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32.1 General Principles of Planning and Target Delineation

- Anatomic location, size, depth (with respect to the superficial fascia), and pathological features dictate the management of soft tissue sarcoma (STS).
- Invasion is typically in the longitudinal direction within muscle and confined to the compartment of origin. Suspicious peritumoral changes, henceforth referred to as edema, may harbor microscopic disease. Edema is most often pronounced in the cranio-caudal dimension and should ordinarily be encompassed in the radiotherapy target volume.
- STS generally respect barriers to tumor spread such as bone, interosseous membrane, and major fascial planes, and this concept should be exploited in tissue/function preserving radiotherapy planning, especially in extremity lesions.
- Retroperitoneal tumors commonly grow to a large size and initially displace but eventually invade adjacent organs and tissues.
- In the event of an “unplanned” surgical resection with positive margins (surgical error), the RT target volume needs to generously include all disturbed muscle compartments in addition to any other tissues considered to be directly involved (see Figs. 32.1, 32.2, and 32.3).

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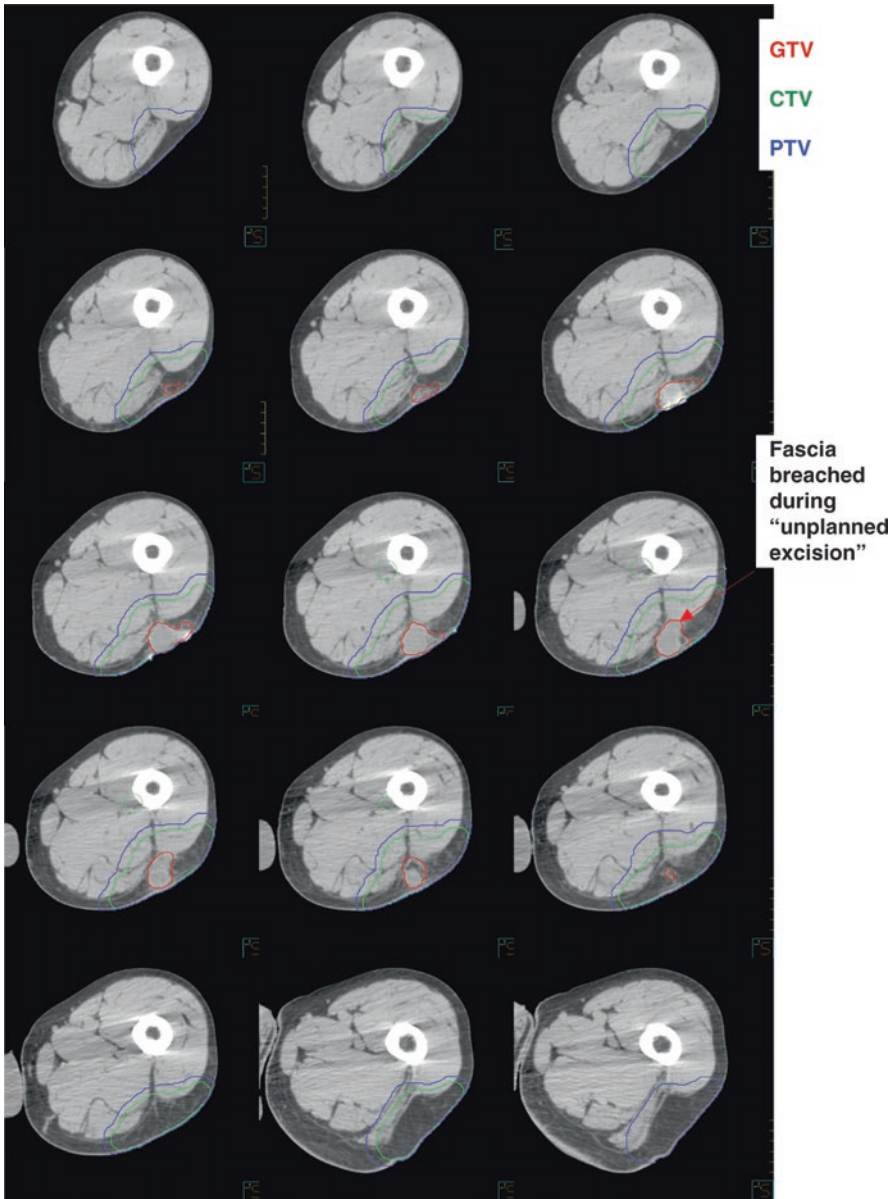


Fig. 32.1 A patient with a T1N0M0 Grade 3 dedifferentiated liposarcoma in the posterolateral thigh. This patient presented having had a previous unplanned excision of a superficial lesion where the fascia of the vastus lateralis was breached but did not involve the deeper compartment originally. CT simulation used 2.0-mm slice thickness. Notice the area of violated fascia due to previous surgical error. Shown are representative slices

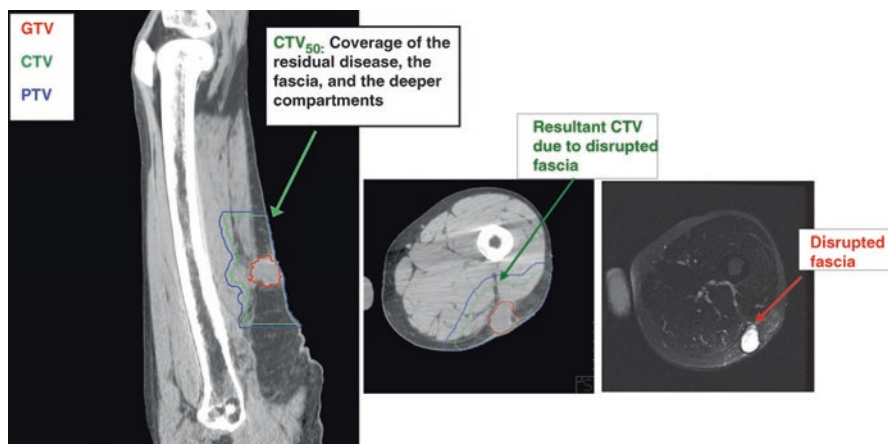


Fig. 32.2 Example of GTV, CTV, and PTV displayed in the sagittal view as well as an axial view of the disrupted fascia as a result of an unplanned excision with the corresponding planning CT target volumes

- For preoperative planning target volume definition, CT simulation imaging fused with MR imaging should be performed, ideally with the patient in the treatment position, to help guide delineation of the gross tumor volume (GTV) and clinical target volume (CTV) (see Figs. 32.1 and 32.2).
- For postoperative planning target volume definition after assumed complete surgical resection, there is no GTV to delineate. The location of the original GTV following the operation (GTV_{postop}) should be recreated in the planning CT dataset using preoperative CT/MRI imaging if available (see Figs. 32.4, 32.5, and 32.6).
- Note: The stage classification has changed in the recently published eighth edition of the TNM. Principle changes include different size thresholds for different anatomic sites and the elimination of depth in classification.
- For preoperative cases, 50 Gy is ordinarily used and target volumes include the GTV and the CTV_{50} and should be delineated on every slice on the planning CT (see Figs. 32.1, 32.2, 32.7, and 32.8).
- For postoperative RT delivery, 66 Gy is ordinarily used (60 Gy can be used in margin clear, low-grade cases) with an additional peripheral CTV volume for tissues with a lower risk of tumor infestation (see Figs. 32.4, 32.5, and 32.6).
- For unresectable residual gross disease, 70 Gy in 2 Gy/fraction or equivalent dose fractionation is ordinarily used depending on the tolerance of the anatomic region.
- Suggested GTV and CTV_{50} for preoperative IMRT of extremity STS are detailed in Table 32.1.

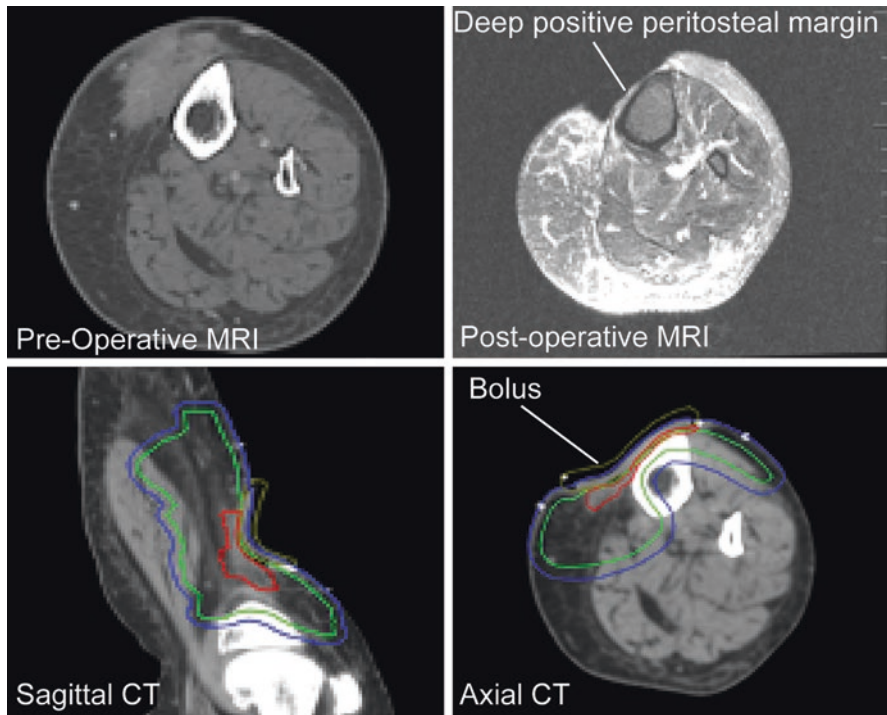


Fig. 32.3 A patient who presented following an unplanned excision of a right-sided 3 cm (T1N0M0) pre-tibial pleomorphic undifferentiated sarcoma. The defect was closed with a split-thickness graft and both radial and deep margins were positive. The recommendation was for 50 Gy preoperative radiotherapy followed by wide re-excision with free-flap closure. The post-op GTV for this case is as described in Chap. 30 Table 30.2. The CTV₅₀ and PTV₅₀ radiotherapy target volumes follow Table 30.1 as described for the preoperative setting. CT simulation used 2.0-mm slice thickness. Axial and sagittal CT simulation views of the radiotherapy target volumes are shown. Gross disease has been excised and the *postop* GTV identifies the position of the original tumor reconstructed from a preoperative CT scan. A representative axial T2-weighted MRI image demonstrates the soft tissue defect and the relationship of the skin graft and positive deep margin to the periosteum. The CTV₅₀ comprises a 3–4 cm radial expansion beyond the site of the positive margins at the edge of the skin graft, and deeply, includes the involved periosteum. The radial margins more closely approximate postoperative margins to account for the lack of a GTV and the contamination from intralesional surgery. A 5 mm bolus plug has been placed to fill the soft tissue defect anterior to the skin graft to provide adequate build-up on the deep periosteal margin. An axial preoperative CT and postoperative MRI view is shown to demonstrate the defect

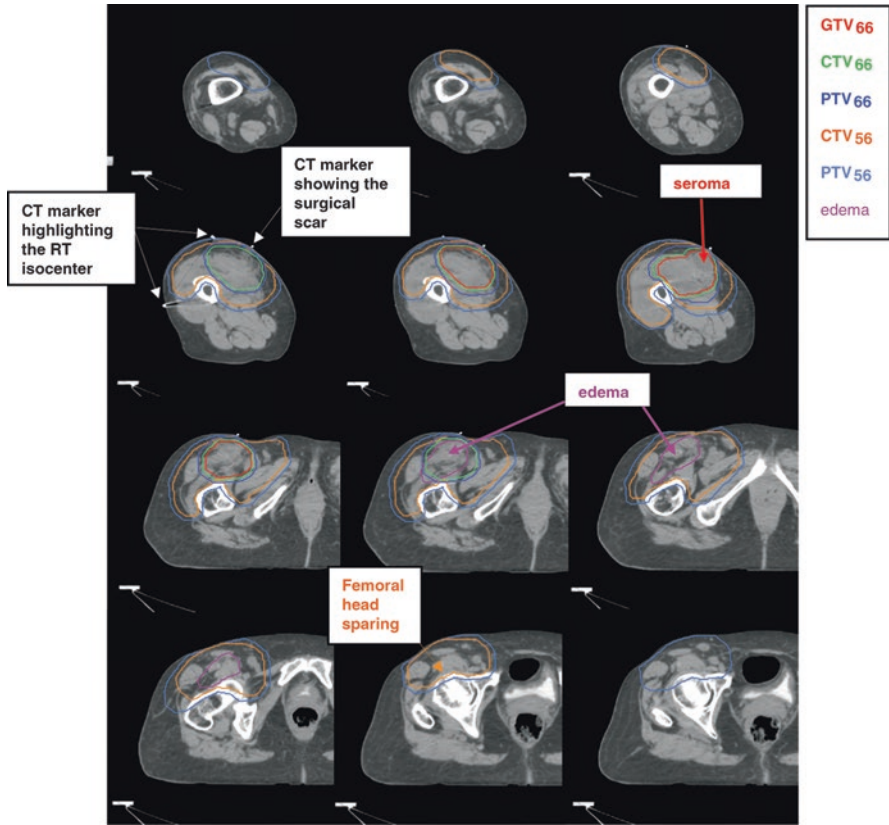


Fig. 32.4 A patient with a deep T3N0M0 Grade 3 pleomorphic rhabdomyosarcoma in the left thigh. This patient received postoperative RT for negative but close margins. CT simulation used 2.0-mm slice thickness. Edema was contoured at the superior aspect of the GTV_{postop} and included in the CTV₅₆. Shown are representative slices. CTV₅₆ is limited by the femoral head and bone throughout the target. In some cases where the subcutaneous tissues have been contaminated, bolus may be applied to the surgical scar for a component of the treatment (e.g., 50 Gy)

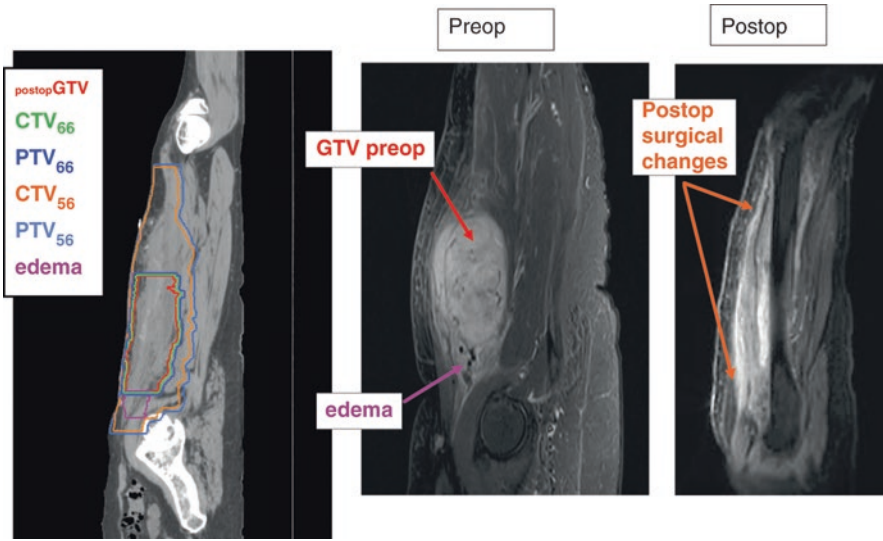
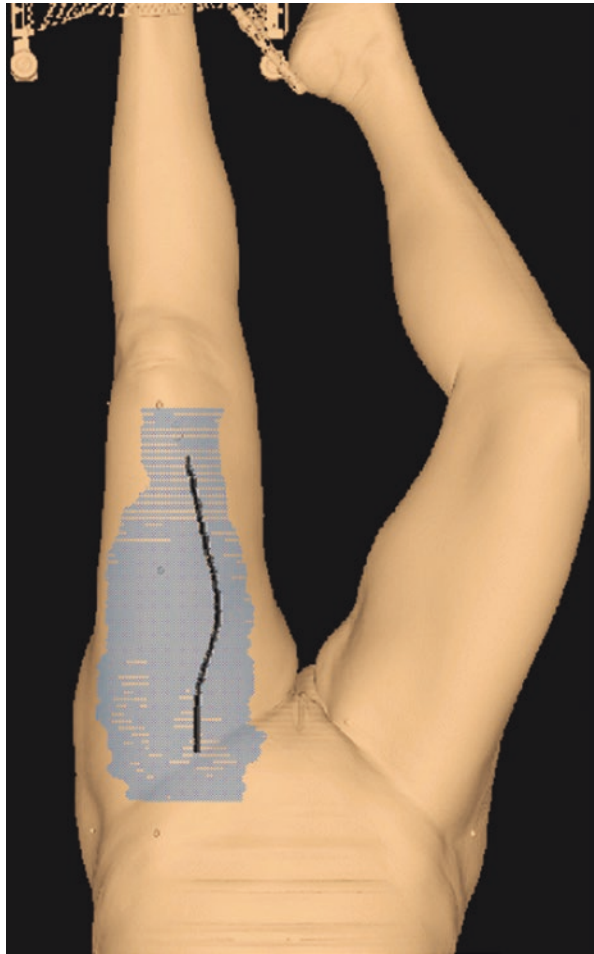


Fig. 32.5 Sagittal CT simulation view of the radiotherapy target volumes for this postoperative STS case and corresponding preoperative and postoperative MRI. Note the CTV_{56} is defined by edema and the postoperative surgical changes. Where the target may appear coincidental in this scaled anatomic illustration, the usual margins were applied (e.g., 0.5- to 1-cm PTV expansion). In addition, the preoperative imaging was imported and co-registered with the postoperative RT planning CT dataset in order to appreciate the original tumor extent for delineation of the GTV_{postop}

Fig. 32.6 The digitally reconstructed skin rendered image displaying the surgical scar and the planning target volume (PTV₅₆) shown in light blue that includes the surgical scar with a margin



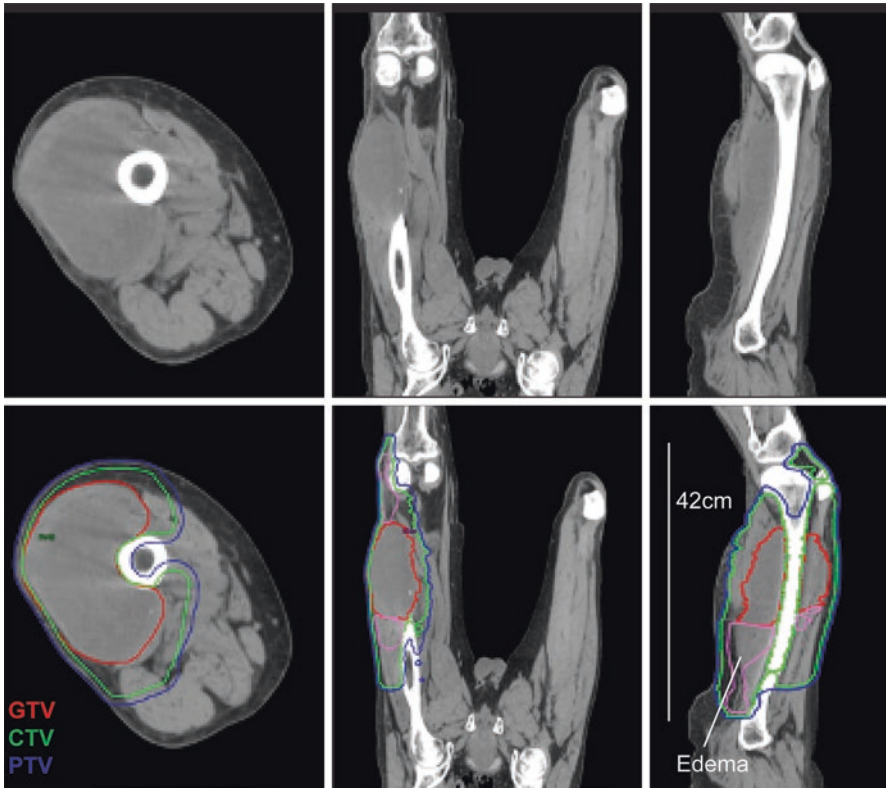


Fig. 32.7 A patient with a deep T3N0M0 grade 2 myxofibrosarcoma in the left lateral thigh. The patient received preoperative RT to minimize the necessary treatment volume. CT simulation used 2.0-mm slice thickness. The patient had extensive peritumoral edema extending superiorly and inferiorly that was included in the CTV₅₀ and shown in representative slices. The CTV₅₀ is limited by bone throughout the target. The PTV was 42 cm long exceeding the maximum machine capabilities for a single isocenter technique. Planning used a dual isocenter IMRT technique. The isocenters are strategically placed to approximate the center of both adjoining volumes and cooptimized to ensure uniform PTV coverage. Axial, coronal, and sagittal CT views are shown with corresponding target volumes delineated



Fig. 32.8 Sagittal CT simulation view and corresponding sagittal T2-weighted preoperative MRI image that demonstrates extensive longitudinal peritumoural edema. Note that the CTV_{50} is defined by edema and usual margins were applied (e.g., 0.5- to 1.0-cm PTV expansion). The preoperative imaging was imported and co-registered with the planning CT dataset in order to appreciate the edema extent for delineation of the CTV_{50}

- Suggested GTV_{postop} and CTV_{66} for postoperative IMRT of extremity STS are detailed in Table 32.2.
- Suggested GTV and CTV (dose 50–50.4 Gy) for preoperative IMRT of retroperitoneal STS are detailed in Table 32.3 (Figs. 32.9 and 32.10).

Table 32.1 Suggested target volumes for preoperative extremity STS

Target volumes	Definition and description
GTV	Primary: All gross disease on physical examination and imaging. T1-weighted contrast-enhanced MRI preferable. Co-registration of the MRI and planning CT is facilitated by immobilizing the patient in the treatment position
CTV _{50*}	Includes all areas at risk of subclinical spread defined by the distance from the GTV or edema Includes the GTV + a 4-cm margin in the longitudinal dimensions and a 1.5-cm margin in the radial dimension limited to but including any anatomic barrier to tumor spread, such as bone or fascia Suspicious peritumoural edema, best demonstrated on T2-weighted MRI, may contain microscopic tumor cells and should be contoured separately with an adequate margin (usually 1–2 cm) For cases of “unplanned excision,” margins should include $_{postop}$ GTV or any residual GTV + all surgically manipulated and disturbed tissues and violated fascia + 4 cm longitudinally and 1.5 cm radially limited to but including any barrier to tumor spread
PTV _{50*}	CTV ₅₀ + 0.5–1.0 cm, determined by individual institutional protocols and procedure

*Suggested gross tumor dose is 2.0 Gy/fraction to 50 Gy

Table 32.2 Suggested target volumes for postoperative extremity STS

Target volumes	Definition and description
GTV _{postop}	GTV _{postop} should identify the original site of the tumor Important to review and import presurgical imaging when contouring on the CT simulation scan for RT planning to ensure adequate coverage of the original tumor extent
CTV _{66*}	CTV ₆₆ should encompass the entire GTV _{postop} + immediate area of surgical change with a 1- to 2-cm margin in the longitudinal plane and a 1.5-cm margin in the transverse plane. This may, but not always, include all surgically disturbed tissues, scars, and drain sites
PTV _{66*}	CTV ₆₆ + 0.5–1.0 cm, determined by individual institutional protocols and procedure
CTV _{56*}	Includes all areas at risk of subclinical spread defined by the distance from the GTV _{postop} and additional disturbed tissues Includes the GTV _{postop} + a 4-cm margin in the longitudinal dimensions and a 1.5-cm margin in the radial dimension limited to but including any anatomic barrier to disease spread; additional disturbed surgical tissues and any scars or drain sites are ordinarily included with a 1- to 2-cm margin if they are not included in the CTV ₆₆ Suspicious peritumoural edema should be contoured separately and included with an adequate margin. Like surgically disrupted tissue, it is best identified from a recent postoperative MRI scan Discussion with the surgeon and review of surgical and pathology reports will facilitate the decision about whether or not a seroma, lymphocele, or hematoma should be included
PTV _{56*}	CTV ₅₆ + 0.5–1.0 cm, determined by individual institutional protocols and procedure

The table describes single-phase simultaneous boost technique. An alternative is the more traditional-phased shrinking field technique that delivers 50 Gy in 25 fractions to all areas of subclinical disease followed by a boost to deliver the final 16 Gy in 8 fractions using a second radiotherapy plan

*High-risk subclinical dose: 2.0 Gy/fraction to 66 Gy; for lower-risk subclinical regions 1.69 Gy/fraction to 56 Gy delivered to the CTV₅₆

Table 32.3 Suggested target volumes for retroperitoneal STS

Target volumes	Definition and description
GTV ^a	Primary: All gross disease on physical examination and imaging
CTV	Includes all areas at risk of subclinical spread defined by the distance from the GTV Includes the GTV + 2-cm margin in the longitudinal dimensions and a 0.5–2.0-cm margin in the radial dimension limited to but including any anatomic barrier to tumor spread and critical anatomy. For example, if the tumor is approximating an intact liver, 0.5 cm of the liver is included 2-cm margins are usually used posteriorly to include fatty tissues and vessels Ipsilateral kidney may be sacrificed provided the contralateral kidney has acceptable function. In such a case, dose to the uninvolved opposite kidney should be kept as low as reasonably achievable Other organs at risk include the small bowel, liver, spinal cord, and lungs
PTV	CTV + 0.5 cm, determined by individual institutional protocols and procedure

^aSuggested gross tumor dose range of 50 Gy/25 fractions to 50.4 Gy/28 fractions

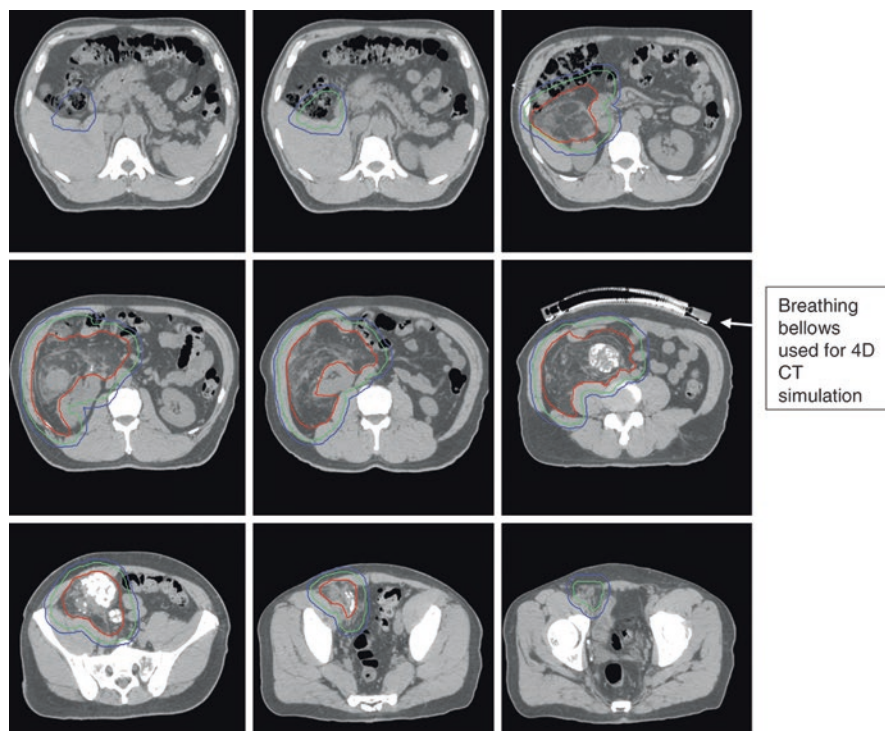


Fig. 32.9 An example of a right-sided T2bN0M0 Grade 3 undifferentiated pleomorphic retroperitoneal sarcoma juxtaposed to the duodenum, the right kidney, and the iliac vessels. CT simulation used a 2.0-mm slice thickness. Representative slices are shown. Note the small amount of liver included in the CTV and PTV in the first three axial slices. Multifocal areas of calcifications within the tumor aided in daily image guidance for targeted IMRT. 4D CT simulation is encouraged

Fig. 32.10 An axial, coronal, and sagittal display of the right-sided retroperitoneal sarcoma. Note the bowel displacement by the tumor, one of the major advantages of preoperative radiotherapy in this setting

