MEDICAL RADIOLOGY

Diagnostic Imaging and Radiation Oncology

Radiation Therapy Physics

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Foreword

The discovery of X-rays in 1895 by Roentgen set in motion a long period of discovery and rapid progress in technology. Investigators inadvertently played leapfrog – with one laboratory then another announcing new records for the highest voltage generated for the most intense X-ray beam. Technological advances were first driven by the desire for better "pictures" and then separately by the need for more penetrating radiation to treat deep-seated tumors. Concomitantly, new dosimetric methods were continually introduced to keep pace with the ever-increasing energy of the X-rays produced by newer and newer machines.

Initially, there was little or no distinction between diagnostic and therapeutic X-ray equipment. Eventually, however, the divergent uses resulted in different, very specialized designs, with function dictating form. The radiation therapy tubes had to run continuously for many minutes and they needed to deliver large, up to 25 cm, uniform, flat and symmetric beams at distances ranging from 15 to 100 cm. Additionally, the power supplies and control units had to support these operating conditions. These new therapy designs accommodated several different kinds of X-ray therapy arbitrarily categorized as Grenz-ray, contact, superficial (Roentgen), intermediate (medium), deep (orthovoltage), and supervoltage therapies. The resulting beams had to be collimated and delivered accurately to the intended target. Thus, the delivery technology evolved from bare tubes, to bare tubes with lead sheets on the patients, to mountable cones and, ultimately, to adjustable collimators with light localizers. Additionally, beam modifiers such as filters were designed to maximize therapeutic ratios, that is, deep-target dose to skin-surface dose. Meanwhile, dosimetry evolved from describing X-rays only by voltage and current to using half-value layers to quantify the X-ray spectrum. Beam intensity measurements also evolved from photographic plates darkening per minute to current data derived from ionization chamber measurements. Exposure and dose measurements evolved from "skin erythema" dose to film densitometry to various kinds of ionization measurements, first in air and then in phantom.

As radiation oncology matured, X-ray tubes and transformer-based power supplies were gradually replaced by other, more efficient and effective X-ray production machines at high energies, including electrostatic Van de Graaf generators, betatrons, and, eventually, linear accelerators.

The years from 1950 to 1970 were a time of both consolidation of previously developed technologies and of continued development. While progress and discovery continued, they did not occur at the same pace as during the earlier period. Technological advances continued to be driven by the desire for "better" dose distributions within the patient. Concomitantly, dosimetric methods evolved with improved understanding of the underlying physics and with international standardization of description and methods. While the evolution of technology continued across the spectrum of therapy-related endeavors, perhaps this period is best characterized by the clinical introduction of medical linear accelerators, Linacs, and by that of their direct competitors, the Cobalt-60 teletherapy gamma ray units.

The physics community worked toward producing higher and higher energy accelerators for use in basic research into the nature of matter. The ancillary technologies developed for these basic research atom smashers enabled the manufacturers of medical accelerators to increase the efficiency and reduce the size of the clinical machines.

The book by Smith and his colleagues demonstrates clearly the application of these foundations in contemporary clinical radiation oncology. It covers the broad array of basic data, instrumentation, clinical technologies, and their application in the highly sophisticated management of the patient with cancer. The authors have produced a landmark text serving the basic foundations in terms of physics applications in clinical radiation oncology.

Philadelphia/Hamburg, November 1994

L.W. Brady
H.-P. Heilmann

Preface

During the last decade there has been a virtual explosion of advances in the field of radiation therapy physics. It is difficult to keep abreast of the literature during periods of rapid change and individuals are apt to learn more and more about increasingly fewer topics. Thus our field, like others, has tended to be characterized by increasing specialization which makes it less likely that optimum integration and generalization of knowledge will take place.

The goal of this volume the Springer-Verlag series in Medical Radiology: Diagnostic Imaging and Radiation Oncology, is to promote the integration of the various areas of radiation therapy physics by reviewing most of the recent advances and discussing how these new technologies have been implemented and utilized in the service of radiation oncology. The authors were asked to present up-to-date reviews of their topics for an audience of professionally mature medical physicists. Therefore this volume is not intended to be an introduction to the field of radiation therapy physics however anyone with sufficient background and serious intent will find a wealth of information herein. Moreover, the comprehensive literature citations will enable interested readers to pursue their learning to broader scopes and deeper levels. The material in this volume covers topics ranging from tumor localization to treatment verification. The chapters cover advances in imaging, dose calculation models, treatment planning, biological modeling, accelerators, devices and techniques, radio-chemistry, dosimetry, and quality control, and describe how these advances have enabled us to improve the delivery of radiation therapy. We have not always hit the mark and, as in every like venture, there is not uniformity in quality and depth of coverage among the chapters, however this was not caused by any lack of the authors' abilities or intent but was, in part, a product of the happenstances of fate: people changed jobs, labored through personal and professional trials, and kept up with their busy lives while working hard on these chapters and each author has given us something of particular value.

It will be quite some time before we are able to fully exploit the multiplicity of technologies which recent research and development efforts have placed at our disposal. Our challenge is to use these new tools wisely and to design even more effective and efficient means to use radiation in cancer therapy. We present this book with the hope that the information we have provided herein will assist readers in their work toward achieving these ends.

Boston, November 1994 ALFRED R. SMITH

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