South West Radiotherapy
Operational Delivery Network

SABR Peripheral Lung Tumours

Contents

This protocol has been adapted from the Stereotactic Ablative Body Radiotherapy (SABR) Consortium guidelines.

Stereotactic ablative body radiotherapy (SABR) refers to the precise irradiation of an image-defined extra-cranial lesion with the use of a high radiation dose in a small number of fractions.

1.1 Selection criteria

Inclusion criteria

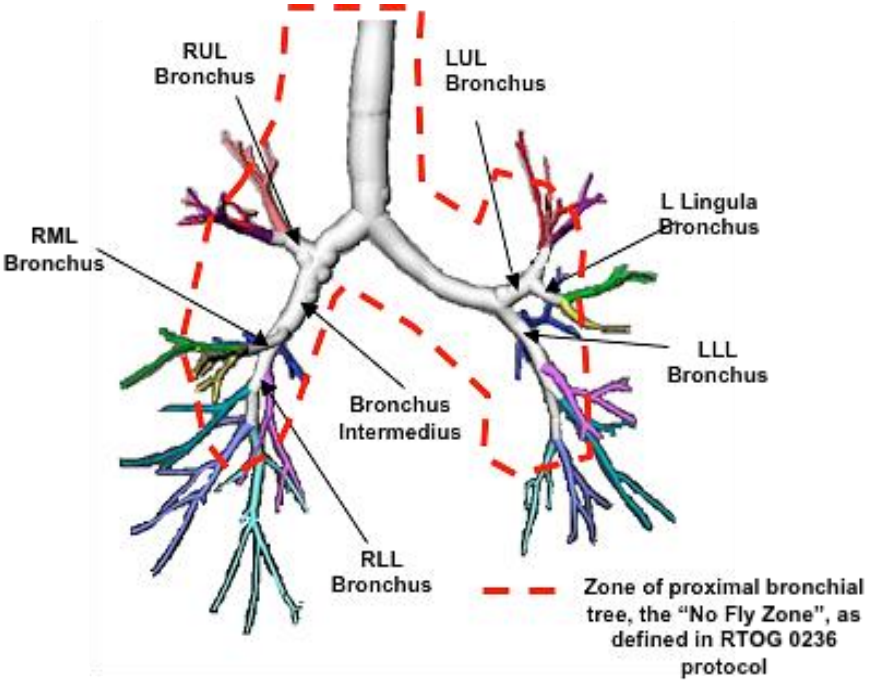
- MDT confirmed diagnosis of NSCLC based on findings of positive histology, positive PET scan or growth on serial CT scan
- Clinical stages of T1 N0 M0 or T2 (≤5cm) N0 M0 or T3 (≤5cm) N0 M0 [radiologically N2 (CT or PET), patients only eligible if possible nodal disease is subsequently confirmed as histologically negative with mediastinoscopy or endoscopic bronchial or oesophageal ultra-sound biopsy]
- Not suitable for surgery because of medical co-morbidity, lesion is technically inoperable or patient declines surgery after surgical assessment
- WHO performance status 0-2
- Peripheral lesions outside a 2cm radius of main airways and proximal bronchial tree. This is defined as 2cm from the bifurcation of the second order bronchus e.g. where the right upper lobe bronchus splits (see Figure 1)
- Age ≥ 18 years

Exclusion criteria

- NSCLC patients with T2 or T3 primary tumours > 5cm.
- T3 primary NSCLC tumours involving the mediastinal structures or central T3 primary tumours.
- Metastatic lung tumours
- Any tumour that is not clinically definable on the treatment planning CT scan e.g. surrounded by consolidation or atelectasis.

- Tumours with respiratory motion ≥ 1cm despite using techniques to reduce tumour motion. If it is possible to achieve the suggested normal tissue and tumour planning constraints only then can mobile tumours be treated with this technique.
- Primary NSCLC tumours with clinical evidence of regional or distant metastasis after appropriate staging studies.
- Previous radiotherapy within the planned treatment volume
- Pregnant or lactating females
- Inability to obtain informed consent or comply with treatment requirements

Figure 1: proximal bronchial tree as defined by RTOG 0236 protocol



1.2 CT localisation

Patient positioning

Patients will be positioned supine with their arms above their head using the WingSTEP wingboard or holding an arm pole with a customized vacuum bag to ensure accuracy, reproducibility and comfort. In patients whose lesion lies superior to the carina, reproducibility may be improved through using a beam directional shell with arms by sides. A thin foam mattress can also be used for comfort.

Tumour motion

4DCT will be used in the majority of patients to account for tumour motion as described in the non-small cell lung cancer protocol. A 3DCT in breath hold using the Active Breath Control (ABC) device is an option for patients whose tumour is anticipated to move by >2cm with respiration (e.g. lower lobe tumours).

CT simulation

A 3-D scan will be performed prior to performing the 4D-CT scan. Patients will undergo a treatment planning CT scan in the treatment position. Contiguous axial slices of 2mm 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. Intravenous contrast will be used if requested at a flow rate of 1.0 to 1.5ml/s.

1.3 Volume definition

Tumour delineation

- Gross Tumour Volume (GTV) = The GTV is defined as the radiologically visible tumour in the lung, contoured using lung settings. Mediastinal windows may be suitable for defining tumours proximal to the chest wall. Where available, information from PET/CT will be incorporated into delineating the GTV.

- Clinical Target Volume (CTV) = The CTV is the GTV with no margin for microscopic disease extension. This is the accepted standard in the majority of SABR trials.

- Internal Target Volume (ITV) = tumour volume obtained using a 4DCT scan. The volume is initially outlined using the maximum intensity projection and reviewed in 0% and 50% amplitude data set to ensure the contour encompasses extremes of tumour motion.

- Planning Target Volume (PTV) = The isotropic margin from ITV to PTV will be 5mm for patients treated using 4DCT

A margin of 6mm in axial directions and 8mm in the cranio-caudal direction is used for patients treated using ABC.

1.4 Organs at risk (OAR) delineation

The following organs at risk will be delineated on the CT planning average dataset:

1 Spinal Cord

The spinal cord should be contoured on all slices based on the bony limits of the spinal canal.

2 Oesophagus

The oesophagus will be contoured using mediastinal windowing on CT to correspond to the mucosal, submucosa, and all muscular layers out to the fatty adventitia.

3 Brachial Plexus

For treatment of lesions other than those in the lower lobes, the major trunks of the ipsilateral brachial plexus will be contoured by using the subclavian and axillary vessels as a surrogate for identifying the location of the plexus on head and neck windowing. These vessels will be contoured from the bifurcation of the brachiocephalic trunk into the jugular/subclavian veins (or carotid/subclavian arteries), following along the route of the subclavian vein to the axillary vein and ending after the neurovascular structures cross the 2nd rib.

4 Heart

The heart will be contoured along with the pericardial sac. The superior aspect (or base) for purposes of contouring is defined as the superior aspect of pulmonary artery (as seen in a coronal reconstruction of the CT scan) and extended inferiorly to the apex of the heart.

5 Trachea and Proximal Bronchial Tree

The trachea and bronchial tree will be contoured as two separate structures using lung windows. For this purpose, the trachea will be divided into two sections: the proximal trachea and the distal 2 cm of trachea. The proximal trachea will be contoured as one structure, and the distal 2 cm of trachea will be included in the structure identified as proximal bronchial tree.

5 Proximal Trachea

Contours should begin 10cm superior to the superior extent of the PTV or 5cm superior to the carina (whichever is the more superior) and continue inferiorly to the superior aspect of the proximal bronchial tree.

6 Proximal Bronchial Tree

This will include the most inferior distal 2cm of trachea and the proximal airways on both sides as indicated in Figure 1. The following airways will be included: distal 2cm trachea, carina, right and left mainstem bronchi, right and left upper lobe bronchi, the bronchus intermedius, right middle lobe bronchus, lingular bronchus, and the right and left lower lobe bronchi. Contouring of the lobar bronchi will end immediately at the site of a segmental bifurcation.

7 Great vessels

The great vessels within the mediastinum should be contoured for at least 2cm superior and inferior to the PTV

8 Whole Lung

Both lungs should be contoured as one structure using pulmonary windows. All inflated and collapsed lung should be included. However, GTV and trachea/ipsilateral bronchus as defined above should not be included. The Lungs-GTV should be kept at V20< 10%.

9 Chest wall

The chest wall will be defined as the 3cm rind of the ipsilateral hemi-thorax outside the lungs and contoured at least 5 cm superiorly and inferiorly to the PTV.

10 Skin

Defined as a 3-5mm inner rind of body contour if adjacent to PTV and in regions receiving more than 10Gy.

11 Liver

For lower lobe tumours, the liver may need to be contoured.

1.5 Treatment planning

Beam Selection

The paradigm dictates that the high-dose region should be conformal to the PTV, the medium-dose region surrounding the PTV should be compact and the low-dose region is permitted to be relatively large by comparison to the other regions. All dose calculations should be performed using heterogeneity correction.

Treatment Planning System

Inhomogeneity corrections have a large influence on the dose delivered to the PTV and OARs for SABR of lung tumours. Consequently, the type B Collapsed Cone algorithm, that considers changes in lateral electron transport, will be used.

Tumour Location/OAR Doses

As defined above, the GTV must be outside the defined 2cm margin around the proximal airways (Fig. 1). Table 1 lists the dose constraints for three and five fraction treatments used in the ROSEL study (Hurkmans CW, 2009) and endorsed by the UK SABR consortium (6.1)(Hanna GG, 2018). These dose limits are based on the highest dose/fractionation regimes reported in lung SABR and therefore should be safe for lower biological equivalent dose regimes used. The UK OAR constraints for SABR are also largely based on the constraints reported in the AAPM-101 report (Benedict SH, 2010). The eight fraction mandatory constraints are those used in the LungTech trial (Adelbahr S, 2015). These are based on eight fraction SABR for central lung cancers (Haasbeek CJ, 2011).

Note: when non-coplanar treatment beams are used additional organs may be irradiated (e.g. liver, bowel) – allowances must be made for this.

Structure	Metric	1 fraction		3 fractions		5 fractions		8 Fractions		Endpoint
		Opt	Man	Opt	Man	Opt	Man	Opt	Man	
Brachial Plexus	$D_{0.1cc}$		15Gy		24Gy	30.5Gy	32Gy	35Gy	39Gy	G3+ neuropathy
Bronchus	$D_{0.1cc}$		20.2Gy		30Gy	35Gy	38Gy		40Gy	G3+ stenosis/fistula
Chest wall	$D_{0.1cc}$ D_{30cc}	30Gy		36.9Gy 30Gy		43Gy				G3+ fracture/pain
Great Vessels	$D_{0.1cc}$		30Gy		45Gy		53Gy	60Gy	65Gy	G3+ aneurysm
Heart	$D_{0.1cc}$		22Gy	26Gy	30Gy	29Gy	38Gy	40Gy	46Gy	G3+ pericarditis
Lungs	V_{20Gy} D_{mean}	10% 8Gy	15%	10% 8Gy	15%	10% 8Gy	15%	10% 8Gy	15%	G3+ pneumonitis
Oesophagus	$D_{0.1cc}$		15.4Gy		25.2Gy		35Gy		40Gy	G3+ stenosis/fistula
Skin	$D_{0.1cc}$ D_{10cc}		26Gy 23Gy	33Gy 30Gy		39.5Gy 36.5Gy		48Gy 44Gy		G3+ ulceration
Trachea	$D_{0.1cc}$		20.2Gy		30Gy	35Gy	38Gy		40Gy	G3+ stenosis/fistula

It is recommended the entire liver be scanned, especially for lower lobe lesions and where non-coplanar beams are to be used. The tolerances for these organs are detailed in the OAR section of the guidelines. In addition, the dose to skin should be limited to minimise cutaneous and subcutaneous toxicity. This is assisted by ensuring that beam entry points do not overlap on the skin.

1.6 Dose prescription

Acceptable dose fractionation regimes are:

Standard Dose Fractionation	18Gy x 3 fractions (N.B. 20Gy x 3 is not allowed)
Conservative Dose Fractionation	11Gy x 5 fractions
Very Conservative Dose Fractionation	7.5Gy x 8 fractions

The conservative dose fractionation is recommended when any part of the PTV is in contact with the chest wall. It is recommended that the inter-fraction interval be at least 40 hours, with a maximum interval of ideally 4 days between fractions.

The very conservative fractionation schedules may rarely be used if the dose constraints cannot be met at 55Gy in 5 fractions and the patient has been discussed in the lung Q/A rounds. The conformity constraints are as per 55Gy in 5 fractions.

1.7 Dose distribution requirements

Successful treatment planning can be achieved by a range of planning techniques but will require accomplishment of all of the following criteria:

- The dose prescription will be chosen such that 95% of the target volume (PTV) receives at least the nominal fraction dose (e.g. 18Gy per fraction = 54Gy total), and 99% of the target volume (PTV) receives a minimum of 90% of the fraction dose (i.e., 16.2Gy per fraction = 48.6Gy total)

- The maximum dose within the target volume should be between 110% to 140% of the prescription dose. For example, for dose prescriptions of 54Gy in 3 fractions, the dosemax within the PTV should preferably not be less than 59.4Gy (i.e. 110%) or exceed 75.6Gy (i.e. 140%)). A minor deviation will be scored in cases where the dosemax lies between either 56.7-59.4Gy or between 75.6-78.3Gy.

- Dose conformity using the modified metrics will be evaluated as per tables 4 and 5 which are endorsed by the updated UK SABR consortium guidelines.

Tables 2 and 3 Updated dose conformity requirements using modified metrics endorsed by the UK SABR consortium guidelines

Table 2: Prescription dose spillage requirements

Vol (PTV) / cc	Vol (100%) / PTV V100%		
	Target	Tolerance	Minor Dev
<20	1.2	<1.25	1.25-1.40
20-40	1.1	<1.20	1.20-1.30

>40	1.1	<1.15	1.15-1.20

Table 3: Modified gradient index and other requirements

Vol (PTV) / cc	Vol (50%) / PTV V100%			Lung – GTV V20 (%)	Max dose > 2cm	
					3 fractions	5-8 fractions
	Target	Tolerance	Minor Dev	Tolerance	Tolerance	Minor Dev
<20	7	9	9-11	<5	<35.1Gy	<35.8Gy
20-40	5.5	6.5	6.5-7.5	<6	<37.8Gy	<38.5Gy
40-60	5	6	6-7	<10	<37.8Gy	<38.5Gy
60-90	4	5	5-7	<10	<37.8Gy	<38.5Gy
>90	4	4.5	4.5-6.5	<10	<37.8Gy	<38.5Gy

R100% = Vol (100%) / Vol (PTV): ratio of prescription isodose (eg 54Gy or 55Gy) volume to the PTV

R50% = Vol (50%) / Vol (PTV): ratio of 50% prescription isodose (27Gy or 27.5Gy) volume to the PTV

Prescription dose spillage = Vol (100%) / PTV V100%: ratio of prescription isodose (eg 54Gy or 55Gy) volume to volume of PTV receiving at least 100% of prescription dose.

Modified dose gradient = Vol (50%) / PTV V100%: ratio of 50% prescription isodose (eg 27Gy or 27.5Gy) volume to volume of PTV receiving at least 100% of prescription dose.

Max dose >2cm: maximum dose (% of nominal prescription dose) at least 2cm from the PTV in any direction

V20: percentage of total lung volume – GTV receiving >20Gy

1.8 Verification

Patient setup will be verified before each treatment, with CBCT imaging for online image matching and correction. The patient should have an initial CBCT, followed by image registration and patient shifts if required. A verification CBCT is suggested to ascertain that the shift was made in the correct direction. Further CBCT imaging should be performed if there are concerns that the patient has moved during the treatment.

1.9 Treatment assessment and follow up

Post-SABR we suggest that the first follow up should be at 4-6 weeks post radiotherapy to assess acute toxicity. Patients should have a repeat chest x-ray at each follow up visit. Subsequent follow up visits should be of the order of 3 monthly for the 1st year, and 6 monthly for subsequent years.
If patient is fit for active treatment of recurrence (i.e. mediastinal RT for nodal recurrence or chemo for metastatic recurrence):
CT chest / abdo (not pelvis) + contrast at 6, 12, 24 and 36 months

If not fit for further treatment (other than SABR for a 2nd primary):
Consider clinical / CXR follow up only - after discussion with the patient
Due attention must be given to the difficulty that can arise in differentiating local recurrence from tumour progression in certain scenarios. In addition a greater awareness of the potential for certain toxicities (e.g. chest wall/rib) is required.