



(Randomised clinical trial testing a 1-week course of curative whole breast radiotherapy against a standard 3-week schedule in terms of local cancer control and late adverse effects in patients with early breast cancer)

Planning Pack for the FAST-Forward Trial

Version 3

**A guide to outlining, planning & verifying
FAST-Forward patients**

FAST-Forward Trial Management Group
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1 INTRODUCTION

This document should be used as an accompaniment to the FAST-FORWARD trial protocol by all clinicians, physicists, radiographers and dosimetrists involved in the planning and treating of FAST-FORWARD patients. It provides basic guidance on localisation, outlining, planning and treatment verification. However, it should be noted that the planning methods are not intended to be entirely prescriptive – it is hoped that they will provide a good starting point from which each centre may decide to develop its own technique to meet the planning aims. Please feel free to discuss any aspect of this planning pack with the FAST-Forward QA team.

2 LOCALISATION

Delineation of the tumour bed is strongly recommended for all patients who have had breast conserving surgery as this facilitates appropriate placement of the tangential breast field to maximise target coverage whilst minimising dose to organs at risk (OAR).

To assist the delineation, it is strongly advised that titanium clips or gold seeds are implanted into the walls of the tumour excision cavity (tumour bed) at the time of breast conserving surgery as per British Association of Surgical Oncology (BASO) guidelines [1].

It is recommended that pairs of clips/seeds are positioned at the medial, lateral, superior, inferior, anterior and posterior margins of surgical resection. Placing the clips in pairs as shown in Fig. 1 ensures that any clip migration will be evident by the visualisation of single clips [1].

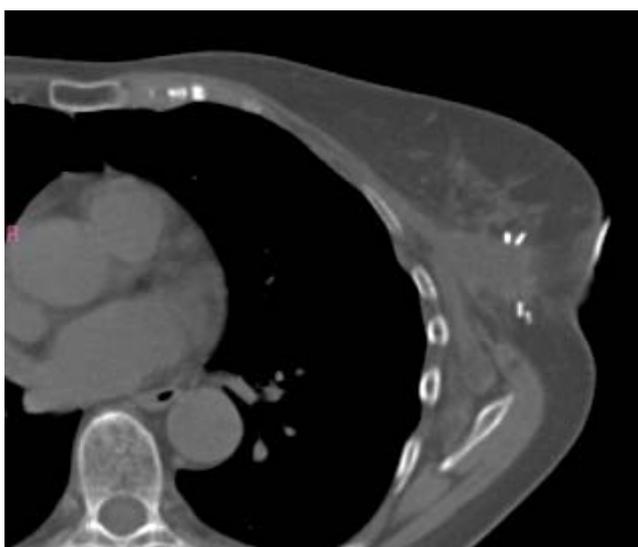


Fig. 1: CT slice showing 2 pairs of titanium clips implanted around the tumour bed

The tumour bed may be localised if there is a well-defined seroma in the absence of implanted markers. At least one of these localisation methods will be necessary if the boost radiotherapy is to be delivered with a conformal photon plan. For more detailed guidance, please refer to the IMPORT surgical clips protocol.

The same method of localisation, outlining and planning must be adopted for all trial groups.

3 OUTLINING

3.1 Target Volumes

It is compulsory to outline target volumes and the relevant organs at risk for radiotherapy planning of FAST-Forward patients. A summary is presented in Table 1. Outlining the boost is mandatory only for patients that are to receive tumour bed boost treatment.

Table 1: Summary of radiotherapy planning volumes and margins

	CTV	PTV
Whole Breast (WB)	CTV _{WB} = Soft tissues of the whole breast, 5 mm below the skin surface	PTV _{WB} = CTV _{WB} + 10 mm margin
Chest Wall (CW)	CTV _{CW} = Skin flaps and soft tissues	PTV _{CW} = CTV _{CW} + 10 mm margin
Boost	CTV _{TB} = tumour bed	PTV _{TB} = CTV _{TB} + 10 mm margin

3.1.1 Tumour Bed

CTV_{TB} is outlined by drawing around the implanted markers and any changes in the surrounding tissue architecture (Fig. 2). For patients with no visible seroma centres should consider contouring around the clips and adding a 5 to 10 mm margin to it to obtain the CTV.

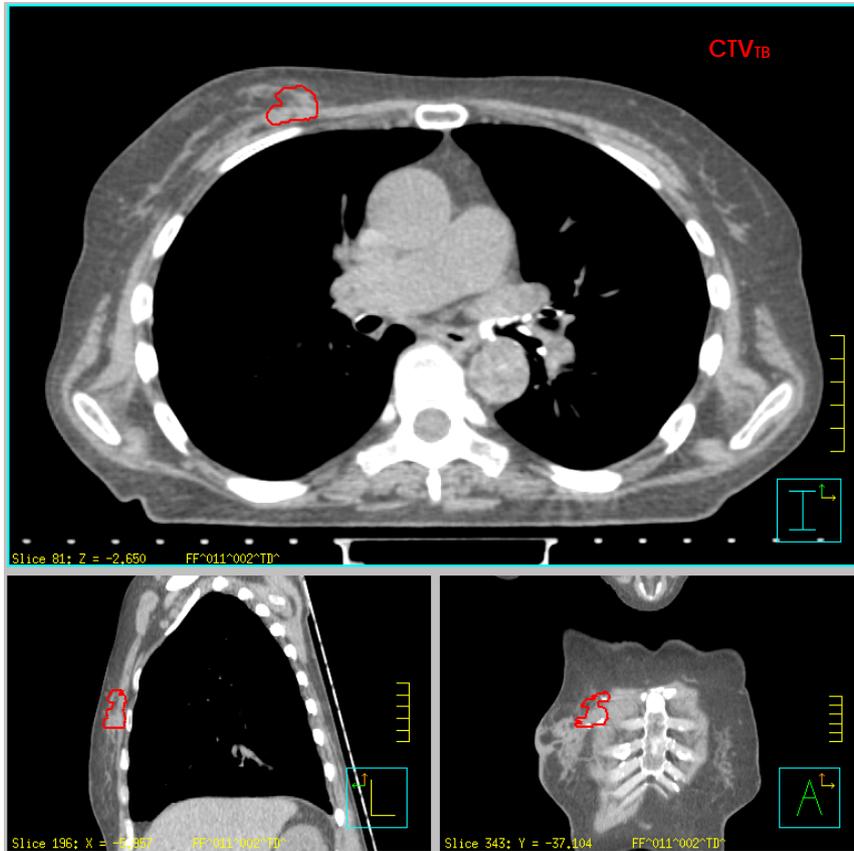


Fig. 2: Tumour bed CTV in axial, sagittal, and coronal planes

This is grown by 10 mm to give the tumour bed PTV or PTV_{TB} (Fig. 3). When planning the tumour bed boost, the treatment fields should be positioned to cover the unmodified PTV_{TB} with an appropriate margin for penumbra.

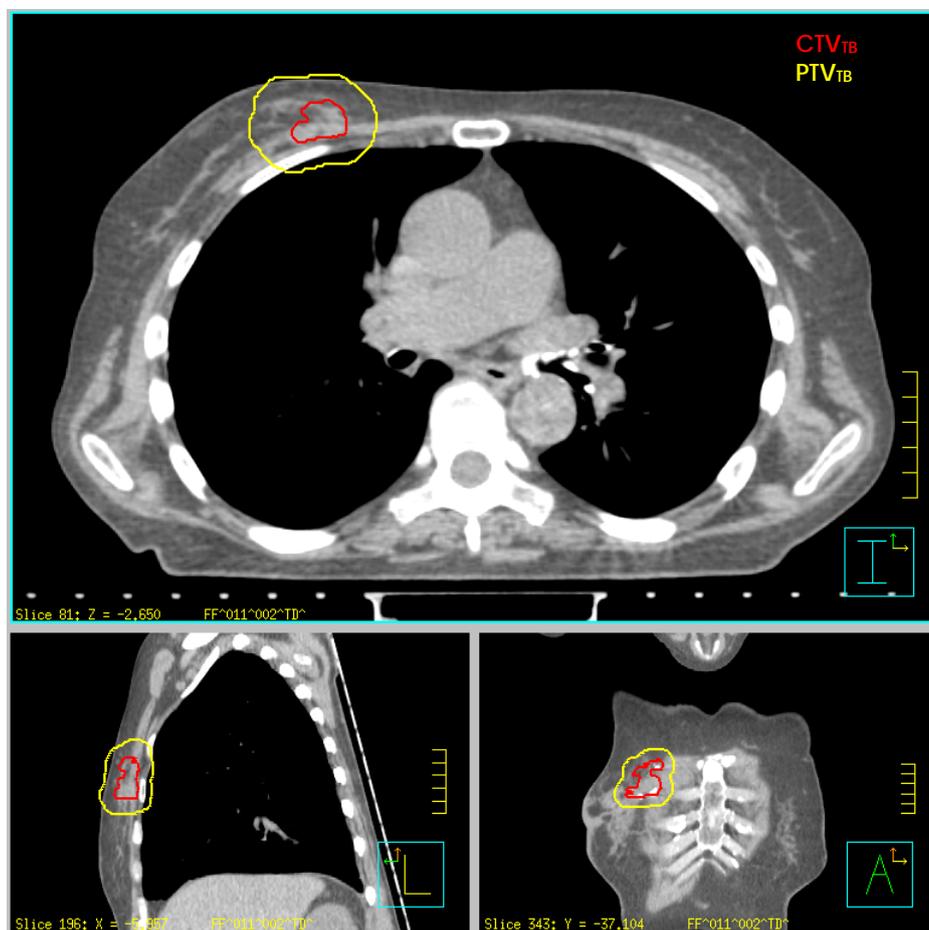


Fig. 3: Axial slices showing tumour bed PTV on central axis

For reporting purposes only the PTV is then modified 5 mm inside the skin surface and 5 mm around the lung (Fig. 4). This structure is denoted as PTV_{TB} DVH.

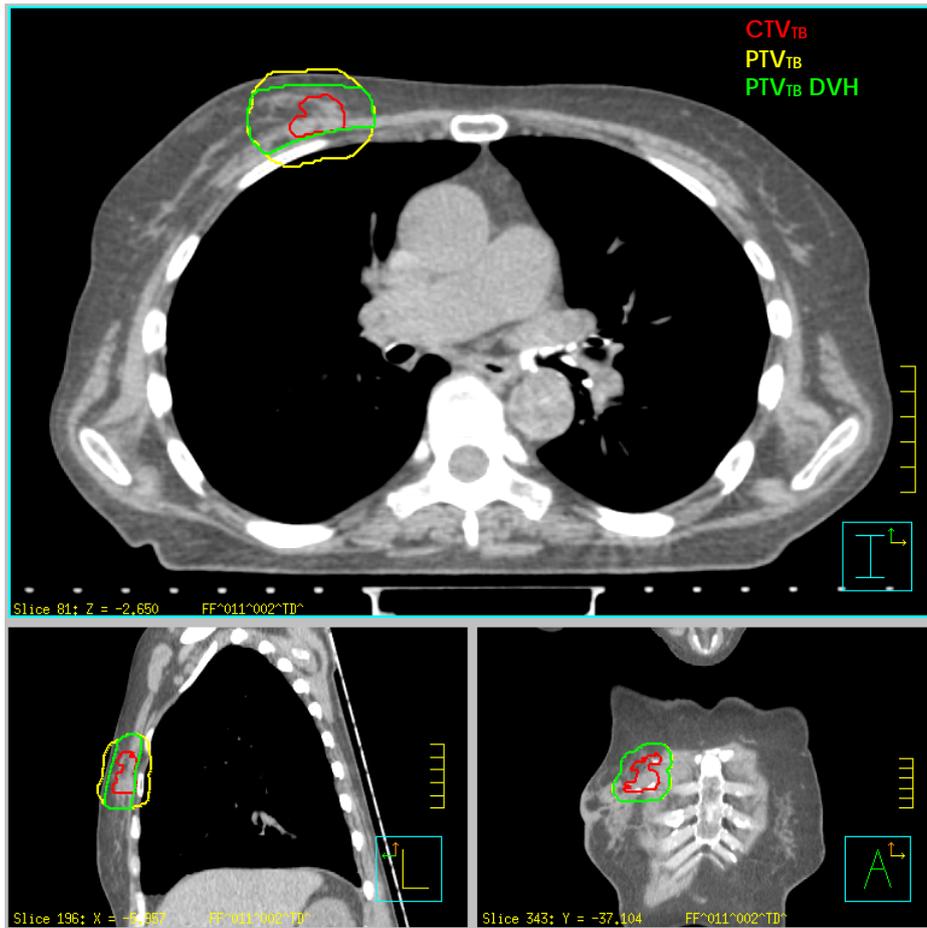


Fig. 4: Axial slice showing modified tumour bed PTV

3.1.2 Whole Breast and Chest Wall

3.1.2.1 Volume-based planning

The Whole Breast CTV is based on the recommendations in the START trial protocol. The CTV includes the soft tissues of the whole breast from 5 mm below the skin surface down to the deep fascia, excluding muscle and underlying rib cage. The posterior margin should not extend beyond the deep fascia (unless clearly breached by the tumour). If the anatomy of this region cannot be easily visualised, the posterior margin should be limited to 5 mm anterior to the lung/chest wall interface. CTV_{WB} should not extend beyond the edges of the visible/palpable breast in medial and lateral directions. A 10 mm margin is added to create the Whole Breast PTV (PTV_{WB}). The treatment fields should be positioned to cover the unmodified whole breast PTV with an appropriate margin for penumbra.

This PTV_{WB} is then cropped 5 mm inside the skin and 5 mm from the lung surface for dose reporting purposes only. This structure is denoted as PTV_{WB} DVH.

3.1.2.2 Field-based planning

When outlining a CTV volume on each axial slice it can be very difficult to accurately delineate breast tissue on X-ray CT images, and this can result in an overestimate of the whole breast volume, especially in obese patients. An alternative strategy is to generate a field-based structure which is not a true PTV, but is helpful for reporting purposes. A provisional tangential field pair is selected to cover the breast tissue and minimise dose to the normal tissues, by scrolling up and down the CT dataset. The whole breast field based PTV is then generated according to the following criteria, as illustrated on the images below:

- 5 mm from the skin surface
- 5 mm from the lung/chest wall interface
- 5 mm from the posterior beam edge (or the MLC if it is used on the main beams)
- 10 mm from the superior and inferior beam edges

The margins of the field-based PTV from the superior and inferior field borders are valid under the assumption that the isocentre of the plan has been placed in the central region of the target. For a mono-isocentric technique or if divergence has been removed from the superior edge using floor twist please contact the QA team for guidance.

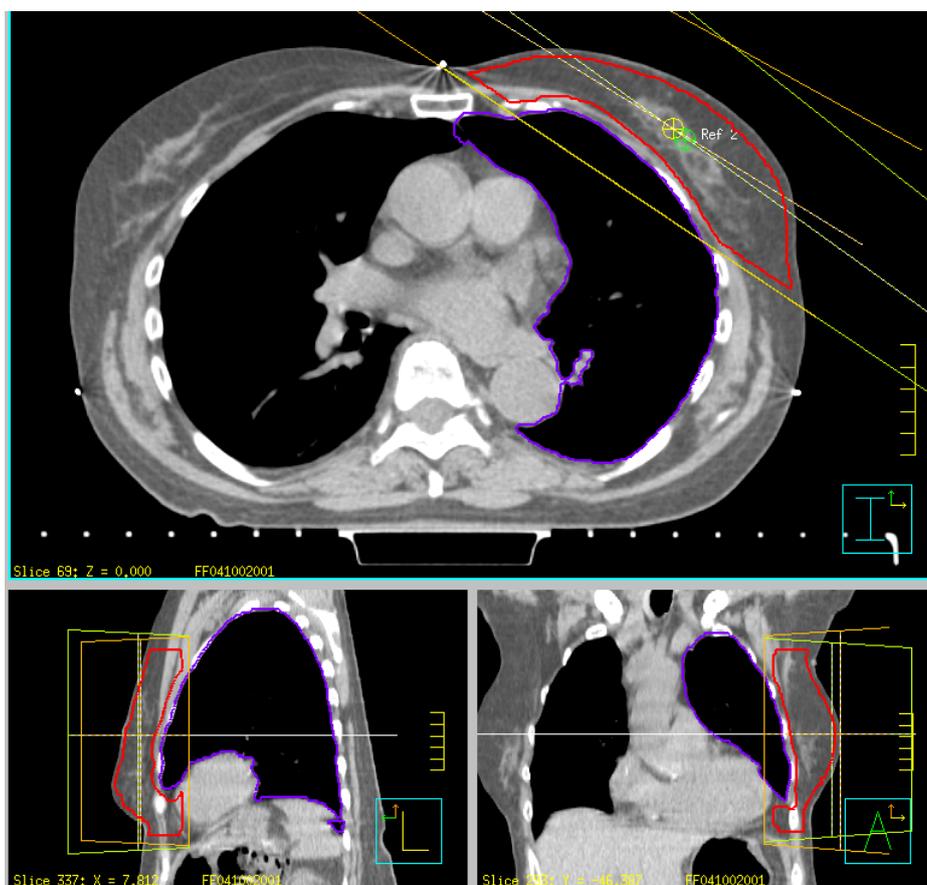


Fig. 5: Field-based whole breast PTV in axial, sagittal, and coronal planes

The Chest Wall CTV encompasses the skin flaps and includes the soft tissues down to the deep fascia, excluding the underlying muscle and rib cage. A 10 mm margin is added to create the Chest Wall PTV. This PTV is then cropped 5 mm inside the skin or along the skin (depending on the centre's practice of bolus use) and 5 mm from the lung surface for dose reporting purposes. This structure is denoted as PTV_{CW} DVH.

The same field based PTV principle listed above can also be applied to chest wall patients in the trial as shown in Fig. 6. In case of a very thin chest wall when the field-based PTV_{CW} generated according to the procedure outlined above does not represent the irradiated volume adequately, contact the QA team for advice.

If it is the centre's policy to use bolus for part of the treatment fractions, the bolus and no bolus plans should be evaluated and submitted separately, and two dose reporting structures should be created: one cropped 5 mm inside the skin for the no bolus plan, and one including the skin for the bolus plan. Target dose constraints should be met for both structures individually.

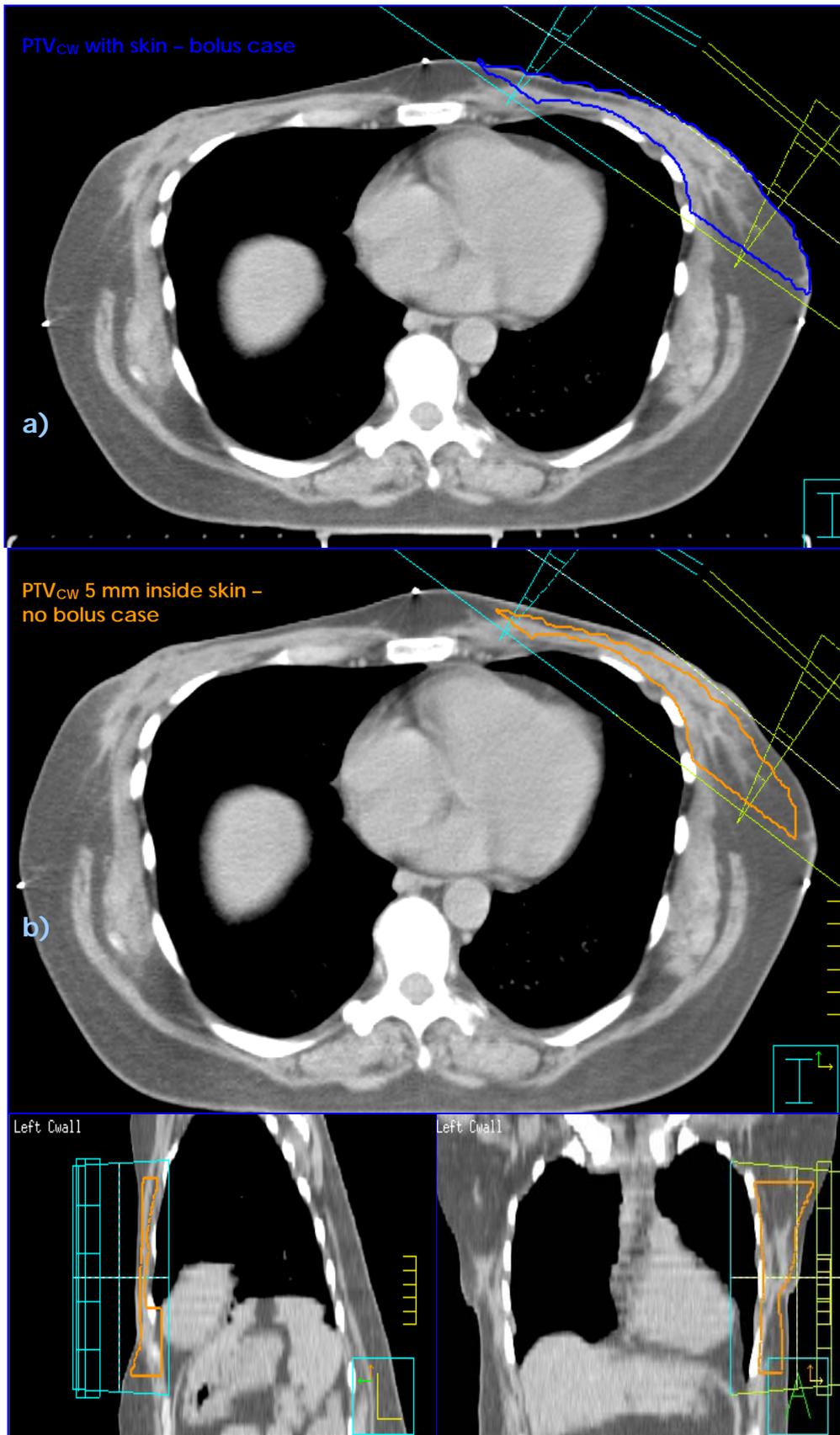


Fig. 6: Field based chest wall PTV with (a) and without bolus (b)

It is often necessary to use the MLC to shield organs at risk in the treatment beams and this is recommended, provided that the tumour bed is away from the shielded area. In cases like this, when the MLC is used on the main tangential beams, the field-based reporting structure should be contoured 5 mm inside the MLC instead of 5 mm inside the field border. The example on Fig. 7 shows a left side patient with MLC shielding for the heart; the same can be done to shield parts of the lung or the liver in right side plans.

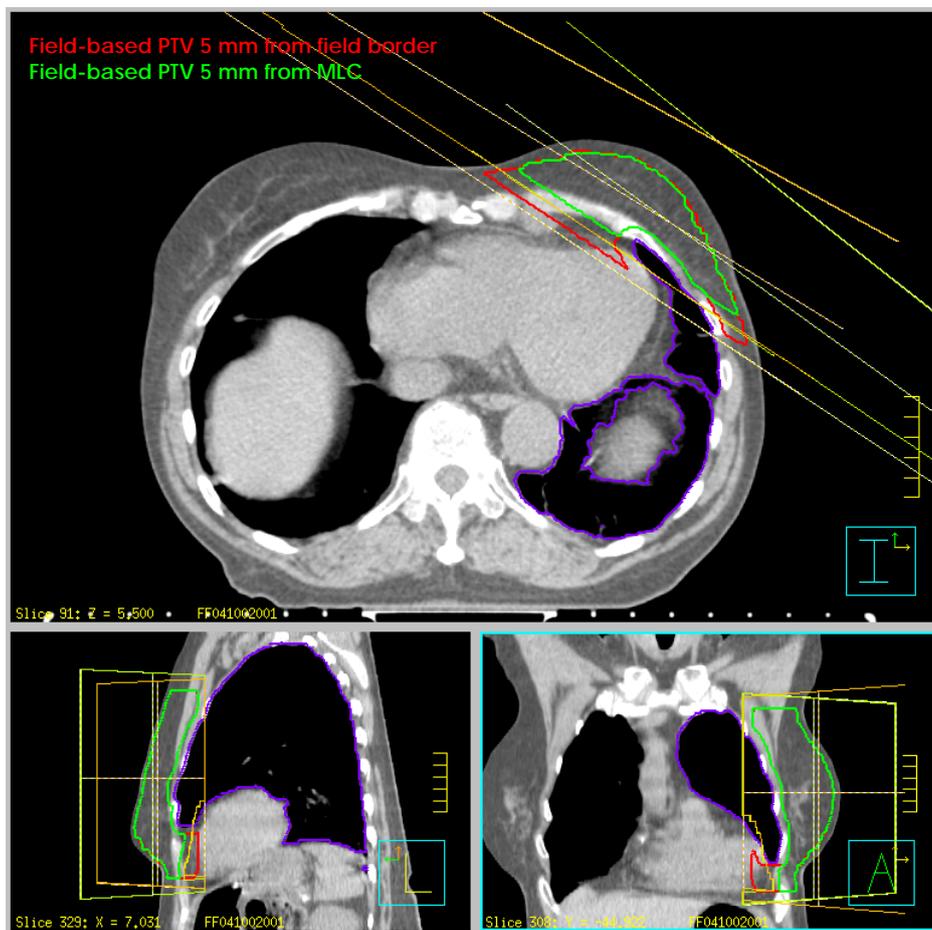


Fig. 7: Field-based PTV in case of MLC shielding for the heart.

The achieved target and OAR dose constraints should in this case be reported for the modified field-based PTV structure.

Once created according to the criteria outlined above, the field-based PTV must not be modified any further. It will sometimes include tissues that are not breast in the

superior and inferior region of the target (Fig. 8); in view of the consistency of the dose reporting structure these should not be manually cropped out.

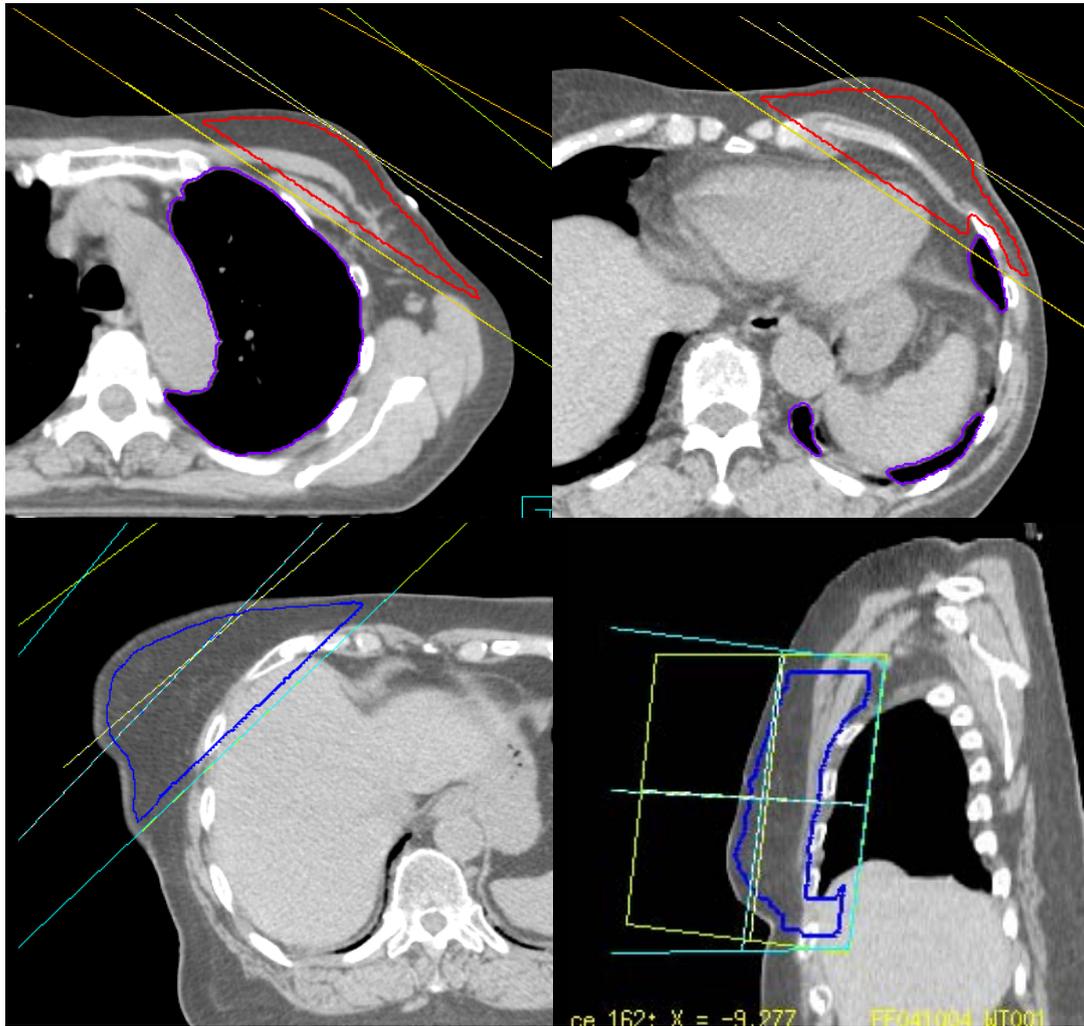


Fig. 8: Non-breast tissue included in the dose reporting structure

Whenever possible, non-breast tissue should be excluded from the treatment fields or shielded using the MLC, as long as the primary tumour site is away from the shielded area.

3.2 Organs at Risk

It is mandatory to contour the ipsilateral lung and heart for dose volume histogram assessment (Fig. 9).

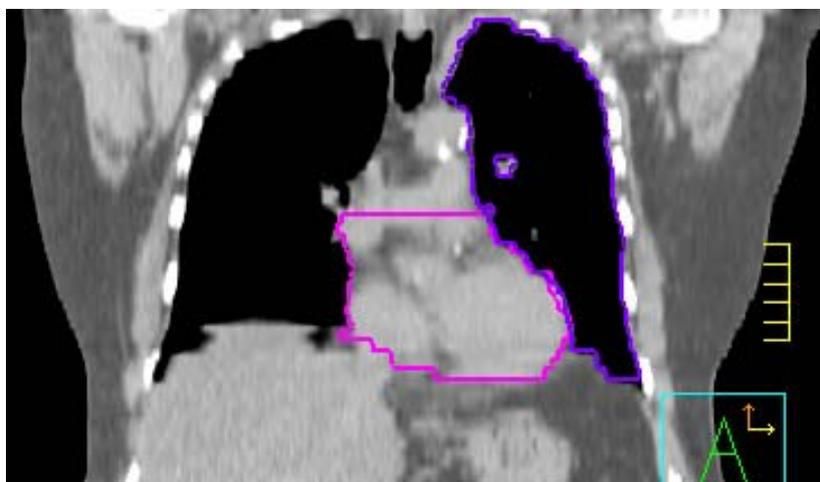


Fig. 9: Delineation of organs at risk: ipsilateral lung and heart in axial and coronal planes

The ipsilateral lung must be outlined as a single structure, and care should be taken not to include any air ways or major blood vessels. The scanning area must cover the entire lung volume.

The following guidelines for heart delineation have been adapted from the Wales Cancer Trials Unit SCOPE1 Radiotherapy Treatment Planning and Delivery Document: leads - T Crosby, J Staffurth and L Wills.

'The whole heart should be outlined to the extent of the pericardial sac (if visible). The major blood vessels (superior to the organ) and the inferior vena cava (towards the inferior extent of the heart) are excluded. The superior extent is often difficult to define and may be simplified by identification of the vessels superior to the heart. Use the point where the pulmonary trunk and the right pulmonary artery are seen as separate structures as indication of the superior extent of the heart.

Shown below in Fig. 10 are alternate CT images for a scan taken at 0.3 cm intervals.

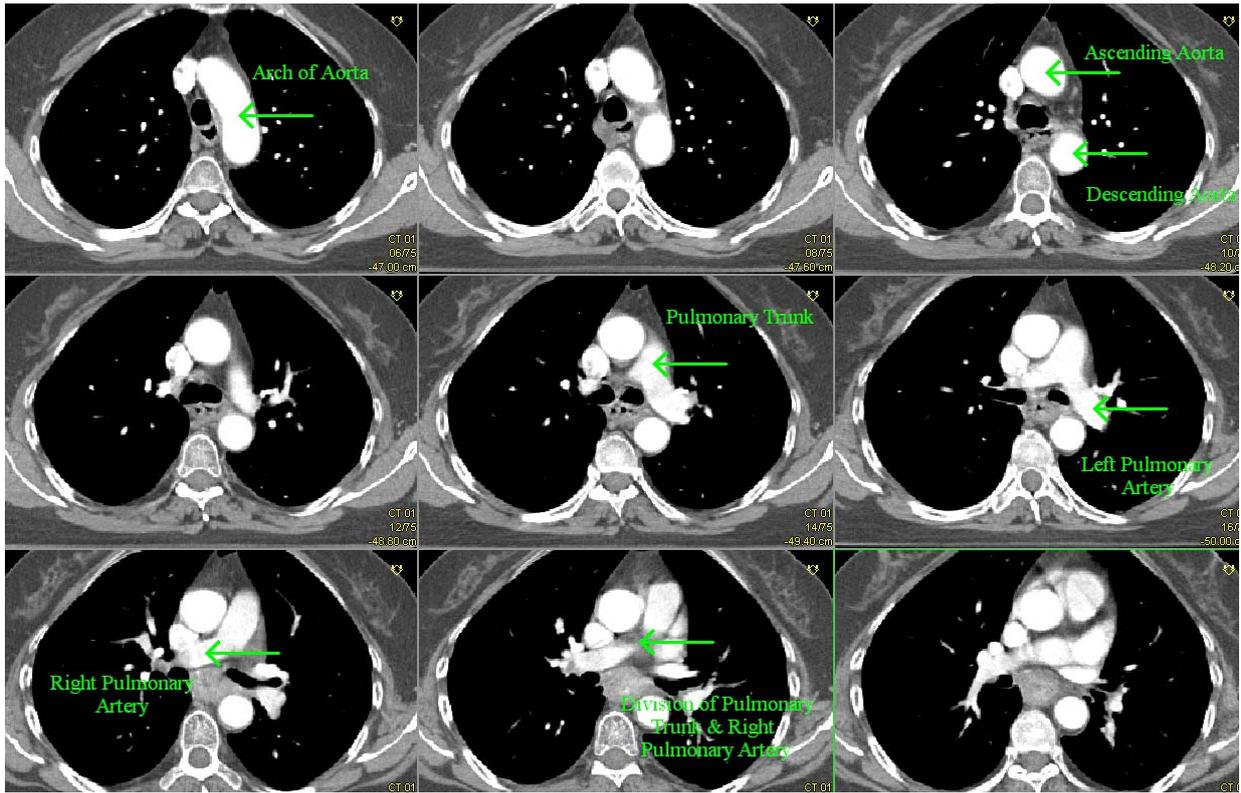


Fig. 10: Alternate 0.3 cm CT slices indicating cardiac anatomy

The definition of the heart is shown in Fig. 11 on the same data set. The superior extent of the heart has been interpreted as the 1st section on which the right and left pulmonary arteries have separated. Throughout, the heart is outlined to the extent of the pericardial sac. The inferior extent is less problematic to delineate as the organ appears well defined compared to the surrounding tissues in the abdomen however if possible the inferior vena cava should be excluded.'

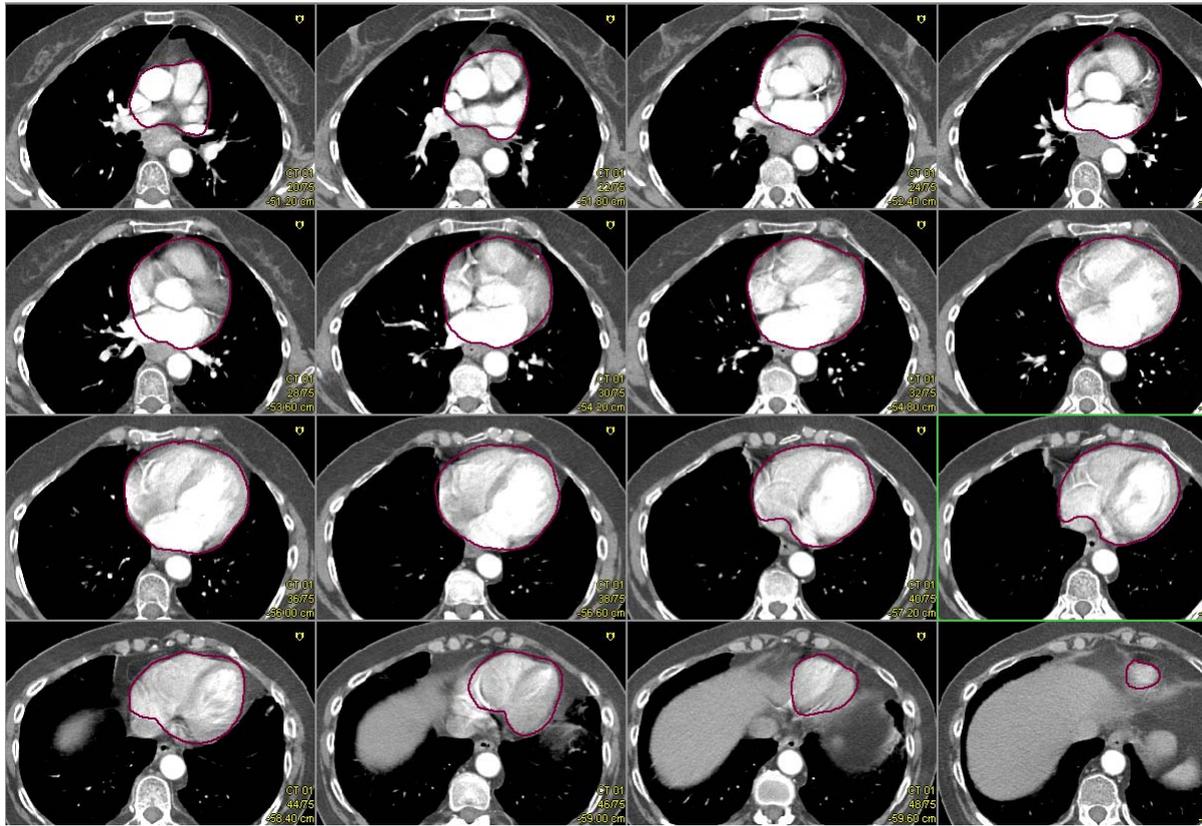


Fig. 11: Alternate 0.3 cm CT slices indicating heart delineation

4 TREATMENT PLANNING

All computer planning must be carried out on a 3D dataset, and correction for tissue heterogeneity must be applied. Usually, a tangential pair beam arrangement is used to encompass the whole breast PTV, minimising the ipsilateral lung and heart in the fields. The treatment plan must be optimised with 3D dose compensation aiming to fulfil the criteria in Tables 2 and 3 below.

4.1 Dose Prescription

The trial schema for the FAST-FORWARD trial is presented on Fig. 12.



16 Gy or 10 Gy in 2 Gy fractions sequential electron or photon boost to the tumour bed is allowed in all 3 treatment groups (boost decision to be declared before randomisation for each individual patient)

Fig.12: FAST-FORWARD trial schema

4.2 Dose Targets and Constraints

4.2.1 Target Volumes

A clinically relevant normalisation point should be used to prescribe the dose to the tangents. Seek QA advice for inverse planned.

The whole breast or chest wall plan should be optimised aiming to fulfil the criteria specified in Tables 2 and 3 below.

Table 2: Upper and lower dose limits for whole breast PTV

	Mandatory	Optimal
Lower limit	V95% ≥ 90%	V95% ≥ 95%
Upper limit	V105% ≤ 7%	V105% ≤ 5%
	V107% ≤ 2%	
	D _{max} ≤ 110%	

The V95% and V105% dose objectives have been divided into mandatory and optimal levels.

Exceptions to the lower dose limit may be accepted if all of the following conditions are met:

- All methods for target dose coverage improvement (field-in-field modulation, mixed energies, MLC-shaped segments, longitudinal wedges, etc.) have been applied within reasonable limits;
- More than 90% of the target receives at least 95% of the prescribed dose;
- Coverage to the target is compromised in non-breast tissue or in tissue that is not clinically important;
- The area of the tumour bed is completely covered by the 95% isodose;
- The clinical oncologist has been notified and has accepted the plan.

Every effort should be made to achieve the dose objectives specified above. However, if planning takes more than 1.5 times the amount of time required for routine breast planning and the objectives are still not met, please contact the QA team for advice.

In case the constraints have not been met the reasons for this should be stated in the Comments box on the Plan assessment form.

4.2.2 Dose Constraints for Organs at Risk

The dose constraints for whole breast radiotherapy using tangential field arrangements are listed below. If non-tangential fields are used, e.g. inverse planned IMRT for patients, then the participating centre must seek advice of the QA team.

These constraints do not take into account the tumour bed boost dose.

Control group

- The volume of ipsilateral lung receiving 12.0 Gy should be less than 15%
- The volume of heart receiving 2.0 Gy and 10.0 Gy should be less than 30% and 5% respectively.

Test group 1 and 2

- The volume of ipsilateral lung receiving 8.0 Gy should be less than 15%
- The volume of heart receiving 1.5 Gy and 7.0 Gy should be less than 30% and 5% respectively.

The dose constraints for the organs at risk for whole breast irradiation are summarised in Table 3. In case of photon planned tumour bed boost the local centre policy may be applied. This should be sent to the QA team and must be adhered to for all

patients regardless of trial group. Alternatively, the QA team can provide some guidelines.

Table 3: Dose constraints for organs at risk for whole breast and chest wall irradiation

	Mandatory	Optimal
Ipsilateral lung	$V_{30\%} \leq 17\%$	$V_{30\%} \leq 15\%$
Heart	$V_{25\%} \leq 5\%$	
	$V_5 \leq 25\%$	

Although it is essentially a clinical decision, the dose constraints for the organs at risk are generally prioritised over the target coverage constraints. Planners should aim to reduce the amount of lung and heart in the treated area by using MLC shielding on the main treatment fields and/or by shifting the field borders as appropriate, taking into consideration the position of the tumour bed.

4.3 Bolus Use

Centres are encouraged to use bolus to cover part or the entire area of the chest wall for all fractions. If bolus is applied, it should be indicated whether it is to be applied a) to part (e.g. the scar area) or all of the chest wall, b) for all or a specified number of fractions and c) thickness of bolus used for a given photon energy. Bolus can be used in chest wall treatment but not after breast conservation surgery. Bolus policy should be the same for all trial groups.

4.4 Whole Breast and Chest Wall

4.4.1 Photons

Treatment of whole breast and chest wall patients should preferably be done with high-energy photons. Beam energies for treatment as per local practice, usually 6 MV, but a mixture of energies e.g. 6 MV and 15 MV can be used for larger patients.

Treatment planning requirements for each of the 3 groups of the trial may be satisfied with a variety of beam arrangements, however for ease of patient set-up and treatment delivery the following coplanar forward-planning technique is recommended.

The plan consists of two standard tangential fields with non-divergent posterior field edges (Fig. 13 and 14). The isocentre can be placed at the centre of PTV_{WB} or on the slice which falls in the centre of the tumour bed, either on the posterior border or in the centre of the tumour bed volume. The field sizes are selected to cover PTV_{WB} with

collimator rotation to minimise the irradiated lung volume. MLC can be used to shield the ipsilateral lung and heart where possible without compromising PTV coverage.

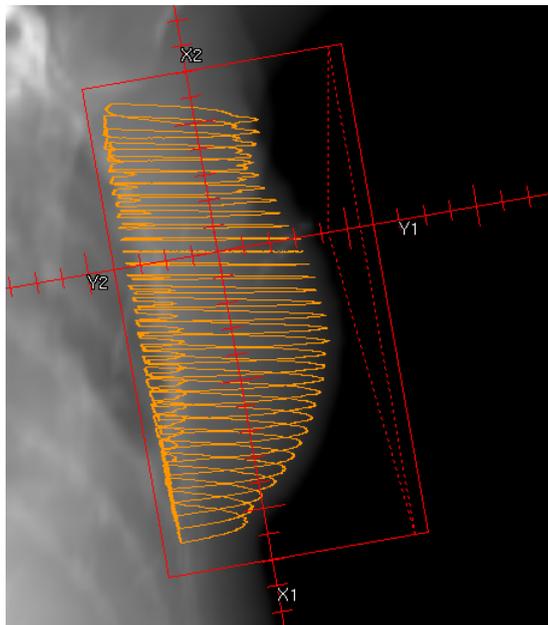


Figure 13: Beam's eye view of whole breast tangent

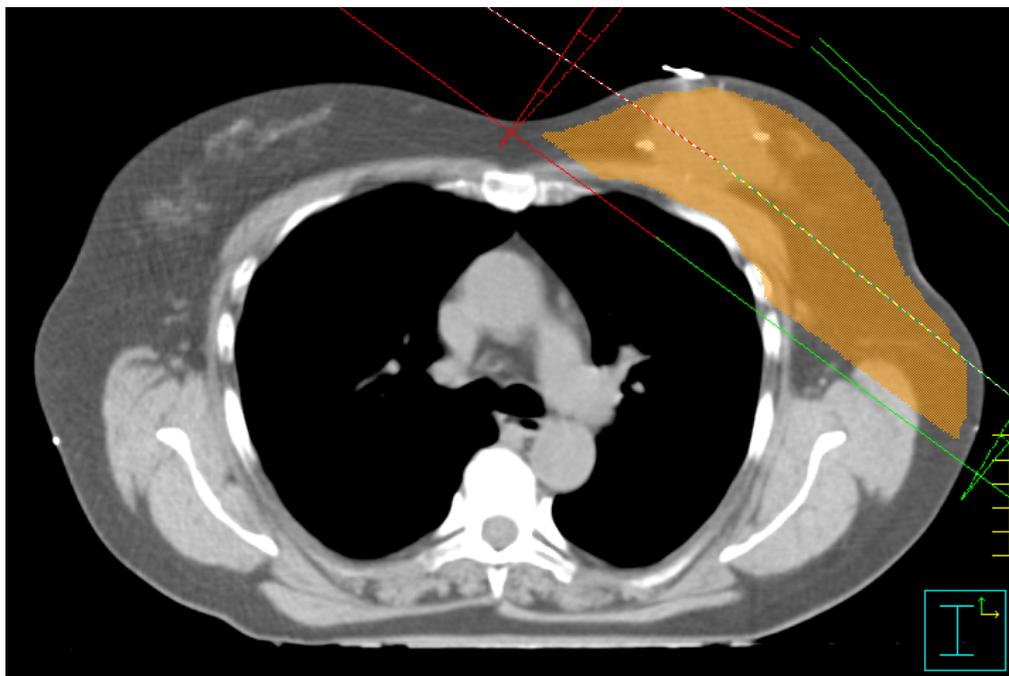


Fig. 14: Whole breast tangential field arrangement

A combination of wedges, simple field-in-field modulation, mixed energies or electronic compensation with step-and-shoot MLC can be used to create a

homogeneous dose distribution to PTV_{WB/CW}. Planners should aim to achieve PTV coverage of between 95% and 107% of the prescribed dose.

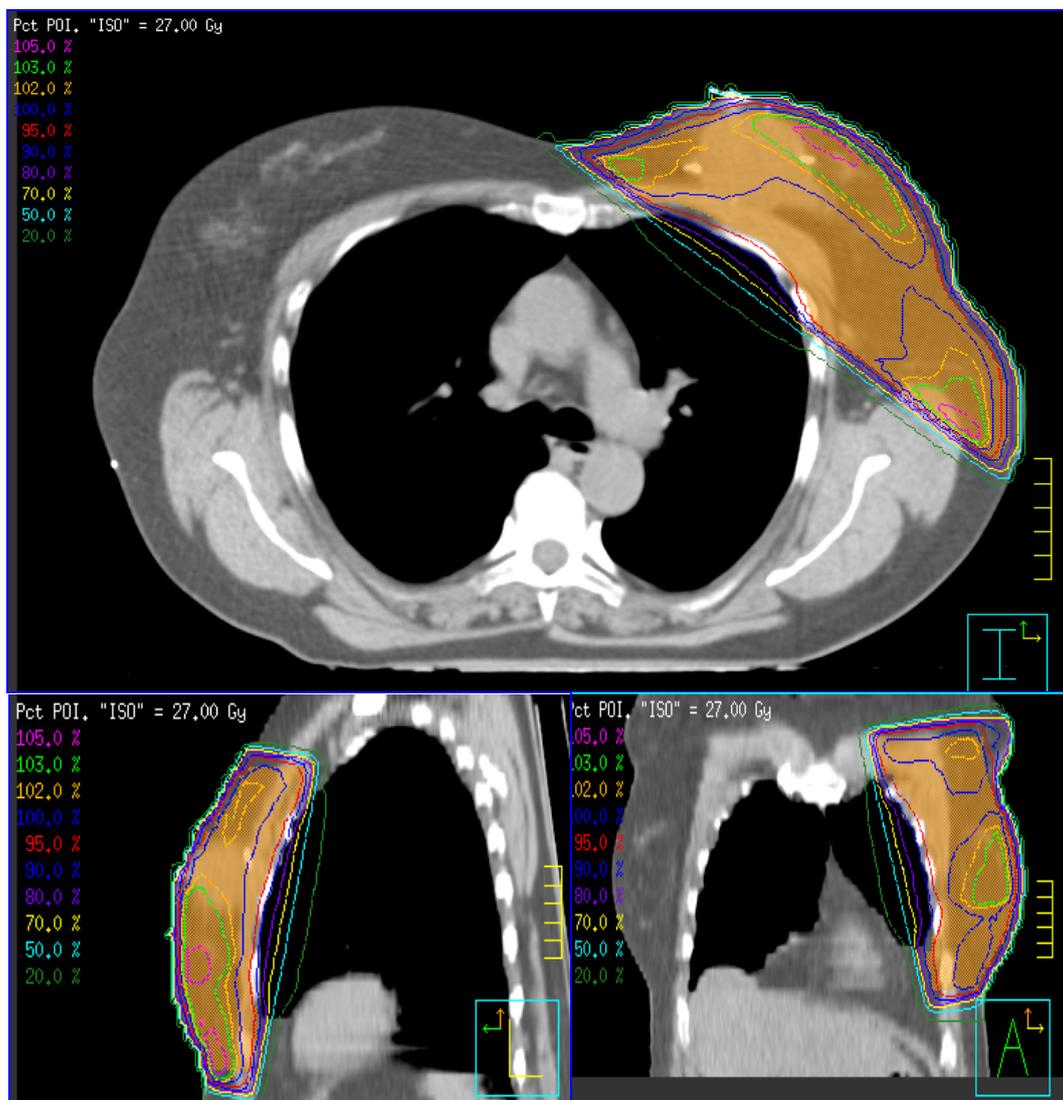


Fig. 15: Dose distribution in whole breast PTV: axial, sagittal and coronal view

On Fig. 16-b) below a projection of the dose clouds in the beam's eye view shows that using simple 3D compensation can minimise hotspots across the breast volume. The image on a) illustrates that using wedged tangents optimised on the central axis with no compensation can produce very large areas of 107% (shown in lavender dose cloud) away from the central axis.



Fig. 16: 3D compensation technique

4.4.2 Electrons

If a centre wishes to treat chest wall patients with electrons, this should be discussed with the QA team.

4.5 Tumour Bed Boost

4.5.1 Photons

Mini-tangential fields can be used for the tumour bed boost, covering the tumour bed PTV with an appropriate penumbra margin. The whole breast field borders are decreased so as to include the tumour bed PTV only. A mini-tangential beam arrangement for the tumour bed boost is presented on Fig. 17.

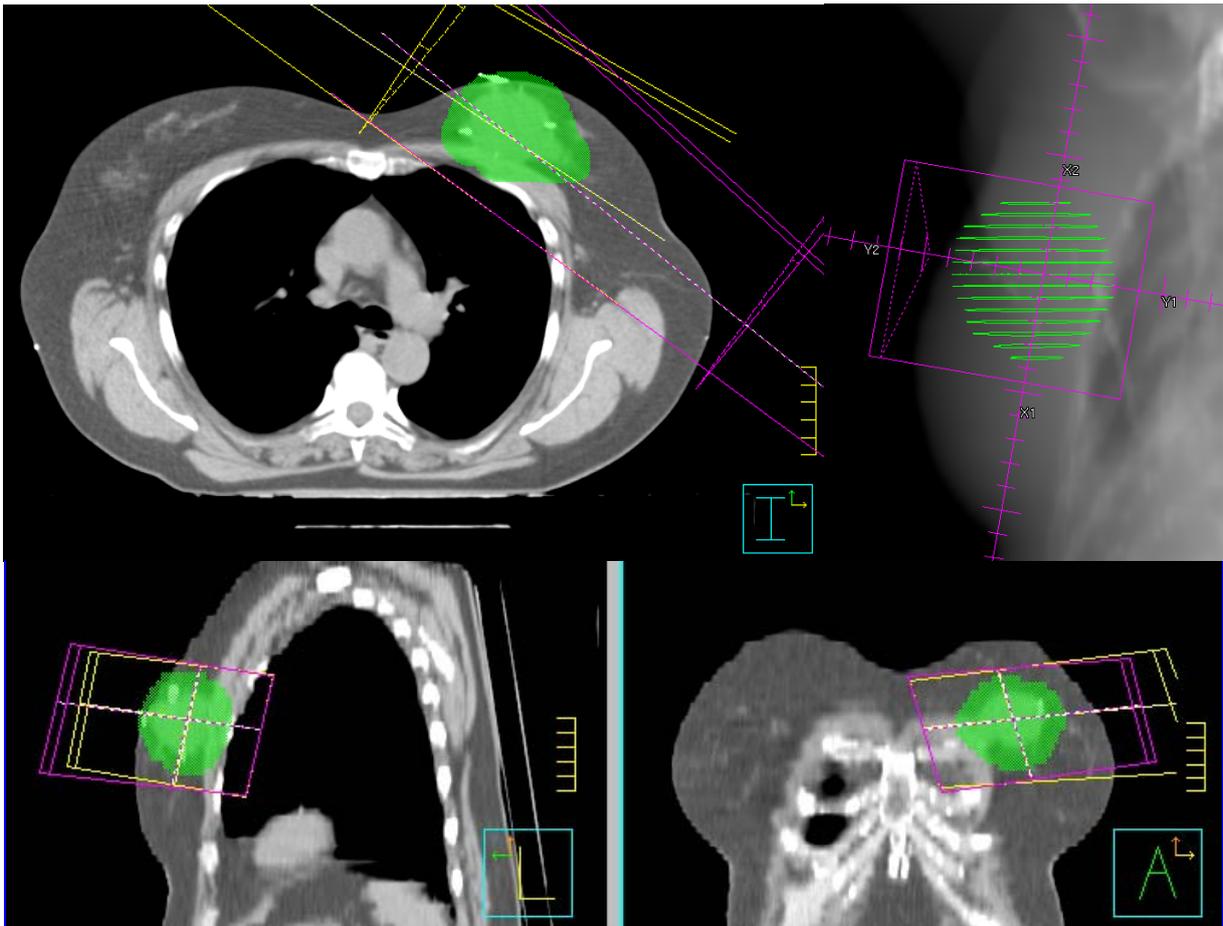


Fig. 17: Image of TB with mini-tangential beams

An alternative field arrangement for the photon boost is a coplanar geometry consisting of 3 to 5 medial and lateral oblique fields. Gantry angles are selected between the whole breast tangents aiming to give 10 Gy or 16 Gy to the tumour bed PTV. The lateral posterior beam(s) will have a shallower gantry angle than the conventional tangent to spare breast tissue, but care should be taken not to exit through the contralateral breast. Extra care should be taken with the lateral anterior beam to ensure the field does not exit through the heart. In the example below 3 beams are added to cover the tumour bed PTV with no margin for penumbra.

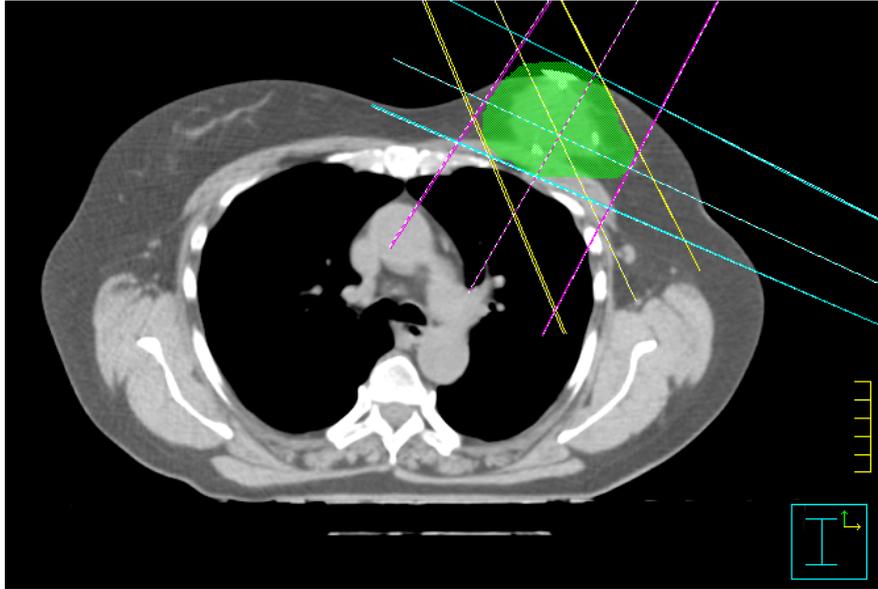


Fig. 18: Tumour bed field placement – coplanar technique

4.5.2 Electrons

Tumour bed boost with electrons can be planned using tabulated depth dose data. Centres should make sure that the beam size, shape, energy and gantry angle are based on the full CT data. The depth of the tumour bed should be used to determine the most appropriate electron energy. The size and shape of the electron aperture should be consistent with the PTV_{TB} contoured in the treatment planning system. Dose should be prescribed to the 100% isodose line, aiming to cover the tumour bed PTV with 90% isodose.

If a centre has the availability to use Monte Carlo or similar algorithm to plan electron boost in the treatment planning system, TPS calculated dose distributions can also be used.

5 RADIO THERAPY TREATMENT VERIFICATION

5.1 Set-up Verification – Breast and Chest Wall

Verification is carried out using electronic portal imaging of the treatment beam. This can be either MV or kV. The following verification methods are proposed for the control and test groups.

5.1.1 Control Group

Treatment verification is required for the first three fractions in the first week of treatment to determine, and correct for any systematic error. All systematic errors should be corrected, and this is recommended as best practice. If a centre wishes to use a correction tolerance on systematic error it should not be greater than 5 mm, and preferable not more than 3 mm, and reported to the QA team. Correction is carried out following local practice as long as this has been approved by the QA team.

Any correction is applied on fraction 4, with imaging to confirm the move. A suitable tolerance for the check of the correction is 5 mm. Verification is then done once weekly throughout the remaining whole breast field treatment with a tolerance of 5 mm.

5.1.2 Test group 1 and 2

Verification imaging is required for each fraction to check for a gross error prior to treatment. A tolerance of not more than 5 mm should be used. Local policy is followed if the check is out of tolerance. A further image may be taken to confirm any correction, and this also applies where daily imaging is used to correct couch position before treatment. Best practice is to correct all measured displacements.

If MV tangential fields are used, the method to derive the couch correction from the images follows local practice, as long as this has been approved by the QA team.

5.2 Set-up Verification – Tumour Bed Boost

5.2.1 Photon Boost

If a conformal photon boost is used, it is recommended to use one of the verification protocols below for both fractionation options (10 Gy in 5 fractions or 16 Gy in 8 fractions).

- i) an on-line verification protocol which corrects for both systematic and random errors in patient set-up but has a time and dose penalty as it requires daily imaging and correction
- ii) an off-line (eNAL or NAL eNAL protocol of de Boer) correction protocol which only corrects for the systematic error but has the advantage of a reduced imaging burden as daily imaging is not required.

If photon mini-tangent fields are used, the first 2 or 3 fractions are imaged (as appropriate for the fractionation scheme). A correction for the systematic error is made for the remaining fractions. It is recommended that all systematic errors are corrected. If a centre wishes to use a correction tolerance on systematic error it should not be greater than 5mm, and preferable not more than 3 mm, and reported to the QA team. A check of the correction may be made on fraction 6 for the 16 Gy in 8 fraction schedule; 5 mm is a suitable tolerance.

Alternatively, as the fractionation schedules are short, daily imaging may be used as described for the whole breast/chest wall Test Groups 1 and 2.

5.2.2 Electron Boost

The electron boost set up is verified daily by visual matching to marks on the skin and checks on the gantry and collimator angles required for matching. If virtual simulation is used, the gantry and collimator angles should not vary by more than 5° from the values identified as most suitable during simulation.

Where the need for more complex treatment planning (e.g. inverse planning or tomotherapy) requires a verification method not described here, centres are requested to discuss this on an individual basis with the QA Team. Similarly, if a centre wishes to use a tighter PTV margin with a more stringent verification protocol, this should be discussed with the QA Team.

5.3 In-vivo Dosimetry

In line with current UK guidelines, it is strongly recommended that all FAST-Forward patients have in-vivo dosimetry within the first week of treatment for the control group, and on the first day for the test groups. This may be performed using diodes or thermoluminescent dosimetry (TLD).

6 TREATMENT GAPS

A gap of up to 3 days is acceptable in the event of machine service, breakdown or patient illness. If the treatment machine is unavailable for more than 3 days, or if you wish to move a patient to a machine with no imaging facilities before the initial correction for systematic error has taken place, please contact the QA team.

7 REFERENCES

1. Surgical guidelines for the management of breast cancer. Eur J Surg Oncol, 2009. 35 Suppl 1: p. 1-22.