5.1 Introduction

Introduction of IMRT in clinical practice remains a challenge. The delivery of IMRT is usually of lesser concern, as reliable MLC-equipped linear accelerators that allow IMRT delivery in step & shoot or dynamic mode are available. Other parts in the chain of IMRT procedures remain to be improved, especially planning and quality assurance. This chapter focuses on pitfalls in planning. Ideally, the IMRT planning system creates a desired dose distribution as a sequence of treatment machine-states and monitor unit values (often called control point sequence). In reality, the present IMRT planning systems are not yet capable of achieving this goal autonomously. The systems are interactive and require the user to specify the desired dose distribution. This chapter focuses on the planning process and the potential pitfalls that can arise.

5.2 The Desired Dose Distribution in Clinical Guidelines and Protocols

5.2.1 Dose Prescription

5.2.2 Dose Provisional Prescription

5.2.3 Dose Values to Contoured Volumes in the Dose (Provisional) Prescription

5.3 From Dose Provisional Prescription to Planning Dose Objectives

5.3.1 Build-up and In-air PTV Regions

5.3.2 Overlap Volumes and Dealing with Conflictual Dose Objectives

5.3.3 Avoidance of Dose Littering Outside PTV and PRV/OAR

5.4 Dose Prescription for the Individual Patient

5.5 Future Directions

Appendix: Properties of Commercial IMRT Planning Systems

A General System Design Questions

A1 Is the IMRT Capability Provided by a Stand-alone System or Is It Integrated into a 3D RTP System?

A2 How Can IMRT Fields Be Combined with Non-IMRT Fields?

A3 How Can a Planner Compare an IMRT Plan to a Non-IMRT Alternative?

B Questions About the Optimization Objectives and the Optimization Engine

B1 How Are the Treatment Goals Parameterized?

B2 Is the Form of the Objective Function Available, or Is It a Commercial Secret?

B3 Can the User Observe the Objective Function Overall Score?

B4 What is the Basic Optimization Method?

B5 Can Volumes Overlap? If Volumes Overlap, How Are Competing Goals Handled? Related Question: What Tools Are Available to Grow Volumes, e.g., from a CTV to a PTV?

B6 How Can a User “Fine-Tune” an Inverse Plan?

B7 Is “Forward-Planning” Supported?

B8 How Long Does an Optimization Run Take?

C Question About the Support of Various Delivery Techniques

C1 What is the Spatial Resolution of the Ideal Intensity Map? What is the Spatial Resolution of the MLC Positions During Delivery?

C2 Can Minimum Segment Widths Be Set?

C3 Can a Minimum Be Set for the Number of MU per Segment?

C4 What is the Relationship Between the Desired Intensity Pattern, the Deliverable Sequence, and the Final Dose Display?

C5 Are Different Dose Calculation Algorithms Used During Optimization?

C6 What Delivery Systems Will the Planning System Support? For the Systems that Are Supported, Are all the Limitations/Capabilities Taken into Account?

D Other Questions

D1 What Future Directions Are Being Explored?

D2 What Was Fixed or Added in Your Last Software Release?

References

5.1 Introduction

Introduction of IMRT in clinical practice remains a challenge. The delivery of IMRT is usually of lesser concern, as reliable MLC-equipped linear accelerators that allow IMRT delivery in step & shoot or dynamic mode are available. Other parts in the chain of IMRT procedures remain to be improved, especially planning and quality assurance. This chapter focuses on pitfalls in planning. Ideally, the IMRT planning system creates a desired dose distribution as a sequence of treatment machine-states and monitor unit values (often called control point sequence). In reality, the present IMRT planning systems are not yet capable of achieving this goal autonomously. The systems are interactive and...
many machine parameters have to be set upfront by a skilled planner. Also, the desired dose distribution may be impossible to achieve and the systems then need expert guidance to achieve an \textit{acceptable dose distribution} as a realistic goal. We define as acceptable a dose distribution that differs from the desired dose distribution 1) within preset limits of dose and 2) only in regions where the desired dose distribution cannot be physically achieved.

It is considered good practice to define key elements of the desired dose distribution in writing as dose prescription guidelines of a protocol. For IMRT planning, the dose prescription guidelines often need to be complemented by additional parameters to obtain acceptable dose distributions. The definition of such parameters as dose-to-volume prescriptions is the subject of this chapter. Other chapters deal with other forms of prescription including EUD, TCP, NTCP and P+.

This chapter offers guidelines and techniques to avoid most of the pitfalls encountered in IMRT planning. Not all commercial IMRT planning systems have all the tools to implement the proposed techniques and the reader who tries to follow the guidelines may get stuck. A discussion with the vendors regarding possible upgrades or even the purchase of a new planning system may be the only way out. We have added an appendix to this chapter, structured as a series of questions and answers, which deals with properties and defaults of commercial planning systems. These questions and answers may be useful as back-up information for a discussion with vendors or for comparative evaluation of different IMRT planning systems.

5.2 The Desired Dose Distribution in Clinical Guidelines and Protocols

5.2.1 Dose Prescription

The desired dose distribution for IMRT is often described in guidelines that are part of a clinical protocol. These guidelines typically describe the desired dose to contoured volumes that represent the tumor (CTV), and set dose constraints to contoured structures that represent normal tissues. The PTV is a construct which helps us to ensure that the desired dose can be anatomically achieved in the CTV. A construct, similar to PTV was proposed by ICRU (ICRU Report 62) for Organ(s)-At-Risk (OAR(s)), namely the Planning Risk Volume (PRV). The use of a margin around an OAR to define a PRV is somewhat controversial. Toxicity to OARs with serial functional unit (FU) architecture is correlated with the maximum dose. The use of a maximum dose constraint to the PRV rather than to the unexpanded OAR will lower the risk of exceeding the maximum dose constraint by motion of the OAR into nearby dose gradients. The value of adding a margin to an OAR with parallel FU architecture is not obvious and the subject of research. We recommend using a positive margin to create the PRV for an OAR with serial FU architecture. No recommendations can be given for an OAR with parallel FU architecture. Further, we will use the term PRV in the context of IMRT planning irrespective of the size of the margin applied to the OAR and we will use the term \textit{dose prescription} for the definition of desired doses as well as for the application of dose constraints.

5.2.2 Dose Provisional Prescription

The authors of clinical guidelines formulate a dose prescription for a group of patients from whom the selection criteria are specified. They cannot foresee all aspects of anatomy and biology of the individual patient who will be treated according to the guidelines. In practice, the dose prescription in a clinical protocol may be irrelevant, physically impossible to achieve or internally conflicting in some regions of the planning image set. For example, by implementing a margin around the CTV, part of the PTV may extend outside the patient contour. The part of the PTV outside the patient is important to define beam aperture and intensity but dose prescription to the ambient air is irrelevant. Present optimization engines are not capable of solving this problem. Tricks are needed to secure intensity in the air region of the PTV. When the PTV extends close to a PRV, the dose prescription may be impossible to achieve if the difference between the minimum and maximum dose requirements to PTV and PRV respectively would imply a dose gradient of such steepness that it cannot be physically achieved. Dose prescriptions may be conflicting in regions of overlap between PTV and PRV. Mainly for these reasons, the dose prescription in clinical protocols is a tentative or provisional prescription (Fig. 1) and therefore we will further use the term \textit{dose provisional prescription}.

5.2.3 Dose Values to Contoured Volumes in the Dose (Provisional) Prescription

Analysis of treatment outcome as a function of dose and dose distribution provides us with dose-to-volume indices on local control and organ toxicity that can be used for the dose provisional prescription. Using dose-volume indices that result from scientific evidence may be the best strategy to improve the accuracy of the dose prescription (i.e., to guarantee that the dose-volume indices are suitable to obtain the clinical goals). Using the ICRU (ICRU Report 50 and 62) recommendations as