Practical Guides in Radiation Oncology
Series Editors: Nancy Y. Lee · Jiade J. Lu

Jennifer R. Bellon
Julia S. Wong
Shannon M. MacDonald
Alice Y. Ho *Editors*

Radiation Therapy Techniques and Treatment Planning for Breast Cancer

Springer

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Series editors

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The series *Practical Guides in Radiation Oncology* is designed to assist radiation oncology residents and practicing radiation oncologists in the application of current techniques in radiation oncology and day-to-day management in clinical practice, i.e., treatment planning. Individual volumes offer clear guidance on contouring in different cancers and present treatment recommendations, including with regard to advanced options such as intensity-modulated radiation therapy (IMRT) and stereotactic body radiation therapy (SBRT). Each volume addresses one particular area of practice and is edited by experts with an outstanding international reputation. Readers will find the series to be an ideal source of up-to-date information on when to apply the various available technologies and how to perform safe treatment planning.

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Contents

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Whole Breast Radiation for Early Stage Breast Cancer

1

Rachel C. Blitzblau, Sua Yoo, and Janet K. Horton

Contents

Many patients with early stage breast cancer will be candidates for breast conservation including adjuvant radiotherapy. In this setting, whole breast radiotherapy (WBRT) is the most commonly utilized approach. This can be accomplished with the patient in the supine or prone position, and the treatment course can range from 3 to 7 weeks in duration, depending on patient and tumor characteristics. Generally, 3–6 weeks elapse following lumpectomy before initiation of WBRT to allow post-surgical healing. In this chapter, we cover the basics of the whole breast radiotherapy treatment planning.

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1.1 Initial Simulation

The majority of US treatment centers utilize computed tomography (CT)-based simulation and treatment planning. In the supine position, patients are immobilized with their arms up on a breast board, Alpha Cradle, Vac-Lok, or other immobilization devices (Fig. 1.1a, b). Often, some degree of tilt is applied to isolate breast tissue below the level of the head of the clavicle. The patient's head is positioned with the chin up and may be turned slightly to the contralateral side if necessary to keep it out of the radiation field. In the prone position, the patient is positioned with their arms up and head turned either away from the treated breast, toward the treated breast, or in a neutral position depending on the style of prone breast board and individual patient comfort (Fig. 1.1c, d). The ipsilateral breast falls into the open portion of the breast board, while the contralateral breast is pulled away and supported beneath the patient. Prone positioning may be particularly useful for patients with large breasts in order to reduce the tissue separation size and minimize the inframammary fold.

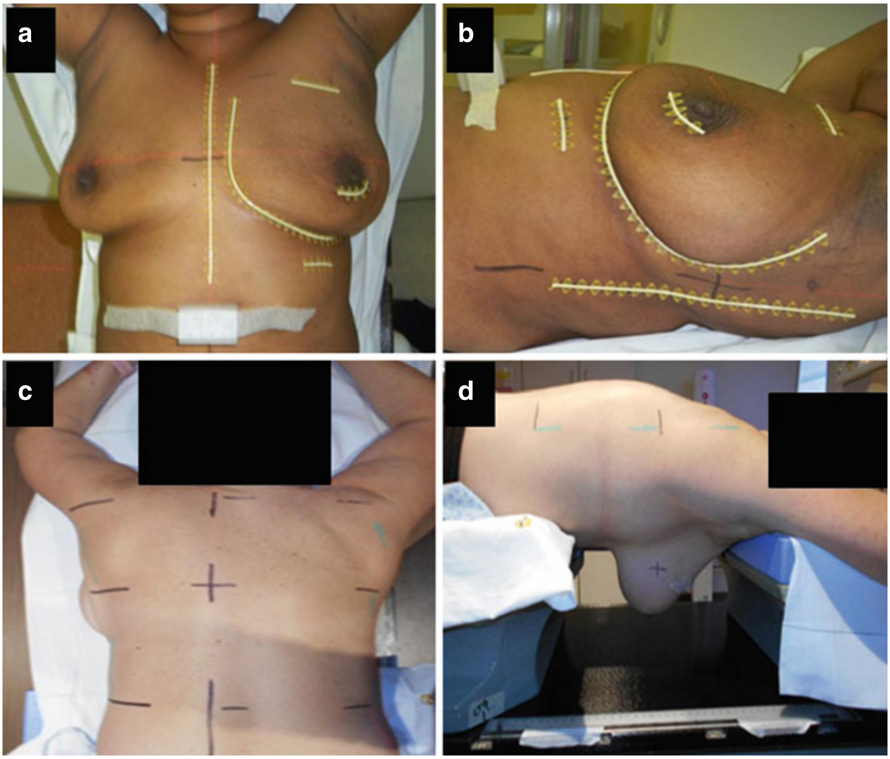

Fig. 1.1 Patient positioning and marking for CT simulation in the supine (**a**, **b**) or prone (**c**, **d**) positions. Radiopaque fiducial wires are placed to mark the superior, inferior, medial and lateral extent of breast tissue plus a margin (**a**, **b**). A wire is utilized over the lumpectomy incision and one delineating the breast tissue from 2 to 10 o'clock (**a**, **b**). Leveling marks are drawn on the patients torso in the supine (**a**, **b**) and prone positions (**c**, **d**) for alignment on the treatment machine

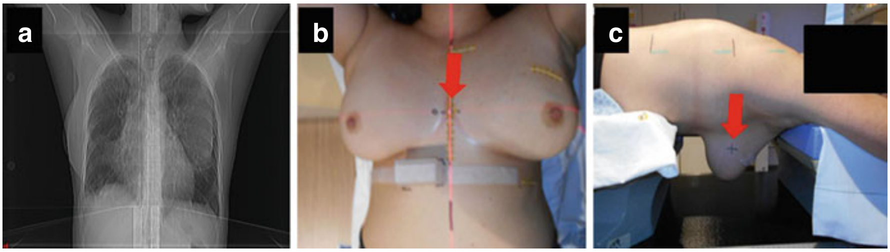

Fig. 1.2 CT scout imaging and reference markings. (**a**) A scout image is taken to confirm the scan area and patient position. (**b**) A stable reference point is set on the central sternum (*arrow*) in the supine position. (**c**) A stable reference point in the prone position is set on the lateral breast (*arrow*)

Prior to the CT scan, radiopaque fiducial wires are placed on the patient in order to delineate the clinical boundaries of the breast tissue (Fig. 1.1). Traditionally, the superior border is placed at the inferior aspect of the clavicular head, the inferior border approximately 2 cm below the inframammary fold, the medial border at midline over the sternum, and the lateral border at the midaxillary line. A fiducial wire is also placed on the lumpectomy scar. Adjustment of the wires from standard physical landmarks may be required to allow approximately 2 cm margin around the palpable breast tissue for patients with larger or smaller breast sizes. Current cooperative group trials often utilize semicircular demarcation of the clinically apparent breast tissue in addition to the landmarks described above. For women simulated in the prone position, all wire demarcation is performed in the supine position with arms up prior to prone immobilization.

Next, a scout CT scan is obtained to verify patient position, alignment, and reproducibility (Fig. 1.2a). Subsequently, 2–4 mm axial CT images are obtained with superior and inferior scan borders several centimeters above and below the desired top and bottom of the treatment fields. If a respiratory gating system is in use, the scan borders should be adjusted to include the necessary apparatus (see chapter on deep inspiratory breath hold for more details).

A stable reference point is then set to facilitate patient positioning on the day of simulation (Fig. 1.2b, c). At our institution, this point is placed along the sternum at mid-chest level in the supine position. For patients treated prone, the reference point is placed in the middle of the breast tissue in the cephalocaudal direction and on the lateral aspect of the breast at the level of the breast board surface in the anteroposterior direction. In either case, the reference point is marked on the patient's skin utilizing the room lasers and subsequently utilized for shifts to the treatment isocenter during positioning on the treatment table. Alternatively, the isocenter may be selected and marked on the patient at the time of CT simulation. Indexing and leveling marks are also made on the patient along the thorax, breast, and arms (prone) and protected with clear stickers to maximize reproducibility on the treatment table. A greater number of markings may be required for prone positioning, due to larger interfraction setup variability [1]. Alternatively, permanent tattoos may be utilized for treatment position markings.

1.2 Boost Simulation

For patients treated in the supine position, the initial simulation scan is often sufficient for boost treatment planning as well (Fig. 1.3a, c, e). However, for patients initially simulated and treated in the prone position, a repeat simulation is usually required in the supine or lateral decubitus position to allow optimal access to the tumor bed. In addition, for patients initially treated in the supine position with lateral or deep tumor beds and/or very large breasts, decubitus positioning may also be a consideration (Fig. 1.3b, d, f). A fiducial wire is again placed to identify the lumpectomy scar and the patient positioned comfortably, though any immobilization in this position is difficult. A tumor bed boost can also be performed in the prone position but is more technically challenging due to physical linear accelerator limitations and the conformation of the tumor bed in this position. Occasionally, for patients with a large seroma at the initiation of treatment, a subsequent scan closer to initiation of the boost may generate a smaller target volume as the seroma will often regress with time. In addition, some institutions use compression devices to flatten the overlying breast tissue as an adjunct or alternative to changes in the treatment position.

1.3 Tangent Field Design

CT images are imported to the treatment planning system. The first step is contouring of normal structures, which for WBRT generally includes body, heart, lungs, and potentially contralateral breast or brachial plexus depending on the clinical situation (Fig. 1.4). Target structures for WBRT include the entire ipsilateral breast, the tumor bed, and level 1/2 axillary nodes (in certain clinical scenarios) plus expansions for margin. Please see the chapter on target delineation and anatomy for further details of this process.

The treatment isocenter is commonly set midway between the superior and inferior as well as medial and lateral aspects of the field (Fig. 1.5a, b) in supine position. Many centers set the isocenter depth just posterior to the chest wall to ensure adequate coverage of the breast but allow half-beam blocking at the posterior edge. Alternatively, the isocenter may be set in the breast tissue and the gantry angle rotated to match the posterior beam edge divergence. In the prone position, isocenter selection is more challenging. A point must be chosen that is reproducible and feasible for imaging and will not result in treatment collision. At our institution, this point is at the center in the axial view, which is usually medial to the breast tissue and anterior to the chest wall, and outside the patient (Fig. 1.5c, d).

Standard fields consist of medial and lateral tangential beams designed to encompass the entire ipsilateral breast (Fig. 1.6). Attention is given to adequate coverage of the tumor bed and clearance of the breast tissue. Treatment of axillary levels 1/2 in addition to the whole breast can be achieved by raising the upper border of the fields, also known as high tangents (Fig. 1.6), and utilizing multi-leaf collimators (MLCs) to shape the field. This is best accomplished by contouring the desired nodal levels to ensure that the field length and shape is adequate versus relying on a specific measurement or bony landmark.

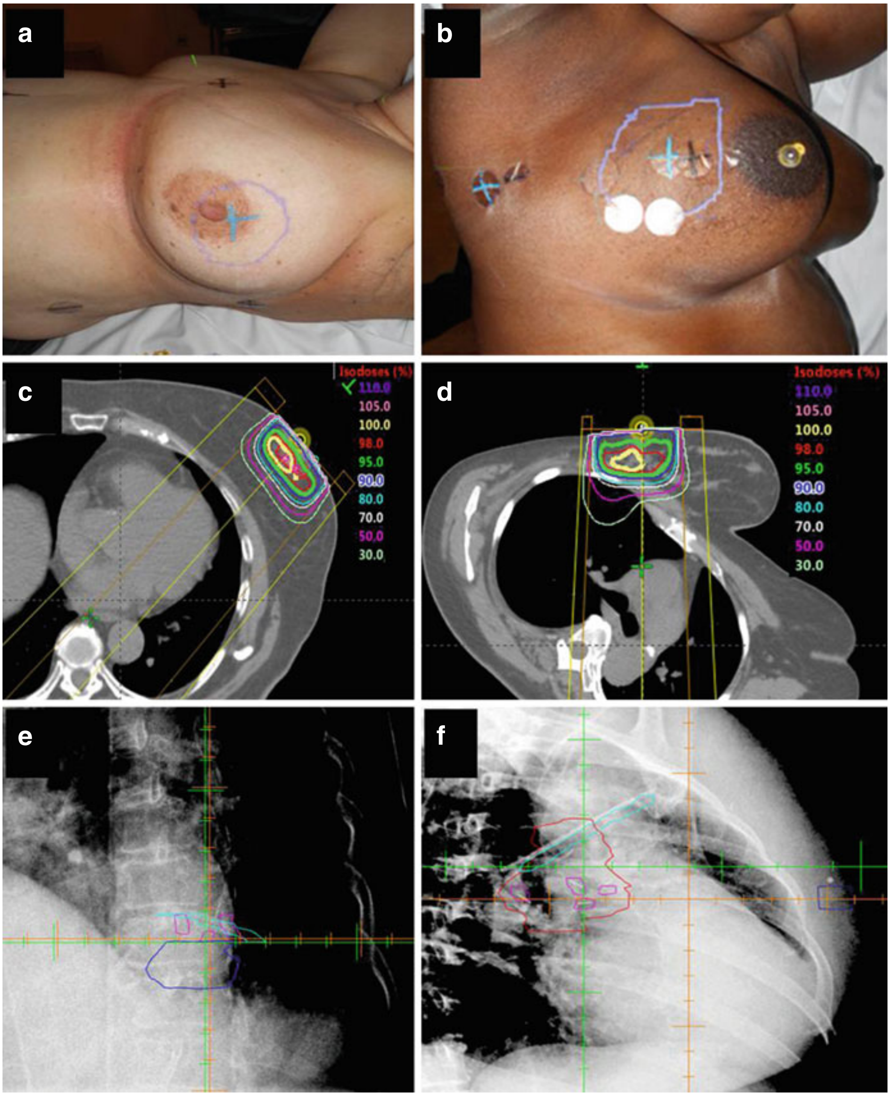

Fig. 1.3 Tumor bed boost performed in the supine (**a**, **c**, **e**) or decubitus (**b**, **d**, **f**) position. Skin marking of the tumor bed boost field shape for a supine (**a**) or decubitus patient (**b**). Axial dose distribution from an en face electron field for a supine (**c**) or decubitus (**d**) patient. In the decubitus position, there is flattening of the lateral breast and enhanced electron dosimetry. (**e**) A typical small shift to match clips using KV imaging for a supine boost patient. (**e**) A larger shift on KV clip match for a decubitus boost patient demonstrating the lesser stability of this position and highlighting the need for daily imaging to ensure appropriate positioning. The scar (*aqua*) and nipple (*blue*) are also marked to aid in positioning

Gantry angle, collimator angle, and table angle can all be adjusted to optimize coverage of desired targets while minimizing normal tissue inclusion within the fields. Custom MLCs can shape the field further and may be particularly useful for blocking the heart (Fig. 1.7a, b). The medial and lateral fields are matched to each

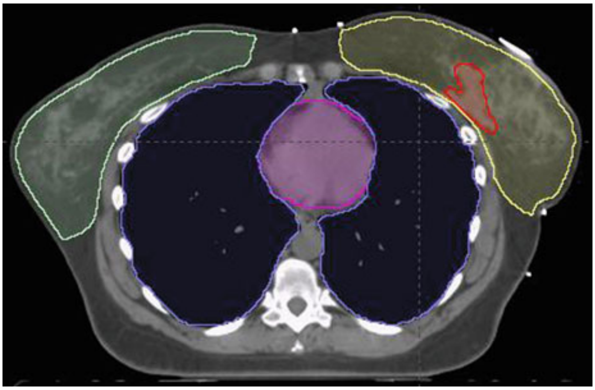

Fig. 1.4 Axial CT image illustrating treatment targets and normal tissue contours. *Pink* heart, *purple* lungs, *green* contralateral breast, *yellow* ipsilateral breast, *red* tumor bed

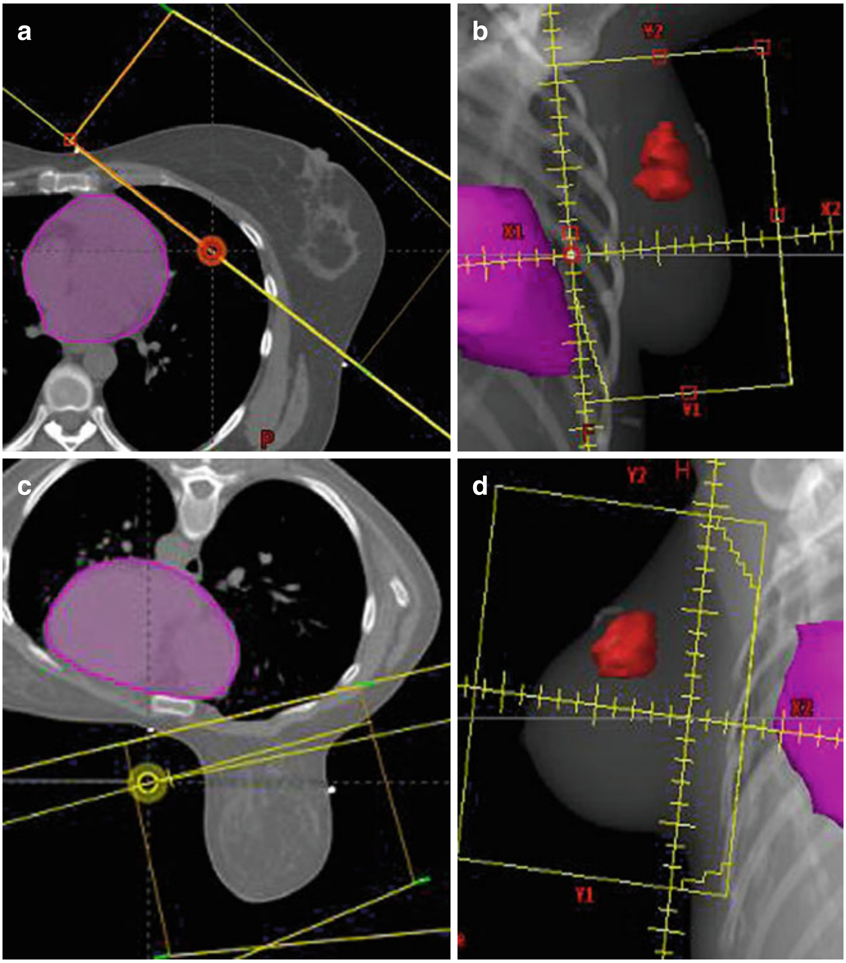

Fig. 1.5 Isocenter placement for tangent fields. (**a**) Axial CT images and (**b**) beam's eye view of isocenter (*circle*, center of graticule) placement for a supine patient. (**c**) Axial and (**d**) beam's eye view of isocenter (*circle*, center of graticule) placement for a prone patient. Due to the superior displacement of the patient on the prone breast board, the isocenter is placed in air medial to the breast tissue in order to avoid collision

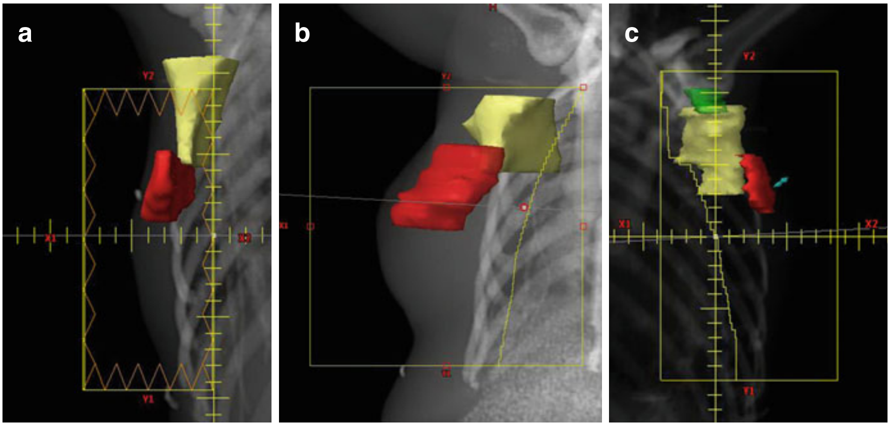

Fig. 1.6 Tangent field design. (**a**) A standard tangent without purposeful axillary coverage shows only incidental coverage of the axilla. (**b**) A high tangent designed for coverage of axillary level I alone. (**c**) A high tangent shaped for coverage of axillary levels I/II

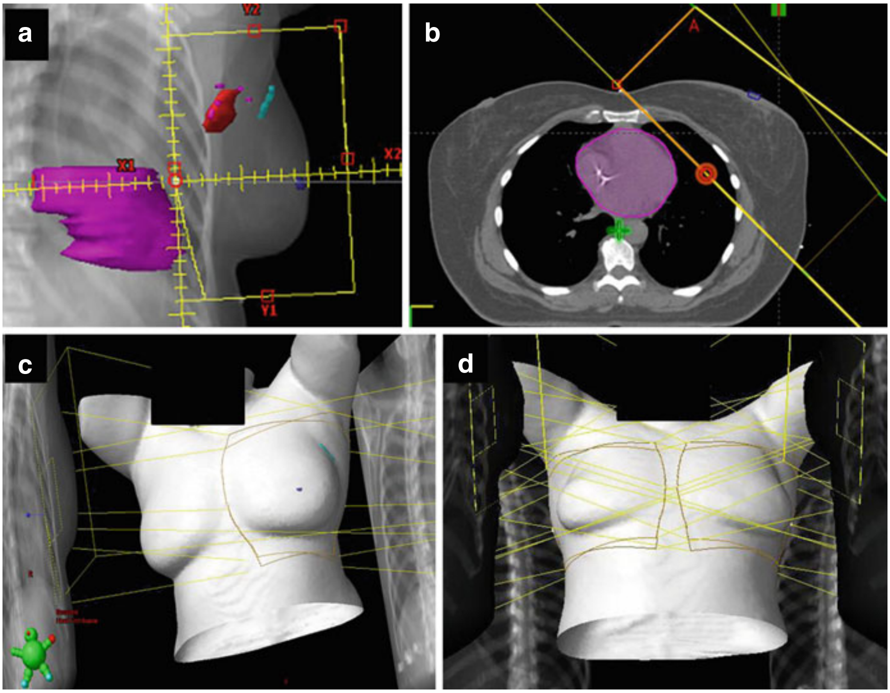

Fig. 1.7 Tangent field optimization with normal tissue protection. (**a**) Beam's eye and (**b**) axial CT images illustrating a custom MLC heart block and non-divergent posterior field edges. (**c**) Skin rendering demonstrating non-divergence of the medial tangent beam entrance and lateral tangent beam exit, including the heart block. (**d**) Skin rendering demonstrating the gap between tangent fields for bilateral breast treatment with non-divergence of medial tangent beam entrance and lateral tangent beam exit as in panel **c**

other in height and shape with offset to prevent beam divergence along the posterior field border. It often is simplest to fully optimize the medial beam shape and then match the lateral beam. Care is taken to align the exit of the lateral beam with the entrance of the medial beam to minimize dose to the opposite breast (Fig. 1.7c). Medial alignment is of particular importance in the relatively uncommon situation in which bilateral WBRT treatment is desired. Field design in this setting is as described above, with care to allow a small gap at the central chest between the two sets of fields such that daily overlap is unlikely (Fig. 1.7d). Modern treatment planning software facilitates this with settings that allow you to see beam entry and/or exit shape on the body contour and in the beam's eye view.

1.4 Boost Field Design

The most commonly utilized method for treatment of the tumor bed is an en face electron field (Fig. 1.3). The treatment isocenter is set at the skin surface and the electron cutout designed to encompass the expanded tumor bed volume with a margin. More or less margin may be required to accommodate immobilization position, setup stability, and patient and tumor characteristics. Gantry, table, and collimator angles are selected to allow a maximally en face approach. For very deep or lateral tumor beds, mini-tangent fields or a 4–5 photon field bouquet may be required.

1.5 Dose Calculation and Modulation

Once treatment fields are set, dose calculation is performed. Due to the shape of the breast, there can be large variability in tissue thickness. This leads to inhomogeneous dose distribution, particularly in the setting of larger breast sizes and/or wide separations. The presence of low density lung tissue just behind the breast can also lead to challenges in maintaining adequate coverage near the chest wall. However, multiple methods exist to improve dose homogeneity and are routinely applied in WBRT planning.

Physical wedges are one method traditionally utilized to improve homogeneity (Fig. 1.8a). The placement of the wedge with the heel compensating for the thinnest area of the breast tissue reduces the hot spots in that region. However, field size is limited with a maximum dimension that depends on the wedge angle. Modern linear accelerators allow the use of dynamic wedges, which utilize collimator jaw movement while the beam is on to modulate dose. Dynamic wedging permits larger field sizes, does not require manual placement of heavy wedges by the treating therapists, and reduces electron contamination. Patient-customized physical compensators can also be used, though these may be too labor-intensive to be of practical use in many treatment centers.

One of the simplest and most widely available ways to improve dose homogeneity is combining higher and lower energy photon beams. For additional refinement of the treatment plan, a "field-in-field" technique is often utilized (Fig. 1.8b–e).