IMC
PTVp_Br/CW	PTV Breast (CTVp_Br + 5mm expanded, cropped 5mm from skin), PTV Chest Wall (CTVp_CW + 5mm expanded, cropped 2mm from skin **or** cropped 0mm for inflammatory disease)
PTVp_TB	PTV Boost (CTVp_TB + 5mm expanded, cropped inside CTVp_Br/CW [prevents overlap with ribs])
PTVn_Ax	PTV Axilla (CTVn_L1 +CTVn_L2 +5mm expanded, cropped 5mm from skin)
PTVn_SCF	PTV SCF (CTVn_L3 + CTVn_L4 + 5mm expanded, cropped 5mm from skin)
PTVn_IMN	PTV IMC (CTVn_IMN + 5mm expanded, cropped 5mm from skin)

OAR Contouring Guideline

Name	Guideline
Heart	Heart
Heart (LLesion/RLesion)	Heart (per RTOG guidelines) (Copy of heart for rapid plan model)
Breast_Contra	Contralateral Breast, cropped from skin to match CTVp_Br or CTVp_CW
Humeral_Head	Humeral Head (to level of neck of humerus)
Larynx	Larynx
Liver	Liver (Right Sided Only)
Lung_Ipsilat	Ipsilateral lung (excludes trachea/main bronchus)
Lung_Contra	Contralateral lung (excludes trachea/main bronchus)
SpinalCord	Spinal Cord (extends 3cm above and below PTV)
LADCA	Left anterior descending coronary artery
BrachialPlex	Brachial Plexus
Thyroid	Thyroid (includes both lobes and isthmus)
Trachea	Trachea
Oesophagus	Oesophagus (hypo pharynx to GEJCP)
GEJCP	Gastro-Esophageal Junction

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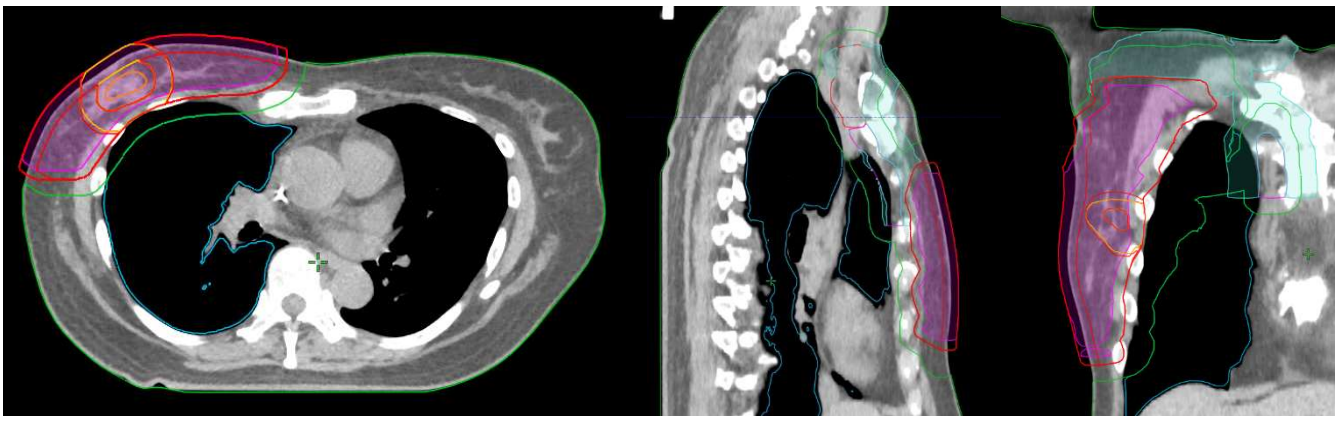
Optimisation Structures Guidelines

Name	Guideline
zzPTVp_Br	**PTVp_Br/CW** (1.0cm LAT, 0.0cm MED, 1.0cm Ant, 0.0cm POST, 0.0cm INF, 0.0cm SUP)
zzCTVp_Br	**CTVp_Br/CW** (1.0cm LAT, 0.0cm MED, 1.0cm Ant, 0.0cm POST, 0.0cm INF, 0.0cm SUP)
zzPTVp_TB	**PTVp_TB**
zzCTVp_TB	**CTVp_TB**
zzBrst_sub_Bst	**zzPTVp_Br – zzPTVp_TB**
zzPTV_Ring	margin from **PTVp_TB** (1.0cm LAT, 1.0cm MED, 1.0cm Ant, 1.0cm POST, 0.5cm INF, 0.5cm SUP), crop inside zz**PTVp_Br**
	zzPTV_Ring sub **(zzPTVp_TB + zzCTVp_TB)**
zzPTVn_IMN	**PTVn_IMN – (PTVn_SCF + PTVn_Ax + zzPTVp_Br + zzPTV_Ring + zzPTVp_TB + zzCTVp_TB)**
zzPTVn_SCF	**PTVn_SCF – (PTVn_Ax + zzPTVp_Br + zzPTV_Ring + zzPTVp_TB + zzCTVp_TB)**
zzPTVn_Ax	**PTVn_Ax – (zzPTVp_Br + zzPTV_Ring + zzPTVp_TB + zzCTVp_TB)**
zzPTVp_Br	**zzPTVp_Br – (zzPTV_Ring + zzPTVp_TB + zzCTVp_TB)**
zzPTVp_TB	**zzPTVp_TB – zzCTVp_TB**
Brst_sub_Bst	**PTVp_Br – PTVp_TB**
Humeral_Head_PRV	**Humeral_Head (10mm margin all directions)**
Sternum_PRV	**Sternum (5mm margin all directions)**
Clavicle_PRV	**Clavicle (5mm margin all directions)**
zzLung_Crop	**Lung_Ipsilat** Cropped 1cm from **(PTVn_IMN + PTVn_SCF + PTVn_Ax + PTVp_Br/CW + zzPTV_Ring + PTVp_TB + CTVp_TB)**
zzNTO	**Body** - Cropped 1cm from **(PTVn_IMN + PTVn_SCF + PTVn_Ax + zzPTVp_Br/CW +zzPTV_Ring + zzPTVp_TB + zzCTVp_TB)**
zzAnt_Tune	**(PTVn_IMN + PTVnSCF)** margin of (2.0cm Lat, 2.0cm Med, 2.0cm Ant) – **(PTVn_IMN + PTVn_SCF + PTVn_Ax + zzPTVp_Br +zzPTV_Ring + zzPTVp_TB + zzCTVp_TB)** Crop 5mm from Body

*****zzBreast PTVs and CTVs will extend outside the body structure to provide skin flash overshoot*****



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Target Planning Guidelines

Total Dose		
Clinical Goal Summary		
Brst_sub_Bst	P3	D 90.0 % > 36.05 Gy
	P3	V 42.00 Gy < 10.0 %
CTVn_IMN	P1	D 98.0 % > 38.05 Gy
	P1	D 2.0 % < 42.05 Gy
	P1	D 0.1 cm^3 < 42.85 Gy
CTVn_L2	P2	D 98.0 % > 38.05 Gy
	P2	D 2.0 % < 42.05 Gy
	P2	D 0.1 cm^3 < 42.85 Gy
CTVn_L3	P2	D 98.0 % > 38.05 Gy
	P2	D 2.0 % < 42.05 Gy
	P2	D 0.1 cm^3 < 42.85 Gy
CTVn_L4	P2	D 98.0 % > 38.05 Gy
	P2	D 2.0 % < 42.05 Gy
	P2	D 0.1 cm^3 < 42.85 Gy
CTVp_Br	P2	D 98.0 % > 38.05 Gy
CTVp_TB	P1	D 98.0 % > 47.04 Gy
	P1	D 2.0 cm^3 < 51.36 Gy
	P1	D 0.1 cm^3 < 52.80 Gy
PTVn_IMN	P1	D 95.0 % > 38.05 Gy
PTVn_SCF	P3	D 95.0 % > 38.05 Gy
PTVp_Br	P3	D 90.0 % > 36.05 Gy
	P3	V 45.66 Gy < 30.0 %
PTVp_TB	P1	D 95.0 % > 45.60 Gy
Breast_Contra	P3	Dmean < 1.00 Gy
	P3	D 2.0 cm^3 < 5.00 Gy
Heart_LLesion	P2	Dmean ≤ 1.50 Gy
	P2	V 2.00 Gy < 30.0 %
	P2	V 8.00 Gy < 5.0 %
	P2	V 13.00 Gy < 2.0 %
	P2	V 35.00 Gy < 5.0 %
Humeral_Head	P4	D 0.1 cm^3 < 24.00 Gy
LADCA	P2	D 0.1 cm^3 ≤ 15.00 Gy
Liver	P4	D 2.0 cm^3 < 36.00 Gy
	P4	D 4.0 cm^3 < 30.00 Gy
Lung_Contra	P3	Dmean ≤ 1.00 Gy
	P3	V 2.50 Gy < 15.0 %
Lung_Ipsilat	P2	Dmean ≤ 8.00 Gy
	P2	V 4.00 Gy < 45.0 %
	P2	V 12.00 Gy < 30.0 %
	P2	V 18.00 Gy < 15.0 %
Oesophagus	P4	V 24.00 Gy < 5.0 %
Spinal_Cord	P4	D 0.1 cm^3 < 12.00 Gy
Trachea	P4	D 0.1 cm^3 < 38.00 Gy

Planning Process

All cases used to train and to validate the model were planned using 3 ipsilateral VMAT 6FFF arcs.

RT SIDE Patients	1: g200 -6 0, c350, CW
	2: g60- 200, c0, CCW
	3: g200- 60 CW, c10, CW
LT SIDE Patients	1: g300 -160, c350, CW
	2: g160 - 300, c0, CCW
	3: g300 – 160, c10, CW

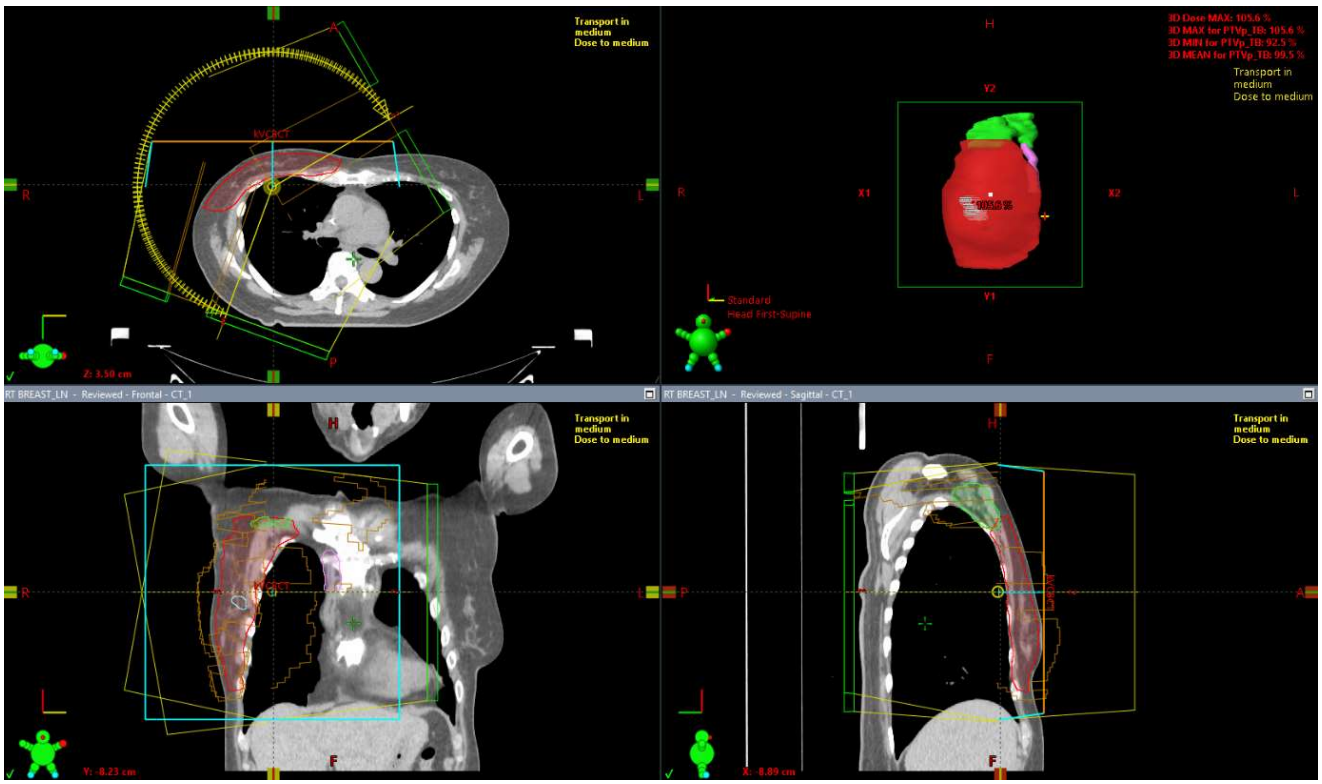
Calculation Models

In the Calculation Model Tab, select 'edit' on the Photon Optimizer Section and change "**Convergence Mode**" to "**On**", "**MR Level at restart**" to **MR3** and "Aperture shape controller" to **Moderate**.

Convergence mode	On
MR level at restart	MR3
Aperture shape controller	Moderate

Isocentre Placement

Adjust isocentre placement SUP/INF so that **all** target volumes fit within field borders throughout arc rotation.



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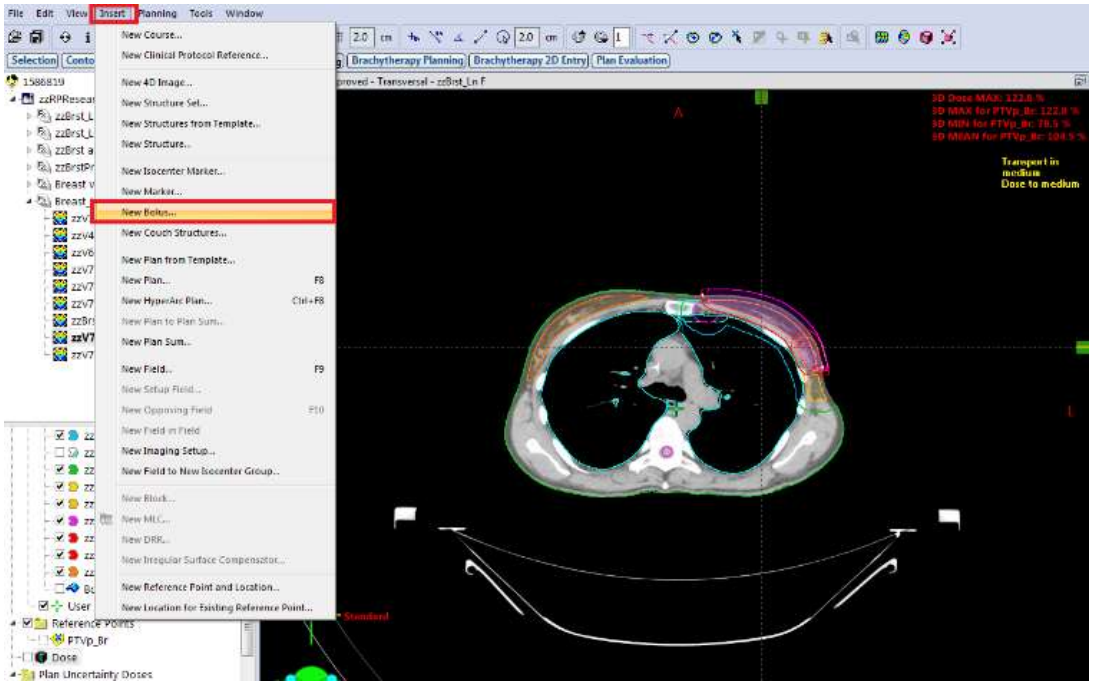
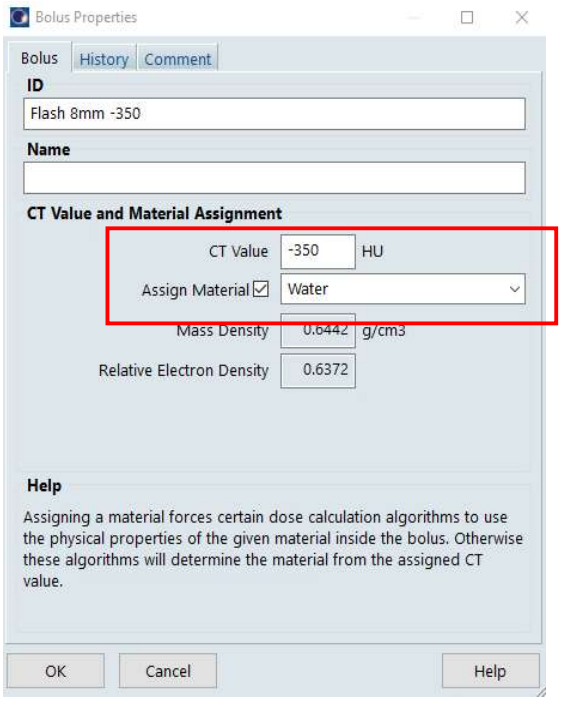
Adding Overshoot for Skinflash

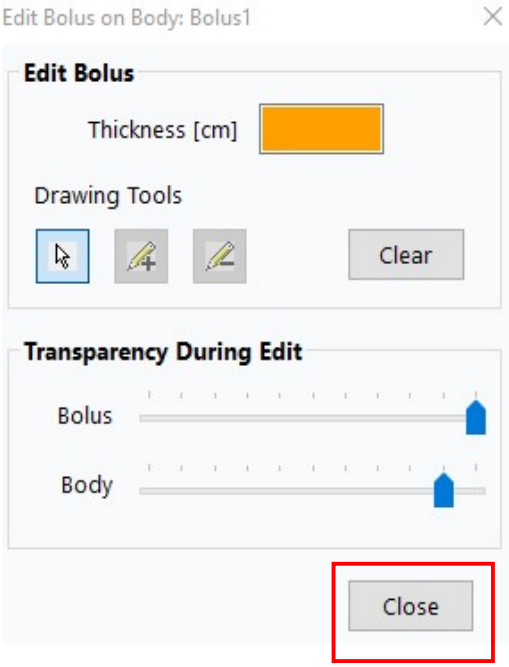
To account for swelling and/or intra-fraction motion (change in breath-hold position) during treatment after image-match, overshoot for skin flash is required (helps maintain D90% > 90% to the target volumes for a 5mm shift in x/y/z patient positioning).

1. Select insert, new bolus:



2. Assign material water and change CT value to “-350” HU, OK and close.

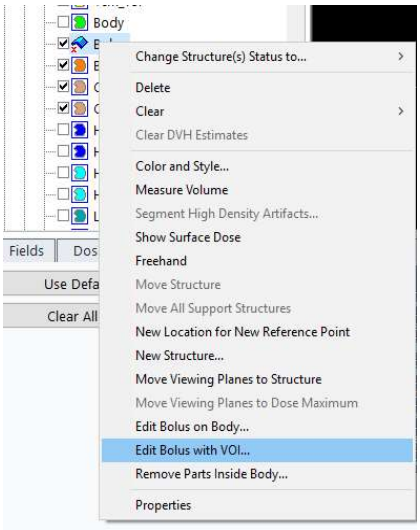


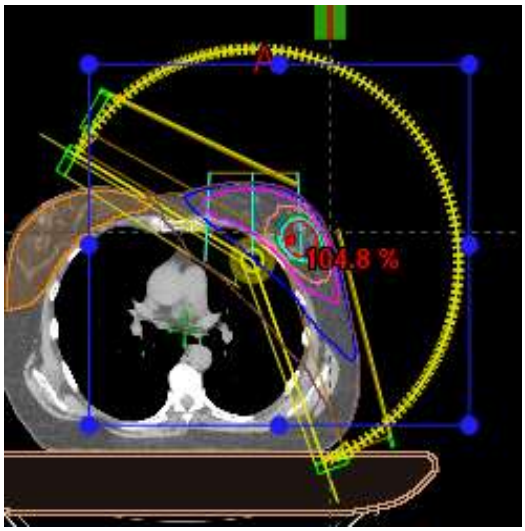


3. Change ID to **"Flash (thickness HU)**" e.g. Flash 8mm -350

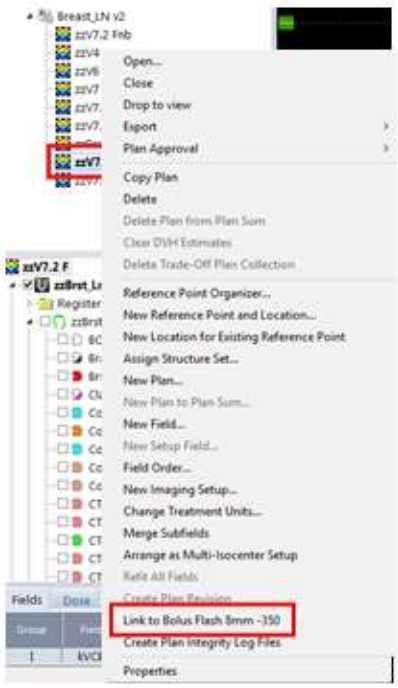
    - Breast (PTVp_Br cropped 5mm off skin): thickness = 8mm
    - Chest wall (PTVp_CW cropped 2mm off skin): thickness = 10mm
    - Inflammatory chest walls (PTVp_CW extends to skin): thickness = 12mm

4. The default is to draw on the body, instead Right Click on new Bolus structure and use Edit bolus using VOI - Ensure VOI covers **all** target volumes and entry points





5. Once created, Right click plan and link to "Bolus Flash Xmm -350". **Do NOT** link any CW bolus at this stage.



Structure Codes

Organ Name in Model	Code in Model	Planning Name in Model	Code in Model
Heart	7088	**zzPTVp_Br**	236190
Heart_(LLesion/RLesion)	236176	**zzCTVp_Br**	236248
Breast_Contra	236178	**zzPTVp_TB**	236214
Humeral_Head	25929	**zzCTVp_TB**	13360
Larynx	55097	**zzPTV_Ring**	224292
Liver	7197	**zzPTVn_IMN**	235800
Lung_Ipsilat	236182	**zzPTVn_SCF**	236138
Lung_Contra	236180	**zzPTVn_Ax**	235802
SpinalCord	7647	**zzBrst_sub_Bst**	24510
LADCA	3862	**zzLung_Crop**	24516
BrachialPlexs	5906	**zzNTO**	24517
Thyroid	9603	**zzAnt_Tune**	24515
Trachea	7394		
Oesophagus	7131		

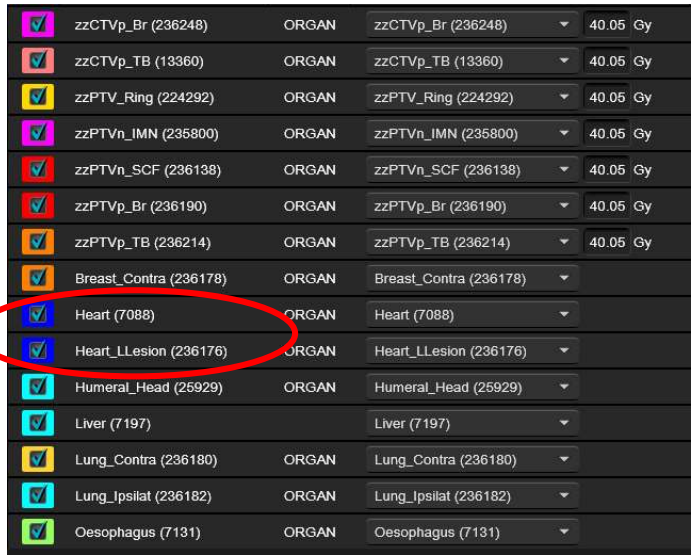
****Please note structure codes of 'zz' structures were only used to assist within inner department automation processes****

Optimisation

Open Optimisation tab (press F7)

- Confirm structures have attached correctly. Doses will be prefilled – all targets should have the whole **breast dose.** Press 'Generate Estimates and Objectives'.
- Note: The RapidPlan models are based on SKAGEN priority in order of: CTV/PTV_TB → CTV/PTV_IMC → LAD → Heart → Ipsi-lung → CTV_Br/SCF/Ax→ PTV_Br/SCF/Ax → Contra-lung → Contra Breast → Other OAR

please make sure "Heart" AND "Heart_ R/L Lesion" are BOTH attached and enter all target doses as whole breast dose



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Optimization Objectives

The following optimization objectives were defined in the model and will be generated when the model is applied to a new case:

Target	ID	Vol [%]	Dose	Priority	gEUD a
Yes	zzCTVp_Br (236248)				
	Lower	96.0	101.0 %	150	
	Lower	99.9	100.0 %	150	
	Lower	97.0	99.0 %	200	
	Lower	100.0	93.0 %	200	
Yes	zzCTVp_TB (13360)				
	Upper	0.0	124.1 %	100	
	Lower	100.0	121.1 %	150	
Yes	zzPTV_Ring (224292)				
	Upper	0.0	120.0 %	100	
	Upper	10.0	113.7 %	100	
	Lower	100.0	101.0 %	120	
Yes	zzPTVn_Ax (235802)				
	Upper	0.0	104.0 %	150	
	Upper	0.1	102.0 %	120	
	Lower	98.0	100.0 %	130	
	Lower	100.0	98.0 %	120	
Yes	zzPTVn_IMN (235800)				
	Upper	0.0	104.0 %	150	
	Upper	0.1	102.0 %	115	
	Lower	99.5	97.8 %	160	
	Lower	100.0	92.0 %	120	
Yes	zzPTVn_SCF (236138)				
	Upper	0.0	104.0 %	150	
	Upper	0.1	102.0 %	120	
	Lower	98.0	100.0 %	130	
	Lower	100.0	98.0 %	120	
Yes	zzPTVp_Br (236190)				
	Upper	0.0	104.0 %	160	
	Upper	0.1	101.4 %	100	
	Lower	98.0	98.0 %	140	
	Lower	100.0	96.0 %	140	
Yes	zzPTVp_TB (236214)				
	Upper	0.0	124.2 %	100	
	Lower	98.0	121.1 %	150	
	BrachialPlexs (5906)				
	Breast_Contra (236178)				
	Upper	1.0	4.000 Gy	160	
	Mean		Generated	170	
	Heart (7088)				
	Mean		Generated	180	
	Line (preferring target)	Generated	Generated	50	
	Heart_LLesion (236176)				
	Mean		Generated	180	
	Line (preferring target)	Generated	Generated	50	
	Heart_RLesion (236174)				
	Mean		Generated	180	
	Line (preferring target)	Generated	Generated	50	

Target	ID	Vol [%]	Dose	Priority	gEUD a
	Humeral_Head (25929)				
	Upper (fixed dose, generated vol.)	Generated	22.000 Gy	50	
	Mean		Generated	50	
	Upper gEUD		21.500 Gy	50	40.0
	LADCA (3862)				
	Upper	0.0	13.000 Gy	200	
	Larynx (55097)				
	Mean		Generated	50	
	Liver (7197)				
	Upper (fixed dose, generated vol.)	Generated	38.000 Gy	Generated	
	Upper (fixed dose, generated vol.)	Generated	34.000 Gy	Generated	
	Line (preferring target)	Generated	Generated	100	
	Lung_Contra (236180)				
	Mean		Generated	240	
	Line (preferring target)	Generated	Generated	70	
	Lung_Ipsilat (236182)				
	Upper (fixed dose, generated vol.)	Generated	4.000 Gy	150	
	Upper (fixed dose, generated vol.)	Generated	12.000 Gy	150	
	Upper (fixed dose, generated vol.)	Generated	18.000 Gy	150	
	Mean		Generated	Generated	
	Line (preferring target)	Generated	Generated	50	
	Oesophagus (7131)				
	Mean		Generated	50	
	Spinal_Cord (7647)				
	Upper	0.0	8.000 Gy	50	
	Thyroid (9603)				
	Mean		Generated	50	
	Trachea (7394)				
	Mean		Generated	50	
	zzAnt_Tune (24515)				
	Upper	0.0	105.0 %	80	
	zzBrst_sub_Bst (24510)				
	Upper (fixed dose, generated vol.)	Generated	105.0 %	200	
	Upper gEUD		103.0 %	200	40.0
	zzLung_Crop (24516)				
	Upper	25.0	4.000 Gy	185	
	Upper	10.0	18.000 Gy	150	
	Upper (fixed dose, generated vol.)	Generated	18.000 Gy	Generated	
	Upper (fixed dose, generated vol.)	Generated	4.000 Gy	150	
	Line (preferring target)	Generated	Generated	50	
	zzNTO (24517)				
	Upper	0.0	95.0 %	Generated	

Optimization Process

1. Tick Automatic Optimization Mode & Intermediate Dose. Press Start.

2. The following optimisation objectives were defined in the model and will be generated when the model is applied to a new case:

3. Once the optimisation process is complete the Optimizer will close and the plan will automatically start calculating the dose.

4. Keep the original plan and copy (Recommended). Re-optimize making any required changes.

5. Remove Skinflash bolus (-350 HU) and for CW patients **add CW bolus**

    - In general, PTVp_CW is cropped 2mm off skin, requiring **2mm added bolus** to Body contour

    - For inflammatory disease spread to the skin, PTVp_CW as prescribed by the RO will extend to skin surface requiring **5mm added bolus** to Body contour

    - For plans where bolus thickness is not appropriate to achieve 95% isodose coverage of PTVp_CW (i.e. plan too hot or cold at surface under bolus), optimization and/or bolus thickness should be adjusted as required to meet RO prescription.

6. Press calculate volume (F5) … **DO NOT** Calculate with fixed MU.

7. **Normalise plan (100 – 105%)** as appropriate to help achieve plan objectives/clinical goals, due to the removal of skinflash.

Dose per Fraction [Gy]	Number of Fractions	Total Dose [Gy]	Treatment Percentage [%]	Target Volume	Primary Reference Point			Plan Normalization
					ID	Planned Dose per Fraction [Gy]	Planned Total Dose [Gy]	
2.670	15	40.050	100.00	PTVp_TB	PTVp_TB	2.670	40.050	No plan normalization

8. If the plan needs adjustments to assist with improving target coverage/OAR sparing per clinical objectives or at the RO request, re-optimize to tweak.

Model Training and Model Validation

40 CLN-breast patient data sets were initially utilised to develop the KBP VMAT model, which limits low-dose wash using a recursive iterative learning and base-tangential methods as benchmark, with 6X-FFF energy on a Varian Halcyon with SX2 MLC mode.

Another twenty data sets were employed to validate the model comparing KBP-generated ipsilateral VMAT (ipsi-VMAT) plans against the benchmarked hybrid (h)-VMAT (departmental standard) and bowtie-VMAT (published best practice) methods.

Planning target volume (PTV), conformity/homogeneity index (CI/HI), organ-at-risk (OAR), remaining-volume-at-risk (RVR) and blinded plan preference were evaluated.

Following model validation the additional 20 plans and data sets were added into the model and tested further against clinical patients.

Scorecard

An initial score card V1.0 was developed using Varian Medical Affairs ESAPI PlanScoreCard tool based on Radiation Oncologist plan dosimetry preferences and SKAGAN priority ordering recommendations. V1.0 Score Card [Initial] was applied to 5 clinically delivered breast plans outside of the model cohort and compared. Feedback from V1 and integrating data from previously treated patients at our clinical center resulted in the creation of V2.0 Score Card.

Refinements of the V2.0 scorecard, such as further rewarding lower OARs and maxes and penalizing over coverage of plans were carried out and applied to the same patients, resulting in v2.1.
V3.0 was then created by duplicating v2.1 and rescaling the overall available scores from 365 (V2.1) to 319.5 (V3) as well as minor adjustments and once again applied to the same patient cohort.

Finally a refined model was created and used to replan the 5 breast plans as per instructions and nil human intervention and evaluated with V3.0 Score Card with results displayed in table below.

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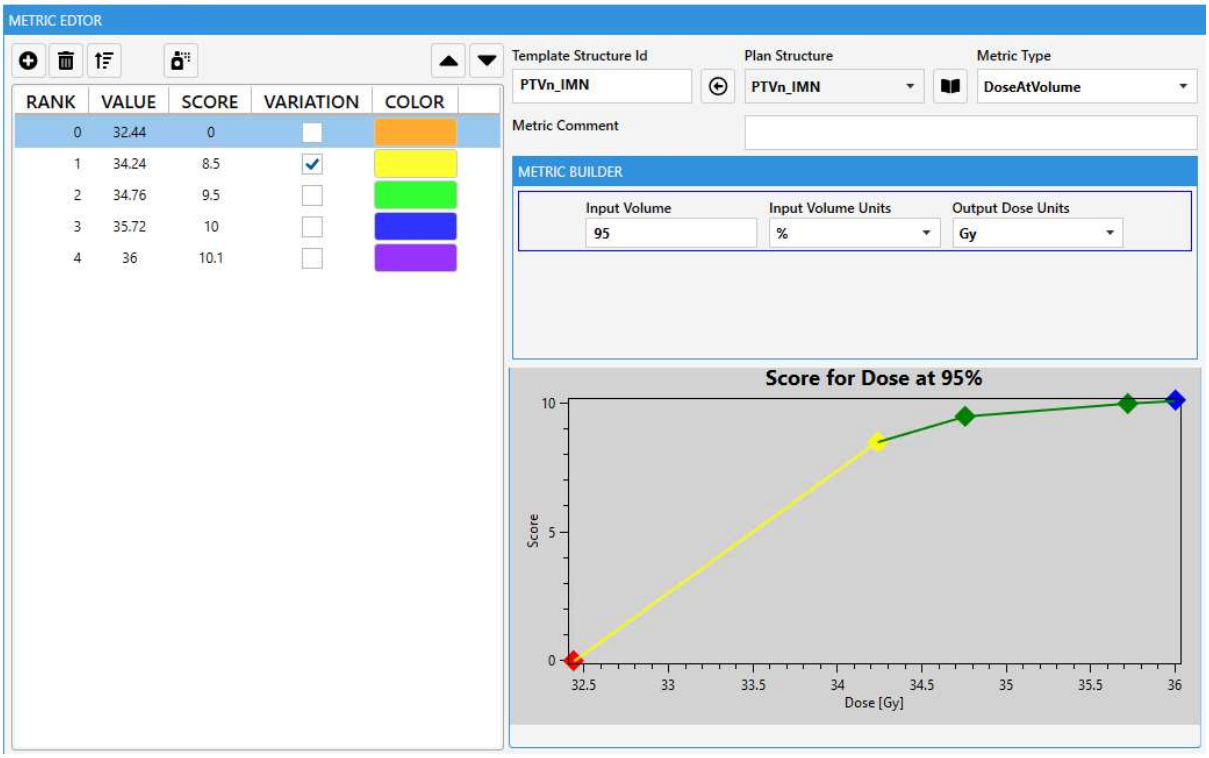
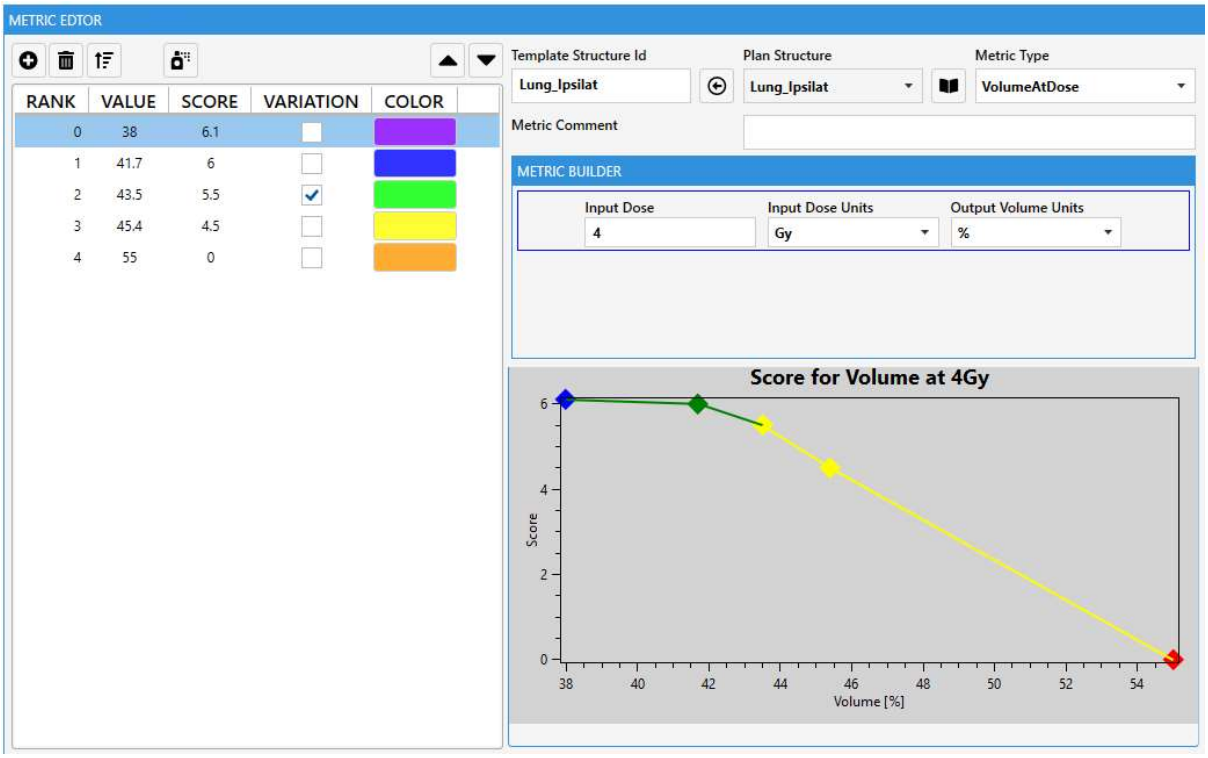
Patient	V1.0 Score Card, [Initial] (Score%)	V2.0 Score Card, [V1.0 + integrated collection statistics] (Score%)	V2.1 Score Card, [2.0 Score Card refinement (Score%)	V3.0 Score Card [rescaling of V2.1] (Score%)	V3.0 Score Card [Refined RP model plans evaluated] (Score%)
1	49.86	81.58	82.02	81.03	88.24
2	59.97	93.12	93.24	93.12	93.90
3	55.87	71.32	68.94	70.43	80.85
4	47.55	71.10	66.29	71.56	71.36
5	53.64	89.43	89.15	88.89	83.07

Examples of the Scorecard point division is shown below; demonstrating quick point drops once target coverage is achieved for a target and a peak in points once OARs are pushed further then protocol.

PTVn_IMN Dose at 95%



Lung_Ipsilat Volume at 4Gy



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PlanScoreCard ESAPI tool

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Currently,