Treatment Planning of Abdominal Lesions

Charles L. Lee

CONTENTS

6.1 Introduction 63
6.2 Pre-Treatment Planning Considerations 64
  6.2.1 Imaging and Fusion 64
  6.2.2 Fiducial Placement 66
  6.2.3 Contouring 67
6.3 Treatment Planning Considerations 68
  6.3.1 Tuning Structures 68
  6.3.2 Dose Grid 69
6.4 Isocentric Treatment Planning 70
6.5 Non-Isocentric Treatment Planning 70
6.6 Additional Considerations 72
6.7 Future Directions 74
References 74

6.1 Introduction

The CyberKnife® (Accuray Incorporated, Sunnyvale, CA) was initially used to treat lesions of the central nervous system (CNS), but in recent years the most rapid increases in utilization have been in the treatment of soft tissue lesions outside the skull and spine. Soft tissue tumors may be broadly classified as lung, abdominal, or pelvic tumors. Like lung tumors, abdominal tumors are sufficiently close to the diaphragm that they normally require correction for motion due to breathing, but the large number of critical organs in the abdomen raises treatment issues that are common to pelvic lesions that move little with respiration, such as prostate adenocarcinoma.

The combination of breathing motion and high organ density has limited the development of stereotactic radiosurgery and hypofractionated radiotherapy for abdominal tumors. Large planning target volumes (PTVs) are a consequence of the appreciable tumor margins needed to account for breathing using either breath holding or gating techniques. The size of these targets restricts the prescription dose for lesions close to high-risk organs, such as the duodenum and kidneys. CyberKnife fiducial tracking throughout treatment, in combination with Synchrony® (Accuray Incorporated, Sunnyvale, CA) continuous breathing motion tracking, reduces PTV volumes [1]. In addition, non-isocentric beam delivery and inverse treatment planning limits hot spots so that abdominal radiosurgery and hypofractionated radiotherapy are readily achievable.

The range of tumor locations that have been treated with CyberKnife in the abdomen is impressive and continues to expand. Metastases from other primary cancers are treated in the liver, as well as primary hepatocellular carcinoma. CyberKnife treatment of late stage pancreatic adenocarcinoma in conjunction with chemotherapeutic agents has been described using both single-fraction and hypofractionated approaches [2–4]. The improved radiosensitivity of renal cell carcinoma to hypofractionated radiation delivery in spinal metastases has been described [5, 6], but only recently have primary renal cell treatments in the kidneys been reported [7]. Several sites have described the treatment of very large (greater than 500 cc) soft tissue sarcomas, many of retroperitoneal origin, and anecdotal evidence suggests similar increases in radiosensitivity for these...
tumors [8, 9]. Metastases may arise in many other parts of the abdomen, including gall bladder, duodenum, spleen, stomach, and lymph nodes; these may also be amenable to CyberKnife treatment.

These abdominal targets raise a number of issues concerning treatment planning and delivery that must be addressed before a safe and efficacious CyberKnife treatment can be offered. In this chapter I describe some of these issues and suggest means of dealing with them based on my experience with the CyberKnife system. Some of these suggestions are based on features found in Multiplan® (Accuray Incorporated, Sunnyvale, CA) version 1.5.2 and may need to be altered for future versions of the software. Note that, although many of the clinical concerns that are outlined below are common to all technologies used for stereotactic hypofractionated delivery of radiation to moving targets, the methods used to address them are specific to the CyberKnife. More general information on this topic may be found in other published sources [10].

6.2 Pre-Treatment Planning Considerations

6.2.1 Imaging and Fusion

Contouring and treatment planning for abdominal CyberKnife cases may be enhanced by fusing additional imaging studies to the main CT image set and through judicious choices during the CT scanning process. Blurring will arise in abdominal MRI scans unless breath holding is employed. While this approach may yield useful information, several effective alternatives have achieved more widespread use.

In recent years, positron emission tomography (PET) has become a standard clinical tool for identifying metabolically active regions of the body and consequently helping to distinguish regions of rapid cell growth from surrounding structures that are radiographically similar. All locations within the abdomen are amenable to PET imaging for fusion to CT, and while breath holding is not normally used for PET scans, their limited resolution (generally no better than 3 mm slice thickness) means that this is generally not a problem.

The automatic image registration tool in Multi-Plan works well when fusing CT and PET scans, especially when these images are obtained as part of a single study. Starting points for automatic registration are best seen in the sagittal and coronal views on the PET scan, rather than the default 3D views. Careful examination of CT/PET registration is crucial to contouring, and in some cases, manual registration at a specific anatomic location is preferable to the automated global registration that does not account for soft tissue deformations. The colorwash overlay mode available in MultiPlan is excellent for CT and PET displays, both when checking the quality of registration and when contouring. Switching to the PET-only display and adjusting the window and level to display only extremely hot regions before using the colorwash overlay mode will maximize the effectiveness of this modality for image registration (Fig. 6.1). Care must be taken to avoid mistaking common areas of high radiopharmaceutical uptake for active tumor, especially near the heart, kidneys, and major vessels.

Intravenous (IV) iodine contrast is highly desirable in abdominal CT scans for differentiating the array of critical soft tissues. For patients with an iodine allergy, a PET scan becomes more important. The timing between the IV injection and CT acquisition is crucial to maximizing uptake in the abdomen, especially if a PET scan is not used for contouring. Oral contrast administered just before imaging is also helpful to distinguish stomach and duodenum from surrounding tissues, and ingesting additional contrast several hours prior to the CT study can opacify the lower gastrointestinal (GI) tract if desired. Treatment planning should use a homogeneous electron density model (chosen in the Setup page of the Plan tab in MultiPlan) when oral contrast is present in the CT scan.

Breath holding during the CT study will remove the motion blurring that will occur if the scan is obtained using normal respiration. The patient’s breath may be held at maximum inhalation, exhalation, or a midpoint between these extremes; patient training will maximize the reproducibility of this technique. Fusing a breathing-blurred PET scan to a CT scan taken during breath holding will lead to mismatch that must be carefully evaluated through manual