Advances in Radiation Oncology (2024) 9, 101535

advances in radiation oncology

www.advancesradonc.org

Scientific Article

Intensity Modulated Therapy for Patients With Breast Cancer. Practical Guidelines and Tips for an Effective Treatment Planning Strategy

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Received 14 April 2023; accepted 16 March 2024

Purpose: Practical guidelines and tips for effective and robust radiation therapy treatment planning for patients with breast cancer are addressed for fixed-field intensity modulated radiation therapy (IMRT) or volumetric modulated arc therapy (VMAT) techniques. The concepts described here are general and valid on all treatment planning systems. However, some details shown here have been applied to the Varian platforms used at the authors' institutions.

Methods and Materials: The specific aspects of using C-arm− or O-ring−mounted linear accelerators are covered in the document, as well as tips for dealing with certain resource constraints, target cropping, and skin flash aiming to reduce risks of skin toxicity and to manage (residual after breath control) respiration motion or edema.

Results: A decision tree is presented, and practical solutions for cases where a target volume is contoured or not and where volumetric modulated arc therapy or fixed-beam intensity modulation should be applied and details about the technical implementation (tangential IMRT, butterfly IMRT or VMAT, and large partial VMAT arcs) are discussed. Target cropping and skin flash implications are discussed in detail, and links to plan robustness are outlined.

Conclusions: Practical guidelines for breast planning are presented and summarized with a decision tree and technical summaries.

Introduction

According to the Global Cancer Observatory Report 2020,[1] female breast cancer is the leading cause of global cancer incidence, the fifth leading cause of cancer mortality worldwide, and the leading cause of mortality in 100 countries. The incidence of breast cancer is increasing fast in developing countries. The management of this burden requires (1) access to care (infrastructures, personnel, and opportunity) and (2) state-of-the-art treatment modalities. Radiation therapy (RT) is one of the founding pillars of breast cancer treatments (eg, after breast-conserving surgery).[2]

Access to care and technology availability in low- and middle-income countries is highly heterogeneous, with substantial treatment gaps identified in many areas worldwide. The disparity in access is particularly obvious in Sub-

Sources of support: This work had no specific funding.

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https://doi.org/10.1016/j.adro.2024.101535

Saharan Africa, where the interval to receipt of adjuvant breast RT is more than 12 weeks in 23% of institutions, with only 22% having access to intensity modulated radiation therapy (IMRT), as reported by the African Organization for Research and Treatment in Cancer network.[3]

The availability of good technical guidelines to assist departments transitioning to advanced techniques can play a vital role in improving the time interval before receiving adjuvant RT as well as the quality of RT received. As such, it is an essential part of implementation science in the developing world.

Treatment planning for intensity modulated external beam RT for breast cancer is a complex multifactorial process. Although the target definition (not addressed here) is adequately addressed by many consensus reports, eg, the European Society for Radiotherapy and Oncology guidelines,[4,5] there is a lack of published guidelines on several of the other technical elements of transitioning to advanced RT techniques in breast RT treatment planning. These include the choice of the treatment platform and the beam energy; the technique (fixed-field IMRT or volumetric modulated arc therapy [VMAT]); optimization strategies; and plan robustness against respiratory motion uncertainties or edema increasing the size of the breast during the course of treatment. In addition, the contouring of high numbers of cases in some resource-constrained environments may constitute a rate-limiting step in providing timeously delivered adjuvant RT.

In this article, we aim to summarize practical guidelines derived from the clinical and educational experience of the home institutions that have been involved with the implementation of advanced IMRT and VMAT planning training and delivery for breast cancer at the Humanitas Research Hospital and at the Groote Schuur Hospital to provide a framework for safely implementing such techniques at other institutions.

It should be noted that the material presented here is intended as an expert's recommendation summary, while more detailed elements can be found in the Supplementary Materials section. Figure 1 provides the comprehensive decision tree and recommended technique solutions and will be discussed in detail in the following sections.

The themes addressed in this report are general and valid for application to breast cancer management planning and treatment in centers equipped with intensity modulation technology, independent of the machine manufacturer and treatment planning system (TPS) platform. Some details have been presented here as applied to the Varian systems for practical reasons. In the frame of implementation science, readers with different systems can easily adapt the guidelines presented here to their local conditions.

The topic of the dose fractionation regimen is not included in this report. Standard or hypofractionated regimens do not directly impact the general planning strategy. Of course, fractionation will determine the explicit dose-volume constraints and clinical aims applied to optimize the dose distributions. The consensus guidelines from the Quantitative Analysis of Normal Tissue Effects in the Clinic[6] or other national/international recommendations should inform the explicit choices. The main organs at risk (OARs) to be considered for dose limitation are the heart, the ipsilateral lung, the humerus, and the contralateral lung and breast; of interest could also be the stomach

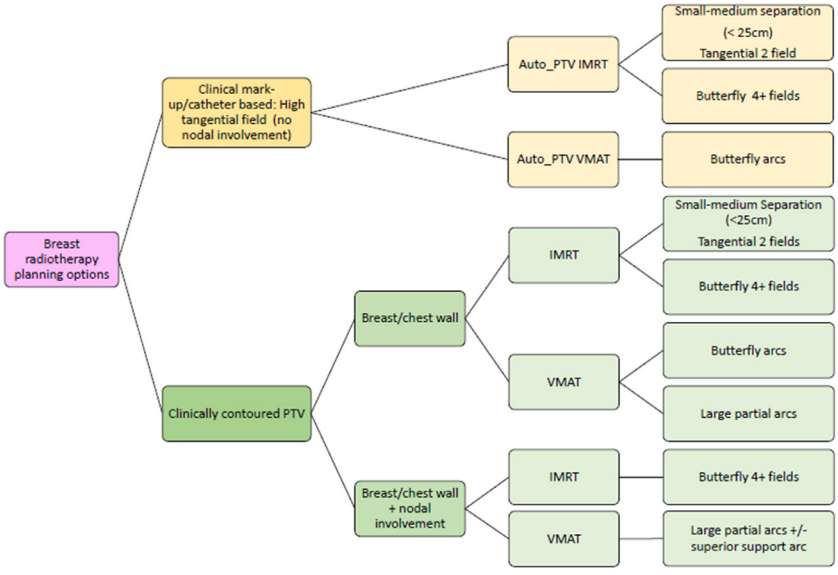

Figure 1 Comprehensive decision tree and recommended technique solutions for the cases with a target initially contoured or semiautomatically generated, for whole breast or breast with nodal involvement, and for fixed-field intensity modulated radiation therapy (IMRT) or volumetric modulated arc therapy (VMAT) (large or butterfly arcs).
Abbreviation: PTV = planning target volume.

for left-sided, the liver for right-sided breasts, the thyroid and the spinal cord for supraclavicular nodes irradiation. Tolerance dose levels are the same for ipsilateral and contralateral structures; however, contralateral structures could be more easily spared, allowing further dose reduction.

RT boost strategies will only be partially addressed in this report because implementation adds further complexity to the required modulation patterns and may require more fields/arcs. Where the radiation oncologist determines that a boost will be of clinical value, a number of treatment delivery options are available. Sequential boosts can be delivered using brachytherapy, electrons, or photons (3-dimensional [3D] conformal RT, IMRT, or VMAT), while simultaneously integrated boost (SIB) RT is possible with IMRT and VMAT.[7]

Choosing the Treatment Platform: C-Arm versus O-Ring Specificity

The choice of the treatment platform and technique depends on the hospital infrastructure. Planning strategies must be adapted to available infrastructure and human resources. Some unique characteristics of C-arm− or O-ring−mounted linear accelerators (linacs) should be considered.

When a C-arm−mounted linac is chosen

Most state-of-the-art linacs offer the choice between flattened (FF) or unflattened (flattening filter−free, FFF) photon beams. To ease the optimization process and mitigate dose heterogeneity issues, FF beams are advisable, although FFF beams can also be used effectively. With FF beams and the 3D conformal technique, wedges (hard or virtual) are needed to homogenize the dose distribution, or forward intensity modulation with the field-in-field (FiF) technique is also possible.

Many linacs include hard jaws and multileaf collimators (MLCs). In these cases, the jaw-defined field size should be matched to the maximum leaf travel of the MLC. Jaw tracking, where jaws are available, is recommended to minimize the dose contribution from leaf transmission and interleaf leakage.

When an O-ring−mounted linac is chosen

Excluding helical tomotherapy and magnetic resonance integrated linacs (MR-linacs), the Varian Halcyon is today's only delivery platform in this category. A single FFF photon beam of 6 MV energy is available and should be used. The marginally lower energy of a FFF beam, compared with an FF beam of the same nominal energy in the Varian domain, should be considered carefully because it can increase the dose delivered to the skin if not managed appropriately. Figures E1 and E2 provide some basic comparisons to clarify the topic.

Halcyon has no jaws but uses 2 fixed square-field (28 cm × 28 cm) collimators, followed by the MLC. The dual stacked-staggered layer MLC design results in negligible transmission/leakage, improving OAR protection.

The primary collimator is rigidly fixed, whereas the secondary collimator rotates with the MLC, the former clipping the corners of the field within 28 cm for collimator angles other than 0° and 90°. This may present a limit for some patients with supraclavicular nodal involvement. Automated dual-connected isocenter planning and delivery can be adopted, which extends the treatment length to 38.5 or 36 cm, depending on the machine version. Figure E3 illustrates the principle. Longer targets are infrequent in the context of breast cancer and should be managed in the same way as, for example, done for craniospinal irradiation.[8]

Patient positioning for treatment on O-ring−mounted linacs should allow for patient clearance within the bore. Two strategies may be followed, using (1) a wing-board immobilization system with the patient in supine position with both arms elevated above the head or (2) a breast-board immobilization system with the board at an angle of approximately 7.5° to stabilize the position of the breast and stomach. The lower breast-board angle increases clearance and allows more flexibility regarding the isocenter position.

IMRT Planning Strategies

The use of fixed-field IMRT is technically simple on both C-arm and O-ring treatment platforms. It can generate dose distributions with minimal involvement of the contralateral structures and an adequate balance between target coverage and ipsilateral OAR sparing. This report refers to the International Electrotechnical Commission IEC-61217 scale conventions for gantry and collimator angles.[9]

Four fields butterfly

This very effective IMRT field arrangement is illustrated in Fig. 2 and consists of 2 medial and 2 lateral fields, with approximately 15° to 20° separation between each coupled field. The collimator angle should be approximately 10° (and its complementary) and fine-tuned according to the patient's anatomy.

This technique grants high coverage and homogeneous dose distributions to the target while maximally sparing contralateral and ipsilateral OARs. It suits all target

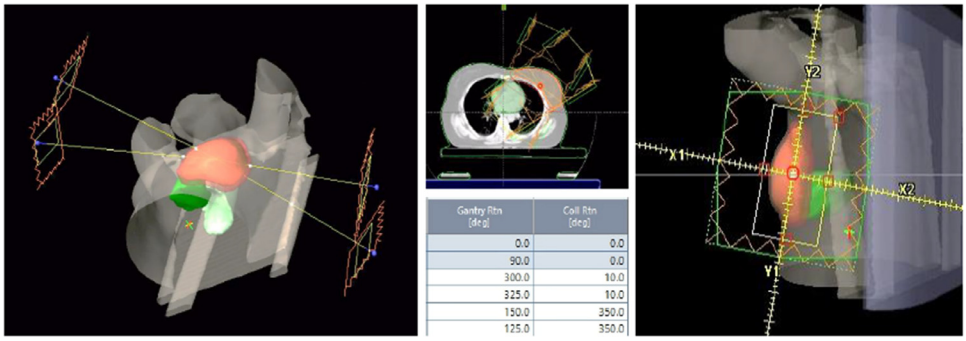

Figure 2 The most effective intensity modulated radiation therapy field arrangement consists of 2 medial and 2 lateral fields, with a 15° to 20° separation between each coupled field. Abbreviation: Rtn: rotation, Coll: Collimator.

conditions (small or large separation, breast/chest wall only or nodal involvement). It is not ideal for SIB schemes.

Fine-tuning of the angles of the lateral fields might be required, particularly for patients with highly concave chest walls. Adding more fields (up to 7) with posterior entrances might benefit these and other geometrically complex cases. This would facilitate shaping the dose distribution and protecting the lung and heart (in left-sided lesions).

Two tangential fields

A more straightforward IMRT approach uses 2 tangential fields, similar to the 3D conformal RT approach. This geometry is recommended only for the whole breast/chest wall target, for patients not having a highly concave chest wall, and for patients with a small-medium separation, in practice, smaller than 25 cm. The tangential approach with larger separation would lead to suboptimal homogeneity and coverage and increase the out-of-target volume receiving high doses. Jaws setting and collimator angles follow the same rules as the butterfly IMRT case.

To achieve good plan quality for SIB regimens with IMRT, it would be necessary to increase the number of fields and adopt a not-only-tangential arrangement.

VMAT Planning Strategies

If the technique of choice is VMAT, 2 main approaches can be followed. The use of continuous partial arcs (or "large" arcs) or paired short arcs to mimic a bow-tie or butterfly geometry, as shown in Fig. 3.[10]

Large arcs

For left breast cases, the arc arrangement consists of 2 partial arcs, with the gantry running from approximately 300° (range, 285°-307°) to approximately 173° (range, 160°-180°). The symmetric setting applies to right-breast cases. The collimator angles are set at 10° to 22° (or higher, when the treatment includes the lymph nodes), with complementary angles for the second arc.

This arrangement mitigates achieving high target coverage and low dose heterogeneity at the expense of more aggressive sparing of the ipsilateral structure and an

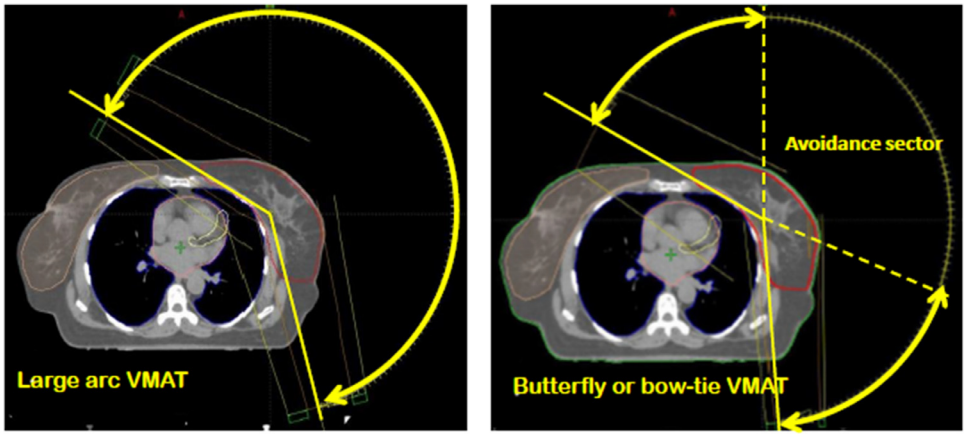

Figure 3 The proposed volumetric modulated arc therapy (VMAT) solutions: the use of continuous partial arcs (or "large" arcs) or paired short arcs to mimic a bow-tie or butterfly geometry.

unavoidable involvement of contralateral structures with exit-dose contributions. It should, therefore, be considered with care depending on the clinical aims and priorities.

It is the preferable approach when nodal structures (internal mammary chain or supraclavicular nodes) are included in the target because this technique is more suitable for more complex target shapes.

Butterfly VMAT

The butterfly technique consists of coupled pairs of short arcs, 1 medial and 1 lateral-posterior. For the left breast, the medial arcs should run from approximately 300° to approximately 350° to 30°, and the lateral-posterior arcs should run from approximately 90° to 110° to approximately 170°. The collimator should be different for each arc in the pair, while following the target anatomy—a symmetrical setting for the right breast. The region of no arc, in front of the breast, can be identified for each patient based on the anatomy seen in the beams-eye-view, aiming to avoid the heart and the contralateral breast. The collimator angles are the same as for the large-arc VMAT approach.

A similar technique can be achieved with a large-arc setting, adding the so-called avoidance sector (arc sector with dose rate dropped to 0) with the limitation of a fixed collimator angle.[10]

The butterfly VMAT solution appears more appropriate when the whole breast (with or without SIB) is treated with no nodal volumes. In these cases, the presence of the avoidance sectors minimizes the exit dose to the contralateral structures (providing dose-volume metrics equivalent to conventional tangential approaches) and enables robust heart and ipsilateral lung protection for patients with left-sided lesions.[11]

Both VMAT solutions can be realized with 2 arcs. In some cases, a third could be beneficial to increase the modulation potential in the optimization. In such a case, a collimator angle of 90° is recommended.

The study by Fogliata et al[10] illustrates in detail the dosimetric potential and features of the large or butterfly VMAT approaches, and readers are referred to that publication for a quantitative appraisal.

Target Cropping

In all clinical cases where target volumes approach the skin and, in particular, in the case of breast cancer treatment, one important topic to address is the balance among target coverage, risk of skin toxicity, and the robustness and accuracy of the dose calculation in the build-up region.

Unless there is clinical evidence of skin infiltration, the critical point is thus the need to retract the breast target volume from the skin. The American Society for Radiation Oncology evidence-based guideline,[12] assuming that the whole breast volume should be defined clinically with the goal of 95% volume coverage with the 95% dose level, strongly recommends retracting the target volume 3 to 5 mm from the skin. This "margin" should ensure greater calculation accuracy and mitigate the risk of "pumping" the fluence maps near the surface to counteract the build-up limits. Excessive fluence in the skin region is associated with higher skin toxicity risk.

Similarly, other organizations also recommend target (clinical target volume [CTV] and planning target volume [PTV]) cropping below the skin, at least for reporting purposes (eg, the guidelines from the Netherlands[13]). The American Association of Physicists in Medicine report on the use of FFF beams clarified that the highest risk is the failure to account for excessive skin dose,[14] with an implicit recommendation to mitigate this risk with available tools (like cropping).

The skin dose and risk of undue toxicity are even more relevant in the O-ring machines (Halcyon), where the FFF beam is the only option.

Figure E5 illustrates the fluence "pumping" effect for 2 IMRT fields in the case of the target's 5, 3, or 0 mm cropping.

In all cases, the target cropping of 3 to 5 mm inside the skin must be considered a mandatory element of proper planning.

Some TPSs may incorporate tools to mitigate the risk of the "pumping" effect in the build-up region. One example is the surface margin tool in the Elekta Monaco TPS (Elekta Solutions AB).

Optimization and Dose Calculation Notes

The following recommendations are generally relevant, although some of the tools discussed pertain to the Eclipse TPS (Varian Medical Systems, Palo Alto, CA). However, those principles can be applied to other TPSs using the corresponding tools.

Final dose calculation and plan normalization

The current TPSs implement type-b (collapsed cone or analytical anisotropic algorithm) or type-c (Boltzmann's equation solvers or Monte Carlo) algorithms. Whenever available, we strongly advise using a type-c algorithm,[15] which properly accounts for particle transport. Examples include Acuros-XB on Eclipse TPS[16,17] or Monte Carlo on Monaco TPS. The dose to medium calculation mode should be set as the default.[18]

All plans should be normalized according to the International Commission on Radiation Units and

Measurements 83 recommendations.[19] This implies that the absorbed dose is preferably prescribed to the median dose $D_{50\%}$ to the target volume or a defined target coverage $D_{V\%}$. No specific recommendations are provided for a coverage-based prescription. However, good coverage (an adequate dose that covers an optimal percentage of the target volume while optimally restricting the dose to the OARs) is advisable.

Avoiding excessive modulation

One risk of inverse planning, especially when highly conflicting clinical aims exist between targets and OARs, is the generation of optimal fluences with very high modulation factors/indices. Conversion of these high-frequency modulated fluence maps into deliverable sequences of MLC positions might be prone to approximations, impacted by spatial resolution issues, and result in less accurate dose calculations.[20] Some practical consequences result from this: (1) a high number of monitor units (MUs) per single field/arc; (2) very small MLC apertures per control point; and (3) disconnected areas within single control points. These contribute to reducing the robustness of plan delivery and will increase the potential discrepancy between expected and delivered dose deposition. This will only be evident when accurate quality assurance measurements are performed, not via in silico checks such as independent MU calculation or low-resolution measurements.

In the case of IMRT, the fluence optimization should be performed by applying smoothing constraints to mitigate these risks. For example, the Eclipse's X- and Y-smooth options should have a value similar to the priorities applied to any dose-volume constraints in the optimization (the default values of 30 and 40 are typically insufficient when the target or OAR priorities exceed 100). In the case of VMAT, the aperture shape control option (Eclipse specific, aiming to connect small open areas in the field) should be activated and set to either low or moderate.

Finally, the MU objective tool in the photon optimizer user interface (available in Eclipse, forcing the MUs not to overcome a predefined value) can be used as an additional constraint whenever the MUs raise too high values. As a good rule of thumb, the total number of MUs per plan should be in the range of 2 to 3 times the dose per fraction (eg, in the case of 100 MU/Gy calibration at isocenter and 2 Gy per fraction, a total plan MU range of 400-600 MU should be acceptable. Rescaling according to different calibration conditions would be straightforward).

Figure E6 illustrates the effect of the X-Y smoothing and the aperture shape control tools for IMRT and VMAT, respectively, by visualizing the MLC shapes at the same control point for one example field/arc. The difference in the average aperture and the degree of connectivity is noticeable.

Regardless of which TPS is used, it is always advisable to use the available tools to reduce the risk of overmodulation by decreasing the number of MUs or by ensuring the field aperture is not too small. For example, in the Elekta Monaco system, the sequencing parameters, such as the number of control points per arc, the minimum segment width, the fluence smoothing, and the segment shape optimization tools, could be used for this purpose. The RayStation TPS (RaySearch Laboratories AB) has implemented limits on the number of control points, segments, and number of MUs.

Medial and lateral hot spots

To mitigate the risk of significant hot spots in the medial and lateral regions proximal to the target (or in any other location), the use of the Automatic normal tissue objective (NTO) tool (as implemented in Eclipse to model the dose fall-off outside the target) is advisable. The priority has to be tuned, depending on the treatment setup; a priority higher than the highest priority of the target's constraints is suggested, especially when the lymph nodes are in the target volume, to improve the dose conformity; a priority lower than the target priority is, on the contrary, better in the case of 2 simple tangential fields IMRT planning. Figure E7 illustrates the case of plans optimized with or without the recommended NTO setting. The position and intensity of the hot spots can vary from patient to patient. Similar tools available in other TPSs aiming to increase the dose conformity around the target should always be applied to control hot spots. In the Elekta Monaco TPS, the conformality cost function and quadratic overdose tools in the multicriterial optimization process allow improving the conformality and the dose fall-off similarly to the NTO of Eclipse. The RayStation TPS solution consists of a dose fall-off function controlling the dose gradient in the healthy tissue by controlling the upper/lower dose limits and the distance over which the desired gradient should be applied.

Skin Flash

There is no CTV to PTV margin in the skin's direction because of the previously discussed 3 to 5 mm cropping. However, this is also the direction of the most extensive motion. The (residual if deep inspiration breath hold [DIBH] is applied) respiratory motion and the potential expansion of the body outline due to edema require particular attention to avoid the risk of underdosing the more superficial fraction of the target volume due to the missing CTV to PTV margin. The currently accepted

approach is to expand the fluence outside the body outline by approximately 1 to 1.5 cm depending on an individualized risk analysis.

IMRT

The most straightforward method (as implemented in the Eclipse TPS) is to use the dedicated skin flash tool where the fluence expansion is determined by a brush. Figure E9 illustrates how the tool operates.

VMAT

Whenever a built-in skin flash tool is available in the specific TPS, it has to be applied. Such a tool is unavailable for VMAT in Eclipse (while available in other TPSs); in its absence, a different workflow must be implemented. What is described here is a simplified and improved version of the strategy initially proposed in 2011.[21] The various steps are summarized as follows:

1. Define a 1.0 to 1.5 cm thick bolus covering the body outside the target with sufficient margins (a few cm in the X-Y planes, a few slices in the Z direction). Extend superiorly to include the lymph node levels if they are part of the target. Assign a Hounsfield Unit value as adipose tissue (fat breast) of approximately −100 to the bolus.
2. Expand the target (PTV) by the same amount of the bolus thickness (PTV_exp) in the anterior and lateral directions only.
3. Link the bolus to the plan (for Halcyon planning) or to each field (for C-arm linacs planning).
4. Optimize the plan (Plan_B) referring to the PTV_exp target and execute a full calculation.
5. Once optimization is satisfactorily completed, copy the plan (Plan_NB) and unlink the bolus from the plan/fields.
6. Recalculate the Plan_NB. Note: never re-enter the optimization phase using the Plan_NB. In case of need, reiterate from point 4. Plan assessment is done referring to the real PTV.
7. Review, approve (based on PTV), and treat Plan_NB. The bolus is not part of the treatment.

With this workflow, the Plan_B, optimized on an expanded PTV_exp, will result in the MLC apertures extended into the air when applied to Plan_NB and reproduce the "skin flash" condition. Figure E10 visually summarizes the virtual expansion process and demonstrates the MLC opening in 2 examples.

It is fundamental to remember that the bolus used for the Plan_B optimization must be removed for the Plan_NB final calculation and, of course, never used for the treatment.

This workflow can also be applied to IMRT, although the fluence-specific flash tool is easier to use.

All of the above stand conceptually for mitigating motion/edema-related risks. The practical implementation on other TPSs might require adaptation according to the TPS-specific tools. In the Monaco TPS, the automatic skin flash tool is available for both IMRT and VMAT and adds a user-defined "auto-flash margin" (with a minimum Hounsfield Unit number ≤ 0) to create the needed fluence expansion. In the RayPlan TPS (RaySearch Laboratories AB), a robust optimization scenario is implemented to generate skin flash (simulating patient setup or organ motion uncertainty).

When No Target Is Originally Contoured

If sophisticated techniques are considered for treatment, the best practice is to have the target contoured by qualified physicians. Nevertheless, in resource-constrained environments, the time taken for target contouring may constitute a rate-limiting step in providing RT timeously. If, for any reason, the breast target volume is not contoured, the minimal approach observed is to plan for tangential fields, using FiF or electronic compensator approaches to improve homogeneity. We propose a straightforward method to generate a "reasonable" automated target volume (Auto_PTV) that will enable the use of all the IMRT/VMAT strategies discussed above. A similar approach is used in the IMPORT HIGH clinical trial.[22]

As with any auto-contouring tool (including the more sophisticated systems based on artificial intelligence), a careful review and approval by the radiation oncologist of the Auto_PTV is a mandatory step before planning and treatment.

This solution of creating an Auto_PTV might not be sufficient for all cases. For example, medial tumors would require that the most medial aspect of the breast be covered but not necessarily the most lateral aspect.

The proposed workflow assumes that external markers like wires, catheters, or other visible references are positioned on the patient's skin before the planning CT acquisition. Figures E11 to E13 visually summarize the process described below.

The following steps are executed to generate the Auto_PTV:

1. Isocenter determination and definition of limits and extensions:
    a. Identify the central slice as the midway slice between superior and inferior markers.
    b. Define point 1 as the midline marker.
    c. Define point 2 as the lung-rib interface at the level of the lateral marker.

d. Use measurement tools to join points 1 and 2 and extend the line to the body outline.
e. Confirm that approximately 2.0 cm of the lung is included above the virtual line.
f. Position the isocenter on the line (and confirm clearance of body/couch with the bore of the O-ring−mounted linac) as a standard half-beam setting.

2. Dummy plan preparation and calculation:

a. Align gantry angle with midline marker for medial field.
b. Align collimator angle with breast using 10/350° (left or right patients).
c. Set field limits to clinical borders, open on breast/chest wall, using either jaw or MLC.
d. Insert the opposing lateral field with proper collimator angle and field shaping.
e. Define a normalization point 1.0 cm into the breast tissue on the central slice.
f. Use an unflattened beam (possibly).

3. Auto_PTV generation and refinement:

a. Using the dummy plan, set the calculation volume to include the breast but exclude all normal tissue posterior to the midline and any extension into the breast board or arm.
b. Calculate its volume dose using the available beam energy (6 MV FF or FFF, if available).
c. Evaluate the 60% to 80% isodose lines to identify the level corresponding geometrically to the best coverage of the breast.
d. Convert the selected isodose into Auto_PTV structure.
e. Edit the Auto_PTV to remove any ipsilateral structures.
f. Crop the Auto_PTV 3 to 5 mm inside the body outline and use it for all planning steps.

Discussion, General Remarks, and Report Exclusions

The clinical evidence suggests that IMRT or VMAT are not the only available techniques for the treatment planning of breast patients. Other approaches include the use of electronic compensators and FiF methods. Limiting to O-ring systems, several planning studies and early clinical reports confirmed the feasibility of these techniques.[23-25] Nevertheless, each of those approaches results in more complex and labor-intensive workflows not correlated with significant benefits in terms of dose-volume metrics or planning or delivery efficiency. We have therefore excluded these methods from the current guidelines.

The use of IMRT or VMAT for breast RT could lead to a significantly higher number of MUs compared with conformal therapy. Despite the mitigation strategies discussed above, this could raise some concerns regarding the risk of secondary cancer induction. Earlier in silico investigations proved that if IMRT and VMAT are carefully planned, this risk can be minimized and kept to levels comparable with those of conformal techniques.[26]

The available delivery platforms could constrain the choice of the beam energy to be used for breast planning. Only a low-energy FFF photon beam is available with O-ring machines, whereas, typically, C-arm machines have multiple energy options. Higher beam energy, like 15 MV, is discouraged for IMRT, but for patients with large separation, a beam of 10 MV could offer better dose homogeneity in the target. Nevertheless, it is important to note that 10 MV photons have a larger build-up (the depth of the maximum dose is approximately 5 mm deeper than that for 6 MV), leading to a trade-off between homogeneity and coverage (in the more superficial section of the target). Clinicians should apply the best energy selection according to the clinical aims. Mixed energy beam solutions can also be adopted.

In the introduction, we mentioned the options available for tumor bed boosts. The use of electrons is not possible on O-ring platforms. In contrast, in C-arm systems, the advantage of photons over electrons was proven and suitable for accelerated partial breast treatments in some in silico investigations.[27,28] In addition, using photons only enables the delivery of SIB regimens and all the recent accelerated regimens.

Another relevant topic not addressed here is the management of breathing-induced motion. The consensus points to the relevance of using some breath control methods, and the most appropriate result is the treatment (and planning) in DIBH. This is, therefore, assumed to be a relevant prerequisite for state-of-the-art breast therapy on any delivery platform. Nevertheless, some clinics might not have respiratory monitoring devices, especially in resource-constrained settings. Moreover, not all the patients are suitable to be treated in DIBH. In the current guidelines, we discussed some motion mitigation or plan robustness elements that, a fortiori, are mandatory in all cases where DIBH cannot be performed. More specifically, the fluence smoothing for IMRT, the aperture shape control for VMAT, and the skin flash methods all concur with this.

Conclusions

This report provides practical guidelines and tips for appropriate and robust treatment planning for patients

with breast cancer using advanced techniques. These guidelines were sourced from several years of clinical teaching at several institutions in low-, middle-, and high-income countries and represent the authors' experience and filtered input from the valuable peer-to-peer exchange with real-world colleagues daily facing the challenges and tribulations of high-quality planning for breasts in various settings. We have covered specific aspects of treatment platform characteristics, treatment techniques and various risk mitigation approaches. The report addresses the case of whole breast or chest wall treatment and the case of nodal involvement. Several complementary pieces of information have been provided to better explain the various topics. In the Supplementary Material, including Table E4, all the guidelines and tips are aggregated in a comprehensive and structured format, which can guide the user to the proper solution for all situations discussed in this summary.

Disclosures

Luca Cozzi is Clinical Physics Innovations Director and Hester Burger is Academic and Strategic Programs Manager of the Medical Affairs Division at Varian Medical Systems. Luca Cozzi reports stock or stock options of Varian Medical Systems. Antonella Fogliata reports grant support from Varian Medical Systems paid to IRCCS Humanitas. All other authors have no conflicts of interest. No artificial intelligence (AI) or AI-assisted technologies have been used in the creation of this article

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.adro.2024.101535.

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