Summary

The spiraling costs of modern cancer care serve as a constant reminder of the need for efficiency and the value-added use of resources. This necessitates a critical approach to the evaluation and selective implementation of advanced technologies for high-precision radiotherapy and creates an environment where practical experience and deep clinical knowledge are key commodities. The papers contained within this thesis address various components of modern high-precision radiotherapy from these perspectives. They begin by evaluating the merits of individual technologies and examining specific clinical scenarios, and conclude by focusing on practical elements of knowledge transfer and implementation strategies.

Introduction: Chapter 1 introduces the thesis and presents the outline. Chapter 2 describes the key elements of modern external beam radiotherapy and highlights the clinical application of recent technological advances.

Imaging and treatment planning: The study described in Chapter 3 focuses on the development of a methodology for performing radiology-pathology correlation studies in lung tumors. Although advances in imaging have helped to improve tumor visualization, the precise relationship between the size of the tumor seen on imaging and its true dimensions is incompletely described, as is the spatial accurate imaging of functional and structural heterogeneity within the tumor. These factors are relevant to delineating the tumor target and selectively targeting tumor sub-regions with high-precision radiotherapy. Radiology-pathology correlation studies are an important tool for investigating these characteristics, however methodologies need to be refined. Chapter 4 takes a critical look at the use of currently available imaging strategies for high-precision spine radiotherapy. Chapter 5 serves as a reminder that the overall delivery accuracy of 1-2 millimeters that is achievable for some high-precision body treatments is overshadowed by the uncertainty in defining the target and critical structures, even amongst experienced practitioners. Inaccurate or inconsistent delineation may adversely affect the quality of any given treatment plan and may mitigate the potential gains from other advanced treatment strategies such as proton beam therapy. A recently developed tool designed to identify and reduce contouring

variation is described. Such tools may also have a role in knowledge transfer and quality assurance.

Treatment delivery and immobilization: With the indications for high precision radiotherapy increasing, recent advances in treatment delivery such as volumetric intensity-modulated radiotherapy appear well suited to complex treatment planning and efficient treatment delivery. Whether they are 'better' than the existing options needs to be evaluated. Chapter 6 compares volumetric intensity-modulated radiotherapy to conventional fixed-beam intensity-modulated radiotherapy for high-precision spine treatments. The robust delivery of treatment plans such as these, with spatially complex dose distributions requires correct and stable patient positioning during treatment delivery. Chapter 7 describes the multi-targeted strategy in use at our center to integrate patient comfort, simplicity, reproducibility, and appropriate use of imaging technology in order to meet these goals.

Imaging after treatment: The impressive results of stereotactic lung radiotherapy and the increasing availability of advanced technologies that facilitate such techniques are leading to their widespread uptake. However with the recent emergence of extremely hypo-fractionated radiotherapy it is also becoming clear that symptomatic or asymptomatic normal tissue responses to such treatments have been incompletely characterized, and that they may confound the use of conventional metrics to evaluate tumor responses to therapy. It may also be difficult to distinguishing normal tissue responses from residual or recurrent tumor. Chapter 8 sets out to describe the incidence and morphology of computed tomography changes that can be expected in the lung after stereotactic radiotherapy. Analogous with drug therapies, the application and diffusion of new technology needs to be accompanied by 'post-marketing' awareness for new patterns of toxicity and normal tissue change and to facilitate effective knowledge transfer. As stereotactic lung radiotherapy becomes widely adopted, more patients, including some who may be potentially operable, are being treated. The early detection of a minority of patients at risk for treatment failure who may then be eligible for salvage treatments has now emerged as an important challenge. Chapter 9 describes the initial outcomes from a pilot study of metabolic imaging as a tool for early response evaluation.

Implementation of new technologies: The previous chapters have illustrated that there is an array of advanced technologies available today in radiation oncology. Integral to realizing the potential for patients of such technologies and the treatment techniques that they have facilitated, is their safe, timely and effective implementation. This relies on the development of departmental and system-wide strategies to acquire, deploy and use equipment in a manner that recognizes clinical priorities and makes best use of available financial and human resources. The critical application of technology and the acquisition and dissemination of knowledge are central to the delivery of value-added healthcare. Such issues are explored further in Chapters 10-12, which include practical implementation strategies for high-precision treatment of lung cancer as well as more generic issues. Advances in technology for treatment planning and delivery, including image-guided delivery, have facilitated the resurgence in biologically potent, high-dose per fraction radiotherapy schedules. In addition to treating patients with localized disease, this is also making it practical to investigate new treatment paradigms such as the ablation of multiple metastases. Chapter 13 is a mini-review exploring the rationale for this in more detail.