Thames Valley and Wessex Radiotherapy Network

Radiotherapy Protocols

Lung: Stereotactic Ablative Body Radiotherapy (SABR)

This document is the standardised Thames Valley and Wessex Radiotherapy Network Lung SABR treatment protocol developed collaboratively by the Lung SABR Protocol Working Group:

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Document History

Date of Issue	Version Number	Date Approved	Responsible for Change	Nature of Change	Ratification/ Approval
12/11/2020	1.1 Draft		ODN Lung SABR Working Group	The existing OUH protocol used as a base for development a standardised Network-wide protocol	
02/12/2020	1.2 Draft		ODN Lung SABR Working Group	Continued developing the Network-wide protocol	
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01/6/2021	2.1 final		ODN Lung SABR Working Group	Minor change: a paragraph moved from section 5 to section 4	The RT Network Overview Group
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10.01.2023	3.0 draft		ODN Lung SABR Working Group	Amendments as per the UK 2022 Consensus on Normal Tissue Dose Volume Constraints	
21.10.2023	4.0		ODN Lung SABR Working Group	Amendments including the LUSTRE trial evidence	

Contents

Primary Objective and Scope

To summarise the planning and treatment of patients receiving stereotactic ablative body radiotherapy (SABR) for primary and oligometastatic lung cancer as defined by the UK SABR consortium v6.1 January 2019, for use in Radiotherapy Centres in the Thames Valley and Wessex Radiotherapy Network.

Indications

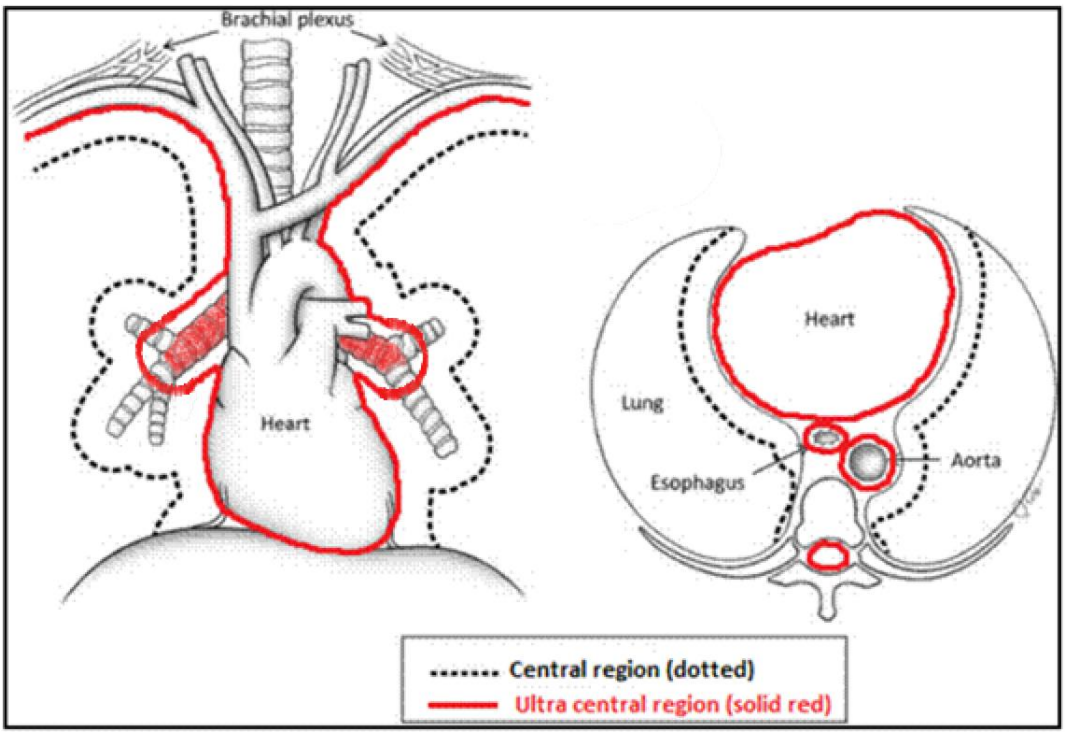
Inclusion Criteria

1. MDT diagnosis of non-small cell lung cancer (NSCLC) based on findings of positive histology or a positive PET scan when predictive models (eg Herder, Brock) indicate a >70% risk of malignancy (BTS guidelines) [1]. SABR may also be considered in situations where there is serial growth and an MDT consensus of radiological diagnosis of lung cancer. SABR is increasingly being used for early-stage SCLC ([2,3,4,5]). SABR for early-stage SCLC is a treatment option in the ASTRO 2020 guidelines [6] and in the 2020 NCCN guidelines [7]. SABR should be considered for early-stage SCLC patients, but it is noted that the evidence base for SABR is limited in early-stage SCLC and is even more limited in central/ultra central SCLC where the risk of lymph node metastasis may be higher than in NSCLC. Given that data is lacking in ultra central early-stage SCLC, conventionally fractionated radiotherapy may be more appropriate in these patients. Given the risk of distant metastasis with SCLC, chemotherapy is generally also considered in this setting for patients who are suitable [3,4]
2. Adult (≥ 18 years) patients *with T1a-cN0M0,T2a-bN0M0* (IASLC *8th Edition 2017-18* Staging system).T3N0M0 disease to be included *by virtue of chest wall invasion* or if the sum of the adjacent nodule and primary do not exceed 5cm in *maximum dimension*.
3. Patients not suitable for surgery due to medical co-morbidity, technically inoperable lesions, or patients decline surgery.
4. WHO performance status 0-*2* in SABR Consortium guideline. We will treat PS 3 if the clinician feels it is appropriate following review and discussion with the patient.
5. Tumours must be peripherally or centrally located to be treated with SABR.
    - Peripheral tumours may abut, but not overlap the central region (shown as the black dashed line in figure 1). The IASLC “central zone”, is a 2cm expansion around the proximal bronchial tree, major vessels, heart, oesophagus, spinal cord, phrenic and recurrent laryngeal nerve and brachial plexus.
    - Central tumours may abut, but not overlap the ultra-central zone (shown as the solid red line in figure 1). The ultra-central zone is defined as the major vessels, heart, oesophagus, spinal cord, phrenic & recurrent laryngeal nerve, brachial plexus, trachea and within 1cm of the main bronchi (shaded red) and trachea. *Centrally located tumours can receive SABR over conventionally fractionated RT on an individual patient basis as there is limited evidence that the benefit outweighs the risk compared to more conventionally fractionated RT [SABR consortium guideline 6.1).*
6. Patients with more than one lesion eligible for SABR may be considered after discussion in the Lung MDT if the treating clinician feels it will be technically possible and safe to deliver.
7. Metastatic lung tumours (referral via the SABR MDT required). Oligometastatic disease as agreed by MDT discussion may be treated in *any* location (including ultra central), however mandatory OAR constraints must be met. This may require a reduction in dose coverage of the PTV.

An alternative regime for central tumours ≥2cm from Oesophagus can be considered based on the RCR COVID-19 guidelines and the Canadian LUSTRE Trial of 60Gy in 15 fractions (BED10, 84Gy) [25,26]. This can be used for tumours up to 4cm T2AN0M0 as allowed in the LUSTRE Trial. It can be considered with caution in tumours 4-5cm ie T2BN0M0 as long as the OAR constraints can be met. Consideration should be made with regard to proximity of the GTV to the oesophagus and whether the maximum dose (0.1cc) to the oesophagus of 50Gy can be met. This fractionation schedule is included in this guideline as criteria for patient selection (not necessarily based on pathology) and primary tumour and OAR delineation are closely aligned with SABR planning, but note that the technical aspects of planning vary from SABR. See section 9 below.

Figure 1.

IASLC "central" zone definition, shown as the dashed black line. Any GTV overlapping the 2cm zone around the proximal bronchial tree, major vessels, heart, oesophagus, spinal cord, phrenic and recurrent laryngeal nerve and brachial plexus is considered central. Any GTV outside this zone is considered peripheral. The main bronchi are shaded red, differentiating from the proximal bronchial tree. The ultra central region is shown by the solid red line.



Exclusion Criteria

1. Patients who have had previous radiotherapy within the planned treatment volume. If the risk of toxicity with treatment overlap is deemed acceptable to the clinician and the patient and this is clearly documented, and peer reviewed then this may be allowed.
2. Any tumour that is not clinically definable on the treatment planning CT scan e.g. surrounded by consolidation or atelectasis.
3. Ground glass lesions with a solid component < 4mm [8].
4. Inability to provide informed consent or comply with the treatment requirements.
5. Presence of pulmonary fibrosis as recommended in the UK SABR. Consortium guidelines (unless the risk of SABR has been fully considered and documented within

a peer group and the patient has been appropriately consented for the increased risk of significant lung toxicity).

6. Ultra-central tumours: GTV/ITV within 1cm of the main bronchi OR any GTV/ITV which overlap central structures (defined as major vessels, heart, oesophagus, spinal cord, phrenic & recurrent laryngeal nerve, brachial plexus, trachea). This is shown in *Figure 1*.
7. Any patient where Physics opinion is that target coverage cannot be achieved or not sufficiently visible on CBCT to be set up accurately.

Pre-Radiotherapy Investigations

Diagnostic imaging to be completed prior to radiotherapy procedures:

- CT scan of chest, liver and adrenal glands
- PET/CT and CT head scan as per NICE guidelines preferably within 2 months of planned treatment
- Pulmonary Function Tests: no minimum requirement. The largest study published to date did not exclude patients for SABR based on lung function [9] and has been supported by 2 reviews [10,11]. We would favour having PFTs prior to SABR as that can inform the consent risk/benefit discussion process as there is a low risk of Radiation Induced Lung Toxicity post SABR. Particularly relevant if treating more than one lesion
- Optional quality measure: Brain imaging as a pre-RT investigation. Head MR or CT with contrast for stage 1 or 2 disease.

Therapeutic Schema

Chemotherapy

Patients should not have undergone chemotherapy within 6 weeks prior to treatment with lung SABR and should not have chemotherapy planned for < 6 weeks following radiotherapy.

Prescription

Inter-fraction interval should be a minimum of 24 hours, keeping to alternate days where possible, with a maximum interval of ideally 4 days between fractions.

Table 1. Dose and fractionation schedules

54Gy in 3×18Gy fractions	**Standard** (no overlap with Chest wall) when the PTV does not abut the chest wall. Where the PTV is close to chest wall 54Gy in 3 # can be used as long as the optimal chest wall constraints are met.
60Gy in 5×12Gy fractions	**Standard** (overlap with Chest wall**)**recommended when any part of the PTV is abutting or overlapping with the chest wall, or organ at risk constraints not met with standard fractionation. If the normal tissue constraints allow. When the PTV overlaps the chest wall we cover the PTV in chest wall with 55Gy and PTV in lung with 60Gy. PTV overlapping chestwall receives minimum of 55Gy, suggested constraint of D0.1cc maximum 60Gy to overlap volume, non-overlapping PTV receives minimum of 60Gy. If this cannot be achieved, 55Gy in 5# prescription is acceptable.
60Gy in 8 x7.5Gy per fraction	**Risk adapted SABR**: for tumours not invading central structures and not “ultracentral” but within the IASLC defined central zone ie any tumour within 2cm of the bronchial tree

	(the no fly zone), major vessels, heart, oesophagus, spinal cord, phrenic or recurrent laryngeal nerve, brachial plexus but >1cm from the proximal bronchial tree overlapping the trachea or main bronchi (***Figure 1***)[12,13] NOTE: there is limited evidence that benefit outweighs the risk compared the conventional fractionation in this situation. Therefore caution should be taken when using SABR in this patient population and decisions should be made on an individual patient basis and peer reviewed.
60Gy in 15x 4Gy per fraction	**Hypo-fractionated regime for Ultracentral tumours**

For both Standard Dose Fractionation Schedules the GTV must be peripheral: i.e outside the defined 2cm margin around the proximal bronchial tree and 2cm away from the major vessels, heart, oesophagus, spinal cord, phrenic and recurrent laryngeal nerve and brachial plexus (IASLC defined "central" zone). This is to reduce the risk of significant late toxicity to the bronchial tree and mediastinal structures. In the case of Risk Adapted SABR the GTV will be within the IASLC defined "central" zone but outside the "ultracentral zone" i.e. >1cm from the main bronchi or overlapping with the trachea and bronchi.

Pre-Treatment: Patient Simulation and Immobilisation

- Patients will be positioned on the CT couch using appropriate immobilisation preferably in the supine position with arms supported above their head. If the patient is unable to raise their arms above their head, or has a superior tumour, the patient should be appropriately immobilised arms down – vac bags to be considered. Physics to be consulted on arm position as may impact beam arrangement.
- The planning CT scans must include a 4DCT to capture target movement. A 3D helical scan may also be acquired.
- OARs should be outlined on a scan representative of the average patient position
- ITVs should be contoured using all available 4DCT information
- Optimisation and calculation may be done on 4DCT average intensity projection (AVIP) or helical scan.

- If the tumour is in the lower lobe close to the diaphragm with Superior-Inferior motion > 2cm abdominal compression, respiratory gating or breath hold should be considered with 4DCT acquisition to reduce respiratory exertion and the margins for motion.
- The extent of the planning CT scan must be sufficient to include all potential organs at risk. As a guide, contiguous axial slices of 2.0-3.0mm will be obtained from the upper cervical spine to the lower edge of the liver, taking care to include all lung parenchyma on the planning scan. Ensure the entire liver is scanned for lower lobe tumours.
- The extent of the 4DCT should be large enough to cover the tumour/targeted area and its motion
- Intravenous contrast may be used to help define the brachial plexus for upper lobe tumours and may be used for central tumour when they are close to mediastinal structures to define the great vessels and pericardium. This will be specifically requested on the planning request form and should be given in the contralateral arm to the brachial plexus of interest.

Tumour Motion

- 4DCT should be used to assess tumour motion at treatment planning.
- For lower lobe tumours close to the diaphragm, we recommend proactive consideration of a motion management strategy.
- Accounting for motion in RT planning
  Provided dose conformity, dose spillage and OAR constraints can be met the whole motion envelope will be included in the ITV and the patient treated under normal respiration (normally applies to small mobile tumours)

NOTE: A patient may be ineligible for SABR if:

- Tumour motion is unacceptable or un-correctable using departmentally available respiratory motion management techniques

Treatment Planning

CT-CT fusion:

Where required appropriate diagnostic images can be registered to the planning CT scan. The image registration shall be reviewed and approved.

Treatment modality and energy

- 6 MV, 6FFF and 10FFF photons may be used for planning
- IMRT / VMAT for treatment

Volume Definitions

- The GTV will be defined as the radiologically visible lung tumour, segmented using lung settings. Mediastinal windows may be suitable for defining tumours near to the chest wall. Whenever feasible, information from PET/CT shall be incorporated in to target definition. In the case of a Part Solid Ground Glass Nodule the full extent of the solid and ground glass component should be included in the GTV.
- The CTV is the GTV with no margin for microscopic disease extension. This is the accepted standard in the majority of SABR trials.
- The ITV encompasses the full range of target position during respiration, outlined on the MIP, the individual phases of the 4DCT scan or the 3D helical scan, with a summed ITV generated after this. Best practice is to use all available imaging to define the ITV, ensuring that the ITV encompasses all the motion captured by the 10 phase bins of the 4DCT.

The margins from ITV to PTV depend on the method of immobilisation and methods for on-treatment set-up verification/repositioning (e.g., CBCT). 4-6mm ITV-PTV margins are acceptable when using daily CBCT for image guided RT. Within this range, centres may use a larger margin sup/inf to ensure the PTV extends onto the next adjacent CT slice.

Volume Outlining

The following target volumes and organs at risk (OAR) will be segmented by the consultant oncologist and *ideally peer* reviewed by a second oncologist. Additional review by a radiologist is recommended if needed.

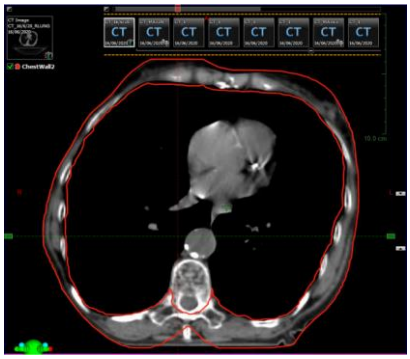
Nomenclature from Mir et al [19] is given in square brackets.

- GTV: GTV generated from 4DCT data set using either the maximum intensity projection or extremes of tumour motion
- (CTV: no margin is added to the GTV for CTV so this is not required)
- ITV accounting for all tumour motion seen on 4DCT. No ITV if scanned with a DIBH or 4DCT unavailable.
- PTV
- In general, any OARs which are traversed by the treatment beam should be contoured. Where OAR constraints are based on the dose received by the whole organ (eg lung, liver, spleen) the whole organ should be contoured. Otherwise, a volume of OAR should be outlined, sufficient to show that the OAR constraints have been met, with particular care paid to the volume receiving the highest doses. OARs should be contoured at least ≥2cm superiorly and inferiorly to the PTV for coplanar techniques. The body contour should be contoured wherever the beams traverse it. The skin should be inspected to ensure that the beams do not overlap, producing excessive skin dose, especially where there is a skin fold.
- Trachea and Proximal Bronchial Tree: can be contoured as either a single structure or as two separate structures using lung windows. For this purpose, the trachea can be divided into two sections: the proximal trachea and the distal 2cm of trachea.
    - Proximal trachea beginning 10cm superior to the superior extent of the PTV or 5cm superior to the carina (whichever is more superior, but to stop below the larynx) and continue inferiorly to the superior aspect of the proximal bronchial tree.
    - Distal 2cm of trachea: to be included in the structure identified as the proximal bronchial tree. Differentiating these structures will facilitate the eligibility requirement for excluding patients with tumours within 2cm of the proximal bronchial tree.
- Proximal bronchial tree (PBT) [Bronchus_Prox]
    - To include the most inferior distal 2cm of trachea and the proximal airways. The following airways will be included: distal 2cm trachea, carina, right and left mainstem bronchi, right and left upper lobe bronchi, bronchus intermedius, right middle lobe bronchus, lingular bronchus, and right and left lower lobe bronchi. Contouring of the lobar bronchi will end immediately at the site of the segmental bifurcation.
- Proximal Bronchial Tree [Bronchus_Prox] + 2cm is a useful guide to determine the best dose /fractionation schedule the clinician should adopt [9].
- For central tumours where there is a concern about its relationship with the main bronchi the central zone +1cm should be defined as (trachea + main bronchi) +1cm OR major vessels, heart, oesophagus, spinal cord, phrenic & recurrent laryngeal nerve, brachial plexus and trachea. Any GTV overlapping this structure should not receive SABR.
- Ipsilateral Brachial Plexus [Brachial Plex_L/R] should be contoured if <10cm from the PTV
    - The ipsilateral brachial plexus is defined as originating from the spinal nerves exiting the neural foramina on the involved side from C5 to T2. However, for the purposes of lung SBRT, only the major trunks of the

brachial plexus will be contoured using the subclavian and axillary vessels as a surrogate for identifying the location of the brachial plexus. The neurovascular complex will be contoured starting proximally at the bifurcation of the brachiocephalic truck into the jugular/subclavian veins (or carotid/subclavian arteries) and following along the route of the subclavian vein to the axillary vein ending after the neurovascular structures across the 2nd *rib [14,15].Use of a contrast enhanced CT may assist with outlining with contrast administered in the contralateral arm to the tumour.*

- Pericardial Sac[Heart+A_Pulm]
    - Heart will be contoured along with the pericardial sac. Defined superiorly as superior aspect of the pulmonary artery (as seen in a coronal reconstruction of the CT scan) and inferiorly to the apex of the heart.
- Oesophagus
    - Contoured using the mediastinal window setting from the thoracic inlet to the gastro-oesophageal junction and to include the mucosal, submucosa and all muscular layers out to the fatty adventitia *at least 2cm above and below the PTV.*
- Chest wall (*for peripheral lesions*) defined as a 3cm expansion of the lungs minus the non_GTV_Lung excluding the anterior vertebral body and mediastinal soft tissue.This is required 5cm above and below the PTV alone. The planner needs to confirm that the 50Gy isodose lies within this at the time of planning.

Figure 2: Chest wall structure



- Any other structures deemed appropriate by the consultant. When non-coplanar beams are used additional organs may be irradiated ie bowel, stomach or liver. Allowances should be made for this. It is recommended that the entire liver is scanned and segmented for lower lobe tumours and tolerances for these organs are defined.
- Great vessels: ie aorta and vena cava (not the pulmonary artery or vein) will be contoured using mediastinal window to correspond to the vascular wall and all muscular layers out to the fatty adventitia. The great vessels should be contoured at least 10cm above and below the extent of the PTV. For right sided lesions, the vena cava will be contoured, and for left sided lesions, the aorta will be contoured.
- For right lower lobe tumours at least 1000cc of the liver must be contoured and left lower lobe tumours the spleen should be contoured.
- Non_GTV_Lung
    - Both lungs segmented as a single structure using pulmonary windows, including all inflated and collapsed lungs. GTV, trachea and ipsilateral bronchus as defined above shall be excluded.

- [Spinal_Canal]
    - Contoured at least for 2cm above and below the PTV based on the bony limits of the spinal canal
- "Skin" is contoured as a 0.5cm inner margin of the body to approximate the region where skin side effects are possible if dose is deposited.
- Body 2cm clear:
    - Patient body outline structure, minus (PTV+2cm) Used for evaluating D2cmMAX.
- If using 60Gy/15# regime, must also contour:
    - **Great vessels:** To include the mediastinal envelope above the Heart+A_Pulm contour.
    - **Trachea and Large Bronchus**
    - **Chest wall**
    - **Stomach**

9.1 Dose Calculation and Plan Evaluation for 3-8 # SABR

Heterogeneity correction will be used. The conformity requirements for the PTV are based on published data where inhomogeneity corrections have been used [16].

A high-resolution dose grid (≤2.0mm) must be used, covering all volumes fully.

Target coverage and OAR requirements and actual values for the treatment plan will be recorded.

Table 2a. Evaluation of Target coverage and dose inhomogeneity for 3-8 fraction SABR regimens

Prescription (Gy)	**54Gy/3#**	**55Gy/5#**	**60Gy/5-8#**	
95% of PTV should get at least (Px dose)	54Gy	55Gy	60Gy	
99% of PTV should get at least (90% dose)	48.6Gy	49.5Gy	54Gy	
Maximum dose at least	59.4Gy	60.5Gy	66Gy	-
Maximum dose not more than	75.6Gy	77Gy	84Gy	

Table 2b. Minor deviations to target coverage may be accepted clinically for 3-8 fraction SABR regimens

Prescription (Gy)	**54Gy**	**55Gy**	**60Gy**
Maximum dose at least (105-110%)	56.7-59.4Gy	57.8-60.5Gy	63-66Gy
Maximum dose not more than (140-145%)	75.6-78.3Gy	77-79.8Gy	84-87Gy

- Evaluation of dose conformity: Good conformity of the prescription isodose to the target volume and a steep dose gradient surrounding the target volume are the hall-marks of SABR planning. Dose conformity levels from the Rosel study [12] have been useful in evaluating lung quality using R100% and R50% metrics where

Conformity Index ≡ R100 is the ratio of prescription isodose to the PTV = Conformity Index
Prescription isodose volume (PIV_{100}) / target volume (V_PTV)
< 1.0 suggests the PTV is not covered.
>1.0 suggests an unnecessarily large volume of normal tissue will receive the prescription dose.

Data from the 147 patients reviewed in the SABR CtE QA programme indicated that the ROSEL "tolerance" and "minor deviation" levels for R100% are appropriate. However the R50% levels are set too high for small target volumes, to usefully indicate that a plan has not been optimally planned. These cases were oligometastases to the lung rather than primary lung tumours. The SABR CtE QA group have suggested modified metrics

$$R100\% = \frac{\text{Vol (100\%)}}{\text{Vol (PTV)}} \Rightarrow \text{Prescription dose spillage} = \frac{\text{Vol (100\%)}}{\text{PTV V100\%}}$$

$$R50\% = \frac{\text{Vol (50\%)}}{\text{Vol (PTV)}} \Rightarrow \text{Modified Gradient Index} = \frac{\text{Vol (50\%)}}{\text{PTV V100\%}}$$

R100% = Vol (100%)_ Prescription dose spillage = Vol (100%)
Vol (PTV) PTV V100%
R50% = Vol (50%) Modified Gradient Index = Vol (50%)
Vol (PTV) PTV V100%

Where
Vol (100%) is the volume of the patient receiving 100% pf the prescription dose
Vol (50%) is the volume of the patient receiving 50% of the prescription dose.
PTV V100% is the volume of the PTV receiving at least 100% of the prescription dose.

When PTV coverage is 100% "PTV V100%" will equal "Vol (PTV)" and each pair of metrics becomes equivalent.

D2cmMAX is the maximum dose (Gy) at least 2cm from the PTV in any direction.

Tables 3 a and b. Dose conformity levels. "Target" values based on the median data recorded in the SABR CtE QA programme. Tolerance and minor deviation values are from the ROSEL study [17] unless updated with values based on the median +1SD and median +2 SD from the SABR CtE QA programme (indicated by *) or based on literature reports **[18]

Table 3a. Prescription dose spillage requirements for lung

Vol PTV (cc)	**Vol (100%) / PTV V100%**		
	Target	**Tolerance**	**Minor deviation**
<20	1.2 *	<1.25	1.25-1.4
20-40	1.1 *	<1.20	1.20 – 1.3
>40	1.1 *	<1.15	1.15-1.2

Table 3b. Modified Gradient Index, D2cm max and lung requirements

Vol (PTV) cc	**Vol(50%) / PTV V100%**			**Lung-GTV V20 (%)**	**Max dose >2cm (% of prescription dose)**	
					3 #	**5-8 #**
	Target	**Tolerance**	**Minor dev**	**Tolerance**	**Tolerance**	**Minor dev**

<20	7 *	9 *	9-11 *	<5	<65%	65-75%
20-40	5.5 *	6.5 *	6.5-7.5 *	<6	<70%	70-80%
40-60	5 *	6 *	6-7 *	<10	<70%	70-80%
60-90	4 **	5 *	5-7	<10	<70%	70-80%
>90	4 **	4.5 *	4.5-6.5	<10	<70%	70-80%

If following internal audit acceptable plan quality is being achieved, the process of checking all plans for conformity may be reduced.

9.2 Dose Calculation and Plan Evaluation for 15 Fraction treatment

15 fraction plans of 50-60 Gy are planned with no specific conformity or gradient indices.Dmax is lower than SABR plans and as a result the plans are more homogonous.

Table 4. Evaluation of Target coverage for patients treated with 50-60 Gy in 15 fractions

Prescription	
PTV-iGTV D 0.1 cc	<110 %

Organs at Risk (OARs) Limits

Dose limitations to OARs are taken from the UK 2022 Consensus on Normal Tissue Dose Volume Constraints for Oligometastatic, Primary Lung and Hepatocellular Carcinoma Stereotactic Ablative Radiotherapy [20]

Table 5. OAR constraints taken from the UK 2022 Consensus on Normal Tissue Dose Volume Constraints for Oligometastatic, Primary Lung and Hepatocellular Carcinoma Stereotactic Ablative [20] Radiotherapy Endpoint is grade 3 or more toxicity.

Dose Constraints for SABR 3-8 fractions

Structure	**Metric**	**3 Fractions**		**5 Fractions**		**8 Fractions**		**End-point**
		Optimal	**Mandatory**	**Optimal**	**Mandatory**	**Optimal**	**Mandatory**	
BrachialPlex	D0.1cc	-	24Gy	30.5Gy	32Gy	35Gy	39Gy	neuropathy
Bronchus_Prox	D0.1cc	-	30Gy	35Gy	38Gy	-	40Gy	Stenosis/fistula
Spinal Canal	Dmax		20.3Gy		25.3Gy		32Gy	Myelopathy (up to 5% risk with 1-5#) [23]
Chest Wall	D0.1cc	36.9Gy	-	43Gy	-	-	-	Pain/fracture
	D30cc	30Gy	-	-	-	-	-	
Oesophagus	D0.1cc	-	25.2Gy	-	35Gy	-	40Gy	Stenosis / fistula
GreatVes	D0.1cc	-	45Gy	-	53Gy	60Gy	65Gy	Aneurysm
Heart+A_Pulm	D0.1cc	26Gy	30Gy	29Gy	38Gy	40Gy	46Gy*	pericarditis
Lungs Lungs-ITV	V20	10%	15%	10%	15%	10%	15%	pneumonitis
	MLD	8Gy	-	8Gy	-	8Gy	-	
Skin	D0.1cc	33Gy	-	39.5Gy	-	48Gy	-	Ulceration
	D10cc	30Gy	-	36.5Gy	-	44Gy	-	

Trachea	D0.1cc	-	30Gy	35Gy	38Gy	-	40Gy	Stenosis / fistula
Liver (constraints only valid if >1000cc of liver imaged)	D≥700cc	15Gy	17Gy	15Gy	-	-	-	Liver dysfunction / radiation induced liver disease
	V10			70%				
	Dmean	13Gy	15Gy	13Gy	15.2Gy	-	-	

**If not achievable, drop prescription dose to 50Gy*

These dose constraints are predominantly based on the SABR-COMET Trial [21]. The Lung constraints have been relaxed compared to UK practice to date and are in line with the lung specific work reported by HyTEC [22]. The V20 constraints apply to SABR for both single and multiple ie 2-3 lung lesions. Similarly the cardiac constraints have also been relaxed. Importantly however, where the 8# cardiac constraints cannot be met the prescription dose should be reduced from 60Gy to 50Gy.

For non-spinal targets the bony canal should be used as a surrogate for the spinal cord throughout the length of the spine (neural foramina should not be included).It is stressed that all chest wall constraints are optimal, and it is therefore accepted that these may not be met when a lesion is adjacent to the chest wall. In this situation the patient should be consented for an increased risk of chest wall toxicity. Similarly, the skin constraints are also optimal, and, in some scenarios, it may be necessary to exceed these constraints in an effort to achieve coverage and in these cases the patient should be consented for an increased risk of skin toxicity.

Table 6: Dose Constraints for Hypofractionated Radiotherapy of 50-60Gy/15#

Dose (Gy)	Volume	50-60Gy/15#
Spinal Canal	Max 0.1cc	36Gy
Oesophagus	Max 0.1cc	48Gy mandatory
	Vol	V45 <10cc optimal
Brachial Plexus_R/L	Max 0.1cc	<50Gy
Heart A_Pulm	Max 0.1cc	63Gy optimal 66Gy mandatory
	Vol	V57 <10cc**
Great Vessels	Max 0.1cc	63 Gy optimal 66Gy mandatory
	Vol	57Gy <10cc**
Proximal Bronchial Tree	Max 0.1cc	63 Gy optimal 66Gy mandatory
	Vol	V57 <10cc**
Rib (chest wall)	Max 0.1cc	63Gy optimal 66Gy mandatory
	Vol	V30 <30cc optimal
Skin	Max 0.1cc	<45Gy
Stomach	Max 0.1cc	<48Gy
	Vol	V45 <10cc
Lung-GTV*	Vol	V20<15% and V15 <30%
	Dose	MLD <20Gy** optimal

Contralateral Lung	Vol	V5<60G% *** optimal

*MLD = mean lung dose; *Lung dose constraints are not acceptable for PORT or after lung surgery due to the reduced lung volumes after surgery; **taken from Faivre-Finn et al 2020 [27] *** taken from 15# conversion from the I-START 20# schedule [24] all other mandatory constraints for 15# schedule are taken from the LUSTRE Trial [25,26]*

If the dose constraints cannot be met with 60Gy/15# regime you can drop the dose to 55/15# (BED10, 70Gy which is equivalent to 55Gy/20# BED10, 70.1Gy. Isotoxic for late complications with BED3)
**taken from 15# conversion from the I-START 20# schedule [24]*

The spleen is increasingly recognised as a potential OAR, with patients who receive higher doses being at risk of infection and infection related mortality. Although constraints for conventional fractionation have been proposed, no constraints for SABR have been defined to date. As such, contouring and reporting of mean spleen doses are needed to facilitate future modelling work in the UK SABR Consortium [20]. These guidelines to date take into account the fact that the spleen is very radiosensitive and RT can impact on splenic function. Patients receiving >10Gy mean dose to the spleen are at increased risk of functional hyposplenism with increased risk of sepsis and sepsis related mortality (overwhelming; post-splenectomy infection, OPSI). The aim therefore is to keep the splenic Dmean <10Gy and record the V10. The assumption is that if only a small part of the spleen is irradiation (eg <25% and not including the hilum) then splenic function may be preserved. If the mean splenic dose is >10Gy the patient should be considered at high risk of OPSI and managed based on National Guidelines for the British Committee for Standards in Haematology. This should include pneumococcal, haemophilus influenzae type B Conjugate vaccine, meningococcal conjugate vaccine at least 2 weeks prior to starting RT. In addition, prophylactic antibiotics should be offered and started when RT starts and given a supply of emergency antibiotics.

Where patients are having more than one lesion treated with SABR at the same time, it is recommended that these should be treated on alternate days and with the same dose/fractionation (usually the most conservative of the two). The use of alternate day treatments reduces the dose per fraction to the whole lung, and is recommended in an effort to limit the risk of severe radiation induced lung toxicity.

Treatment Delivery

- *For all fractions* of VMAT treatments, the Radiographers treating MUST ensure the gantry will not collide with the patient or couch during the treatment.
- Any queries regarding setup and imaging shall be directed to a member of the SABR team or the *IGRT* Lead *Radiographer***.**

Treatment Verification

- Daily on-line CBCT image guidance using the tumour or an appropriate surrogate shall be used for targeting**.**
- Additional imaging can be used if there is any uncertainty regarding patient positioning. e.g. lateral planer image to assess pitch issues
- Intrafractional imaging should be considered

Supportive care

Review on treatment

Given the low risk of acute toxicity on treatment it is not necessary to review patients at the end of a course of treatment.

13. Follow-up after treatment

At the completion of radiotherapy the first follow-up appointment should be at 4-6 weeks post treatment to assess acute toxicity graded according to CTCAE v5.0 .

- Subsequent visits should ideally be 3-monthly for year 1 post SBRT and 6-monthly subsequently. (If possible QoL information should be collected).
- Follow-up CT Thorax should be considered at 3 months post SBRT, and then every 3-12 months.
- Due attention must be given to the difficulty arising in differentiating local recurrence from tumour progression, as well as a greater awareness of the potential for certain toxicities (specifically chest wall/rib fracture). If local progression is suspected this should be discussed in the Lung Cancer MDT. Further imaging such as PETCT, repeat lung function and possible biopsy may be required to confirm disease progression prior to consideration of radiofrequency or microwave ablation for local salvage.
- If feasible full lung function tests should be considered annually.

Appendix 1 Suggested Assessments at baseline and during radiotherapy

Procedure	Base-line	During RT	4-6 weeks post RT
Medical History	X	X	X
Physical Examination	X	X	X
Weight	X		X
WHO PS score	X	X	X
Lung function test	X		
CT scan thorax & abdomen	X		
Chest X-ray	X		X
PET/CT and CT head	X		
Informed Consent	X		

Appendix 2 Suggested Assessments during follow up post-SABR

Procedure	Months post RT											
	3	6	9	12	18	24	30	36	42	48	54	60
Medical History	X	X	X	X	X	X	X	X	X	X	X	X
Physical Examination	X	X	X	X	X	X	X	X	X	X	X	X
Weight	X	X	X	X	X	X	X	X	X	X	X	X
ECOG score	X	X	X	X	X	X	X	X	X	X	X	X
Lung function test		X		X		X		X		X		X
CT scan thorax & abdomen	X			X		X		X		X		X
Chest X-ray		X	X		X		X		X		X	

Appendix 4: CTCAE v5.0 scoring system

To facilitate audit this can be recorded at each patient encounter on FU prospectively under SABR Toxicity Recording.

Appendix 5: OAR nomenclature [19]

41 Minor amendment

BileDuct_Common
Bone_Mandible
Bowel
BrachialPlex_L/R
Brain
Brainstem
Breast_L/R
Bronchus_Prox
Chestwall_L/R
Cochlea_L/R
Eye_L/R
FemurHeadNeck_L/R
Genitals
Glnd_Lacrimal_L/R
Glnd_Submand_L/R
Glnd_Thyroid
GreatVes
Heart
Hippocampus_L/R
Kidney_L/R
Kidney_Cortex_L/R
Larynx
Lens_L/R
Lips
Liver
Lobe_Temporal_L/R
Lung_L/R
Musc_Constrict_I
Musc_Constrict_M
Musc_Constrict_S
OpticChiasm
OpticNrv_L/R
Parotid_L/R
PenileBulb
Pituitary
SpinalCord
Spleen
Stomach
Trachea
Ureter_L/R
Urethra_Prostatc

20 Developed in response to survey feedback

A_LAD
Bowel_Large
Bowel_Small
Canal_Anal
Colon_Sigmoid
Esophagus_S
Eye_A_L/R
Eye_P_L/R
Fossa_Pituitary
Glottis
Heart+A_Pulm
Inlet_Cricophar
Inlet_Esophagus
Jejunum_Ileum
Larynx_SG
Musc_Constrict
Musc_Cricophar
Ovary_L/R
Retina_L/R
Spc_Bowel

6 No amendment

Bladder
Duodenum
Oesophagus
Pancreas
Skin
Testis_L/R

6 Major amendment

CaudaEquina
Cavity_Oral
LumbSacPlex_L/R
Rectum
SpinalCanal
Urethra

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