Chapter 3

WHAT IS RADIOTHERAPY?

This chapter describes the process of external radiotherapy. Fig. 1 outlines the steps in planning and delivering treatment. Depending on the extent of the cancer, the patient's general health, and the objective of treatment, this process may be more or less comprehensive.

Step 1. Diagnostic studies and treatment selection

Before deciding on the best treatment alternative for a given patient, a thorough basic investigation is necessary, identifying the type of tumor, its origin, and spread. This can be accomplished by clinical examination (inspection, palpation), endoscopy, and various imaging methods (x-ray, computed tomography, magnetic resonance imaging, ultrasound, nuclear medicine studies). Tumor type is determined by microscopic examination of tissue samples (biopsy), intended to identify both the type and stage of the tumor. This information, along with the patient's general health status, provides the basis for treatment. It is important to base the investigation and treatment on accepted classification systems so individual patients can both benefit from earlier experience, and contribute new information to the knowledge base.

If investigation shows that radiotherapy is indicated, it may be given either alone or in combination with surgery and/or chemotherapy using standardized methods, eg, based on clinical guidelines. The objective of treatment is either curative (radical) or palliative. Although curative treatment is intended to heal the patient, side effects can be expected.Palliative treatment is intended solely to alleviate symptoms. Hence, one should be restrictive in accepting treatment which may cause side effects.

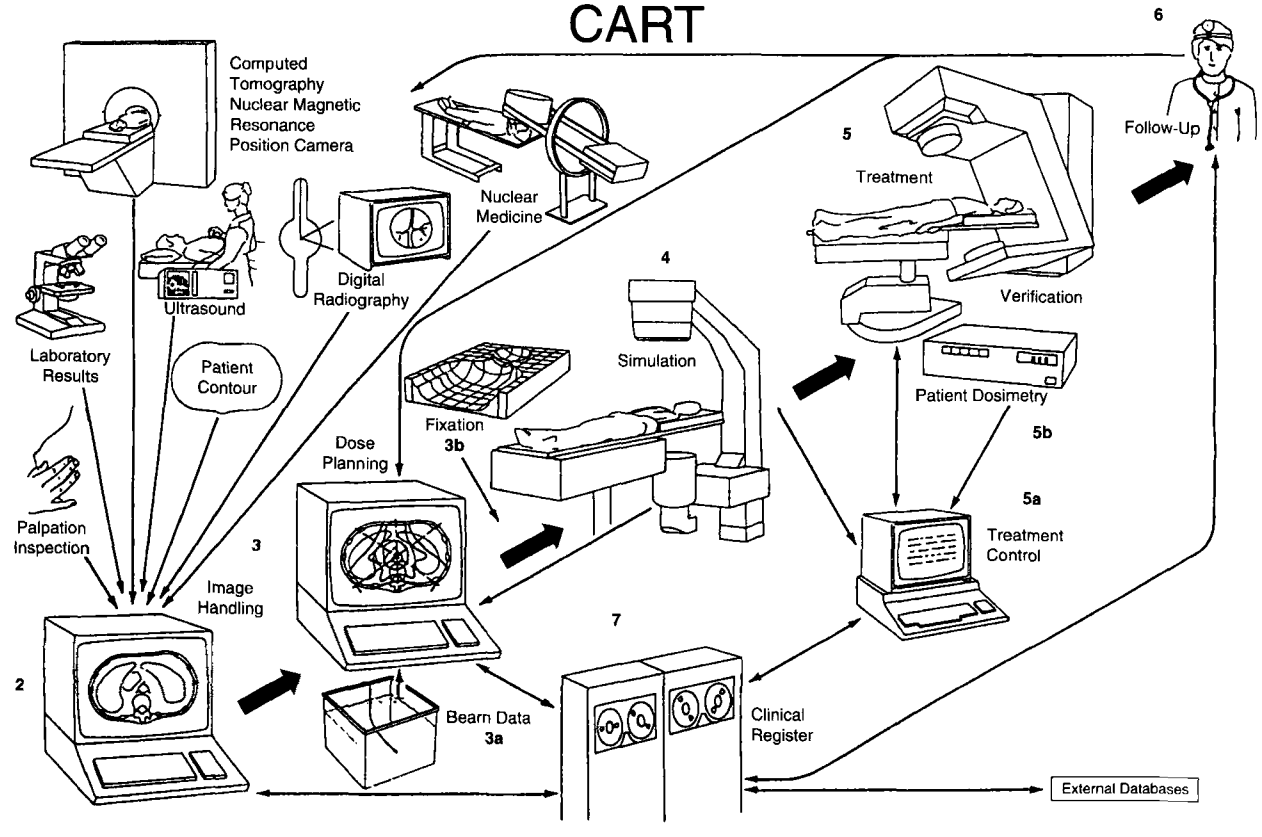

Fig. 1. Overview of the external radiotherapy process. From CART (Computer Aided Radiotherapy), a Nordic R&D project. The figures in the text correspond to "Step 1", "Step 2", etc.

Step 2. Treatment planning

Planning radiotherapy involves defining the anatomic structures for treatment (target volume) and the healthy tissues to be avoided (risk organs). Treatment may engage either visible tumors (eg, radiotherapy prior to surgery) or tissues where tumor growth cannot be found, but where there is reason to believe that tumor cells are present (subclinical disease, eg, clinically negative regional lymph nodes). The latter situation also applies to radically resected tumors if experience shows that local recurrence is likely unless radiotherapy is given to the surgical area. Multiple target volumes may therefore be defined for an individual patient.

Planning radiotherapy also involves determining the appropriate dosage for the respective target volumes, how many treatments (fractions) should be given, and the total treatment time.

Step 3. Dose planning

Once therapy has been prescribed, the patient is placed in a treatment position. To assure that the target volumes are defined as accurately as possible, complementary anatomic information is usually required. This is usually obtained via a series of CT images of the body part in question, taken with the patient in the same position as during treatment. If a complementary dose plan is created, the physician maps the boundaries of the various target volumes and the organs at risk. This is usually done directly in the dose planning computer.

In collaboration with the physicist responsible, the treatment method itself is discussed, ie, how many radiation fields are appropriate and their geometric position, after which the results of dose distribution are calculated by the computer. This estimate is based on data accumulated by measuring radiation fields of the treatment units at the department (Figure 1, 3a). The radiation field must be measured for each device since each one differs, even among devices from the same manufacturer. The radiation field also changes with the age and the condition of the equipment. Quality assurance is therefore essential (Chapter 9).

Fig. 2 illustrates a dose plan. The patient in this example received surgery for breast cancer, in this case limited surgery involving removal of the tumor only. The figure shows a cross-sectional image through the central part of the breast, based on a CT scan. It has been determined that cancer cells may remain in the surgical area, and possibly in other areas of the breast. Hence, a radiation dose of 50 Gy is ordered for the entire left breast (target volume 1), to be given in 25 radiation treatment sessions (fractions) over the course of 5 weeks. During each fraction, two fields are irradiated tangentially toward the breast so that as little radiation as possible reaches the lungs. To irradiate the breast evenly, wedge-shaped metal filters are used to filter the beam to different degrees in different parts of the radiation field. Radiation is delivered by an accelerator that emits x-rays of moderately high energy. The risk for residual cancer cells was found to be particularly high in the tumor bed, so an extra dose (a boost) of 14 Gy is prescribed for that area (target volume 2), with an additional 7 fractions delivered over the course of 1.5 weeks. Here, electron radiation is aimed directly at the tumor bed. The energy of electrons is such that most electrons emit their radiation dose in the breast tissue, and do not reach radiosensitive lung tissue. The total dose distribution is calculated by computer and illustrated on a 1:1 scale.

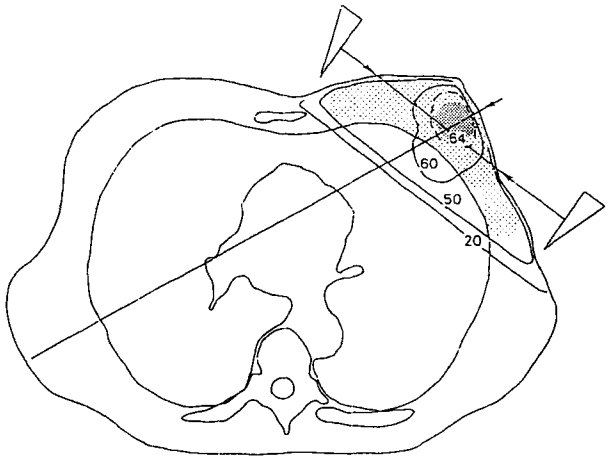

Fig. 2. Dose distribution for irradiating a breast tumor, illustrated by isodose curves for the doses 20, 50, 60, and 64 Gy. The cross-sectional image is obtained from computed tomography. Two tangential radiation beams of 6 MV x-rays are aimed to distribute the dose evenly across the breast (target volume, light shaded area) after filtration through a metal wedge. An extra dose (boost) of electron radiation is delivered to the tumor bed (target volume, dark shaded area), see text.

Dose planning represents an attempt to identify the best options by evaluating the advantages and disadvantages of different radiation alternatives. Within certain limits, larger radiation fields and higher doses lower the risk for local relapse, but increase the risk for side effects. It is important not to miss parts of the tumor by using margins that are too narrow. At the same time, care must be taken to avoid irradiating excessively large volumes and potential "risk organs" where cancer cells are not present. Irradiating a large volume may cause side effects or complications.

The patient's position must be reproduced as precisely as possible for each treatment session, but some geometric uncertainty and variations during the treatment series must be expected. These uncertainties are also taken into account in dose planning. They can be minimized by using special devices that fix the patient's position on the treatment table, eg, using individually fabricated plastic shells (Figure 1, 3b). Irregular radiation fields are sometimes

required, and special collimators must be cast (Chapter 2, Fig. 3).

Step 4. Simulation

After dose planning has been completed, treatment is simulated by a special x-ray device (simulator). This involves placing the patient (including any fixation devices) in the treatment position on a simulation table. X-ray images are taken of the radiation directions, including the field size planned for therapy. The radiation parameters (field size and form, irradiation direction, etc) sometimes require adjustment, resulting in a new, modified dose plan and repeat simulation.

Step 5. Irradiation

The first treatment can now be given. Patients, and any fixation devices, are positioned on the treatment table identically as they were in the simulator. The coordinates are determined by laser light beams projected on the patient, and the radiation field is simulated by a light field on the patient. The first treatment is particularly important since the patient's position and the device setting are repeated during subsequent treatments. The setting is tested using special x-ray film (or a detector-imaging system) that registers radiation passing through the patient. These images are then compared to those from the simulator. The contrast in these images is not as sharp, but generally sufficient for observing any geometric differences between simulation and treatment. If the settings are correct, information about the angles of the treatment apparatus, the treatment table, and field size can be stored in a computer and used as reference for later treatments (check and confirm system, Figure 1, 5a).

During the treatment series, the field is checked regularly by film (verification film) or detectors. Direct dose measurements can be taken via detectors on, or in, the patient. This increases precision and reduces the risk for dosage error.

Step 6. Followup

Once treatment has been completed, it is important to follow the patient in a controlled way. Immediate radiation reactions appear in general during the treatment period itself, but are greatest 1 to 2 months following completed treatment, and may require medical attention. The primary results of treatment in terms of tumor healing must be verified. Late reactions must be assessed using detailed knowledge about the radiation method used. Long-term followup is used to assess treatment results at 5 and 10 years.

Step 7. Documentation and analysis

Each step during the planning, delivery, and followup of radiotherapy must be documented. This information is essential for planning any further radiotherapy for the patient, if such a need should arise. Adequate documentation is also a prerequisite for continually assessing and improving treatment methods within a department, and for exchanging experiences with other centers.

Conclusions

Modern radiotherapy is a precision process that requires thorough diagnostic information about tumor type, origins, and extent, to permit definition of the various tissues (target volume) to be irradiated at a prescribed dose. Dose planning determines the type of radiation to be used, how it will be aimed, confined to the target, and filtered. The goal of planning is to focus the radiation to the extent possible on the target volume, usually the tumor, enabling the delivery of higher radiation doses and thereby increasing the chances for local tumor control. Confining the volume also reduces the risk for side effects or complications in adjacent healthy tissues.

Radiotherapy equipment must offer a wide range of options to optimize treatment. Different types of radiation must be available, eg, x-ray equipment that can use "soft" (low energy) x-rays to treat surface tumors (mainly skin cancer), cobalt-60 apparatus with gamma rays for tumors that lie at a certain depth (although not too deep), and electron accelerators to either produce electrons with different energies or x-rays with intermediately high or high energy. Electrons are used to deliver an equal dose to a given depth, and thereafter the dose rapidly weakens, while x-rays are used to treat intermediate- or deep-lying tumors.

Larger radiotherapy departments should have the equipment to deliver each of these types of radiation, and the necessary related equipment to plan, simulate, and deliver treatment to the individual patient (Chapter 9).

Radiotherapy equipment has become increasingly sophisticated in recent years. Hence, it is important to have access to a wide range of expertise in medicine and radiophysics to utilize this equipment optimally. Quality assurance is particularly important in the different steps of the radiotherapy process, both to reduce the risk for treatment errors and to increase the quality of care for individual patients.