RADIATION THERAPY IN CANCER MANAGEMENT

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PREFACE

As clinical medicine becomes more complex, the need for understanding and communication between physicians increases. Although therapeutic radiologists are involved in the care of a majority of patients with cancer, medical students and consequently most physicians have had little, if any, useful introduction to a medical method (therapeutic radiology) which should be helpful to many of their patients. Recent improvements in medical school curricula have provided a somewhat cursory introduction of subject and student. While there are several good textbooks about therapeutic radiology, these have been written for the radiologist. This text is written for the medical student, the trainee in other medical specialties, or the practitioner who desires a general understanding of therapeutic radiology, but who has no interest in the sophisticated details of application.

If the reader gains enough information to answer the review questions at the end of each chapter, he will be more knowledgeable about therapeutic radiology than most contemporary physicians and should find clinical application of value to his patients.

If the reader develops an interest exceeding the bounds of this text, further information is available in the references listed in the bibliographies or in the many good textbooks available.

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CONTENTS

PREFACE xi

1 RADIATION THERAPY AS A CLINICAL SPECIALTY 1

2 THERAPEUTIC RADIOLOGY: PAST, PRESENT, AND FUTURE 6
Historical Perspectives 6
Current Status 8
Attempted Answers 9

3 FUNDAMENTALS OF CLINICAL RADIATION THERAPY 12
Technical Modalities 12
Effects of Ionizing Radiation on Cells and Tissues 21
Side Effects and Hazards of Radiation Therapy 33
Selection of Patients 45

4 SURGERY AND RADIATION THERAPY 50
Objective of Combined Treatment 50
Indications 50
Need for Data 51
Classification of Combined Treatment 51

5 CHEMICAL MODIFICATION OF RADIATION EFFECT 57
Oxygen 57
Alkylating Agents 59
Analogue Inhibitors 61
Antitumor Antibiotics 61
Alkaloids 62
Vitamins 62
Chemical Protective Agents 62

6 CANCER OF THE SKIN AND MUCOCUTANEOUS JUNCTIONS 66
Basal and Squamous Cell Carcinoma 66
Malignant Melanoma 72
Carcinoma Arising in Sweat or Sebaceous Glands 73
Mycosis Fungoides, Kaposi's Disease, Lymphomatous Infiltrations 73

Metastases to Skin 73
Special Anatomic Sites 73
Premalignant Skin Conditions 74
The Special Problem of Keratoacanthoma 76
Carcinoma of the Lip 77
Carcinoma of the Anus and Anal Canal 82

7 CANCER IN CHILDREN 86
General Considerations 86
Noncancerous Conditions in Children 90
Leukemia in Children 93
Lymphoma in Children 94
Lymphoma in African Children 97
Tumors of the Central Nervous System in Children 98
Malignant Tumors of Bone and Soft Tissue in Children 100
Wilms' Tumor (Nephroblastoma) 101
Neuroblastoma 108
Retinoblastoma 114

8 CANCER OF THE HEAD AND NECK (Excluding CNS, Skin, Orbit) 119
Cancer of the Oral Cavity 119
Cancer of the Hypopharynx (Laryngopharynx) 154
Carcinoma of the Larynx 157
Cancer of the Nasal Fossa and Paranasal Sinuses 174
Cancer of the Thyroid 182

9 TUMORS OF THE CENTRAL NERVOUS SYSTEM 190
General Principles of Radiation Therapy of Tumors of the Central Nervous System 191
Radiation Therapy of Specific Tumors 192

10 CARCINOMA OF THE BREAST 205
Biological Behavior of Carcinoma of the Breast 205
Radiation Therapy 209
Systemic Treatment 213

11 LYMPHOMAS 221
Hodgkin's Disease 221
Other Lymphomas 226

12 LEUKEMIA 234

13 INTRATHORACIC TUMORS 240
Carcinoma of the Bronchus 240
Carcinoma of the Esophagus 251
Thymoma 265

14 CANCER OF THE FEMALE GENITALIA 270
Carcinoma of the Cervix 270
Carcinoma of the Stump of the Cervix 286
Adenocarcinoma of the Cervix 287
Carcinoma of the Cervix Associated with Pregnancy 288
Carcinoma of the Uterine Corpus 292
Carcinoma of the Ovary 296
Malignant Tumors of the Vagina and Vulva 303

15 TUMORS OF THE MALE REPRODUCTIVE SYSTEM 306
Malignant Tumors of the Testis 306
Carcinoma of the Prostate 312

16 TUMORS OF THE URINARY SYSTEM 316
Cancer of the Kidney 316
Cancer of the Bladder 319

17 TUMORS OF BONE 333
Primary Bone Tumors 333
Metastases to Bone 355

18 TUMORS AND TUMORLIKE LESIONS OF SOFT TISSUES 358
Benign and Malignant Tumors and
Tumorlike Lesions of Fibrous Tissue 358
Tumors of Muscle 359
Tumors of Adipose Tissue 360
Tumors of Vascular Tissue 361

19 PALLIATIVE RADIATION THERAPY OF THE PATIENT WITH INCURABLE CANCER 363
Objectives of Palliative Radiation Therapy 364
Radiation Therapy as a Placebo 370
Opportunities of the Therapeutic Radiologist 371
Conclusion 371

20 SOME BASIC PRINCIPLES OF RADIATION THERAPY OF CANCER 373

GLOSSARY 376

INDEX 385

1
RADIATION THERAPY AS A CLINICAL SPECIALTY

Radiation therapy is a clinical medical specialty in which ionizing radiation is used in the treatment of patients with neoplastic diseases.

Ionizing radiation is characterized by its mechanism of energy dissipation, namely, by ionization (and excitation) of atoms and molecules of the absorbing material. This radiation is electromagnetic (x-rays, gamma rays) or corpuscular (electrons, protons, neutrons, alpha particles, mesons) and is of natural (gamma rays from radium) or artificial (x-rays, gamma rays from cobalt-60 or cesium-137) origin. It is assumed that these radiations act on living tissue by the ionization and excitation produced during absorption. Thus, the basic physical mechanism of action of all forms of ionizing radiation is the same. Differences in effects produced are explained by differences in spatial distribution and time of delivery of the absorbed radiation.

In clinical radiation therapy, use is almost exclusively limited to x-rays and gamma rays. Treatment by radioactive beta emitters or by external high-energy electron beams has been useful in a limited number of clinical situations.[1] Use of other ionizing radiations (protons, neutrons) is still being investigated.

Clinical radiation therapy occupies a unique position among medical specialties. Although some are defined anatomically (gynecology, otolaryngology, dermatology, urology) and others by the therapeutic method used in a number of clinical situations (surgery, internal medicine), radiation therapy is the only clinical specialty which uses one method in the treatment of one group of diseases. With a definition so restricted, it may be questioned whether radiation therapy deserves the status of a clinical specialty. Indeed, many physicians consider radiation therapy a technique to be used on prescription.

Radiation therapy as we understand and practice it should be considered "clinical radiotherapeutic oncology.[3,7] This presumes a comprehensive understanding of medical radiation physics, biological effects of ionizing radiation, and the biology of neoplastic diseases in all their complexity.

Close cooperation between radiation therapists and *medical radiation physicists* is essential, resembling that between surgeons and anesthesiologists. However, the radiotherapist must have a sound knowledge of medical radiation physics, so that he may adjust the appropriate technical procedure to the specific individual problem (treatment planning).

An understanding of *pathology* is necessary for several reasons: (1) The therapist must understand the gross and microscopic changes in different tissues caused by ionizing radiation. He must be able to relate these to the quantity of radiation and its distribution in space and time. The pathologist may be familiar with generally recognized radiation effects, but he has little appreciation of the more important relationship of radiation-produced tissue effects and the technical details of irradiation. (2) In addition to knowledge of gross and microscopic tumor pathology, the therapeutic radiologist must be aware of the biologic behavior of various neoplastic diseases. For example, in treatment planning it is important to know that a primary carcinoma limited to the true vocal cord does not spread to regional lymph nodes, whereas a carcinoma of the false cord has a high incidence of lymphatic spread; or that a carcinoma of the tonsil, because of anticipated spread to regional lymph nodes, requires concomitant irradiation of the primary site and ipsilateral neck, although a carcinoma originating on the neighboring anterior tonsillar pillar can be included in a small treatment volume, thus permitting the necessary higher dose of radiation. (3) The therapeutic radiologist, like other clinicians, must be aware of the intricacies, difficulties, and limitations of histologic diagnosis in order to allow a proper appreciation of the pathologist's report.[8]

The diagnosis of epidermoid carcinoma usually is unequivocal. The diagnosis of mesenchymal neoplasms may be a matter of doubt even among experienced pathologists. Yet the therapy and prognosis may depend on such specific differentiation. Integration of the histologic findings with the gross pathologic findings and clinical details may permit a correct diagnosis, with its decisive implications for the patient. If the pathologist's diagnosis does not correlate with the clinical situation, the radiotherapist should challenge the diagnosis or obtain additional consultation.

The need for training in medical radiation physics usually is acknowledged, although the importance of an understanding of pathology frequently is not appreciated. A lack of understanding of the gross and microscopic appearance and biological behavior of tumors may result in a form of mechanical radiation therapy which is a physically well planned and executed, but biologically ineffective or even harmful, introduction of radiation energy into a human phantom instead of an intelligent adjustment of treatment to a human with disease.

Recently there has been an increasing emphasis on radiobiology. The term *radiobiology* currently is ambiguous. However, two major functional divisions can be recognized: (1) radiation effects at the cellular level; and (2) radiation effects at the tissue level. The latter is of practical importance to the clinical therapeutic radiologist, as mentioned in the discussion of radiation pathology. Radiobiology at the cellular level is of great interest and fundamental importance, but to date has contributed little to clinical radiation therapy as the specialty has developed empirically. As Kaplan[5] emphasized in his 1970 Failla Memorial Lecture, ". . . it is an ironic fact that they" (referring here to the classical experiments by Regaud and his collaborators, see p. 27) "are the only radiobiological experiments to date that have had a lasting and universal impact on the practice of radiation therapy."

The radiation therapist is concerned with tumors involving any organ or body structure. Consequently, he must have a working knowledge of the *diagnostic procedures* used in other medical specialties in order to evaluate the gross appearance and extent of tumor. This evaluation often is more important than the tumor histology in estimation of radiovulnerability and radio curability. The response of tumor and adjacent normal tissue during the course of irradiation must be used as a guide for treatment. Therefore, the therapeutic radiologist must be competent in the simpler endoscopic procedures, such as indirect laryngoscopy and nasopharyngoscopy. He should join the special examiner at bronchoscopy, esophagoscopy, or cystoscopy in order to assess the gross appearance and extent of tumor, the response to treatment, or radiation-produced change. An estimate of the gross appearance and extent of the tumor and the condition of the adjacent normal tissues, necessary for the planning and administration of treatment, can be obtained only by inspection and palpation. No detailed report can substitute for this first-hand examination. In addition, the physician, knowledgeable in other medical specialties, does not appreciate the importance of seemingly minor details, which may be useful therapeutic and prognostic guides. The therapeutic radiologist need not be competent in these technical procedures, but he must appreciate the possibilities and limitations of the examinations to foster the necessary close cooperation with the participating specialist.

The radiotherapist must understand the possibilities and limitations of *modern cancer surgery* to enable necessary close cooperation with the surgeon in evaluating the relative merits of surgery and radiation therapy in each situation. Great progress in cancer therapy in the last decade has resulted from the appreciation of the need for cooperation, rather than competition, between surgeon and radiotherapist.

The therapeutic radiologist must have considerable interest in and understanding of *cancer chemotherapy* to promote effective cooperation with the chemotherapist. This rapidly growing medical specialty deserves the tolerance and understanding only recently afforded radiation therapy.

As medicine currently is practiced in the United States, physicians caring for cancer patients in special medical centers are seeing an increasing number with persistent or "recurrent" tumor following inadequate initial treatment. The problems of radiation therapy of these previously inadequately treated patients are numerous and complex.[6] Radiation therapy with intent of sterilization of cancer is a radical procedure. Such treatment cannot be repeated following initial failure. Inadequate irradiation also can preclude later optimal surgery. Therefore, initial patient selection, treatment planning, and treatment implementation must be done carefully. *The patient's fate often is decided by the initial therapeutic attempt.* Errors rarely can be corrected.

Nearly all radiation therapy as now practiced requires a substantial overall application time, for example, two months for the treatment of a patient with cancer of the cervix. Although such long treatment periods have inherent disadvantages, they provide an unparalleled opportunity for the physician to become involved in the interaction of a life-threatening disease and a concerned human host. During this period, the therapeutic radiologist is the physician primarily responsible for the total care of the patient. This responsibility, essential during treatment, frequently is continued on the insistence of the patient and is strengthened by the necessary close post-treatment follow-up.

Optimal therapy for patients with cancer is most likely in special institutions or departments because: (1) There is a need for a wide range of closely cooperating medical specialists. (2) Decentralization makes it impossible for the isolated physician to accumulate adequate experience or even maintain skills previously mastered.

There are about 3,000 new diagnoses of cancer per million general population per year. *By current standards, about 40 percent of such patients should receive radical radiation treatment as the initial therapeutic gesture, while about 70 percent of patients with cancer will receive radiation therapy at some time.* (3) Adequate diagnostic and treatment facilities are expensive and should be fully utilized without wasteful duplication. (4) Adequately trained radiation therapists are presently so scarce that they are found only in special institutions or departments. The current number of about 400 can be contrasted with the estimated need of about 2,000.[2] This rationale for the centralization of personnel and facilities for the treatment of the patient with cancer was documented by Regaud as early as 1927.[9] Such centers have developed throughout Europe, Canada, and parts of Asia, but remain infrequent in the United States.

From this survey, it is clear that radiation therapy, if understood as "clinical radiotherapeutic oncology," deserves status as an independent clinical medical specialty. Yet it has become recognized very slowly in the United States.[7] In many places it still is considered an adjunct to x-ray diagnosis. There are several reasons for this slow recognition. Radiation therapy developed from two separate sources: One source was roentgen therapy initially performed by the "roentgenologist" as an adjunct to x-ray diagnosis; the other source was the surgical techniques used for radium implantation as developed by surgeons and gynecologists. Only slowly has it been recognized that *all radiotherapeutic procedures must be integrated as part of a uniform method of treatment and consequently must be performed by a single specialist.* Another reason for slow recognition is that because of the essential alliance of the few radiotherapists with specialized institutions, often exclusive of medical schools, there has been minimal interchange between radiotherapist, practitioner, medical student, and trainee.

REVIEW QUESTIONS

1. What is the basic physical characteristic of the radiation energy used in the treatment of the patient with cancer?
2. What are the two major physical forms of ionizing radiation? Give examples of each.
3. What are the two general origins of ionizing radiation? Give examples of each.
4. What specific types of radiation are currently used in clinical radiation therapy?
5. Why is clinical radiation therapy similar to, but different from, surgery or internal medicine as a medical specialty?
6. Why must the radiation therapist have an understanding of medical radiation physics? of tumor pathology? of radiation biology?
7. Therapeutic radiology has been described as having a transverse rather than a vertical structure as compared to most other clinical specialties. Can you explain?
8. Surgeons, chemotherapists, and radiation therapists should be cooperating partners rather than competitors in the care of the patient with cancer. Explain.

9. What are the advantages of special medical centers (i.e., cancer hospitals) in care of the patient with cancer? What are the disadvantages?

10. Do you believe that the trend should be toward such specialized medical centers?

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2

THERAPEUTIC RADIOLOGY: PAST, PRESENT, AND FUTURE[7]

Medical students and young physicians interested in therapeutic radiology as a career ask questions which have been recurrent for many years. What is the future of therapeutic radiology? What happens to them if "a cure" or "preventive measures" are discovered? What is the possibility that other medical specialists will usurp the functions of today's radiotherapist? What are the job opportunities? What are the health hazards? What changes are predictable in therapeutic radiology, and how should training programs anticipate these? Considering the cost of facilities and the need for sizable numbers of patients, what does the future hold for private practice? What will be the extent of the "influence" of government?

Answers to these questions and others can be framed in a reference to the short history and current status of therapeutic radiology.

HISTORICAL PERSPECTIVES

The use of ionizing radiation in medicine dates to Röentgen's[22] discovery of a "new kind of ray" (x-ray) on November 8, 1895 and to the Curies' discovery of radium in 1896.[20] The short life-history of medical use, the necessary early empiricism, the delayed appearance of unrelentingly progressive, undesirable sequelae, and perhaps even the mysticism of a powerful biologic agent, which cannot be detected by the usual human receptors, have influenced and continue to influence the attitudes of physicians and others toward use of ionizing radiation in medicine. Unfortunately, some attitudes, based on misconceptions and misinformation, adversely influence today's medical care.[6]

A predictable sequence of reactions followed the discovery of this powerful agent which could cause marked biologic change. The first reaction was that of overenthusiasm, when ionizing radiation was reported as a "cure" for most previously incurable diseases. When such impossible predictions failed to materialize, there was a counterreaction of pessimism and despair, and ionizing radiation was claimed incapable of any beneficial effect. The ultimate realistic appraisal is that *ionizing radiation is a unique agent, beneficial in selected cricumstances*, and, thus, is similar to other medical agents.

Clinical therapeutic radiology had a long and frequently painful gestation period[7] from 1895 to the early 1920s. During this period, most radiation therapy was done, and thus influenced, by surgeons, as they were the physicians most interested in the patient with cancer. Unfortunately, the resulting basic philosophy was that ionizing radiation was a caustic agent to be used to produce a "slough in lieu of excision."[7] This "brutal form"[7] of radiation therapy, used in single, massive doses, resulted in disastrous consequences. Clinical radiation therapy was nearly stillborn, and today's youngster still bears the scars of this period. Some physicians, even today, consider ionizing radiation as a cauterizing agent rather than as a *subtle instigator of chemical change* which produces selective responses in cells, tissues, organs, and whole mammals.

Much of lasting value developed during this gestation period. Even prior to the famous inadvertent, first radiobiologic experiment (non-grant supported) by Becquerel in 1901,[3] when he noted a burnlike sore on his abdominal skin adjacent to a vest pocket in which he carried a glass tube of radium salt, medical therapeutic attempts were reported.[8]

E. H. Grubbe, a Chicago layman manufacturer of vacuum tubes, claimed to have treated a patient with carcinoma of the breast in January, 1896.[17] Voigt, in Germany, treated a patient for pain relief about the same time.[24] Despeignes, in France, treated a patient with gastric cancer in July, 1896.[14] Most physical infirmities, including blindness,[15] were treated and reported to respond favorably. Techniques of application were inconstant and nonreproducible.

Although indications for use and techniques of application continue to change, it soon became apparent that ionizing radiation was primarily beneficial in the treatment of patients with cancer and that definite conditions of application were a prerequisite for use.

Technological advances were more rapid than accumulation of basic biological knowledge. By 1913, Coolidge[10] had developed an x-ray tube with a heated tungsten filament, a tungsten target, an effective vacuum, and a peak energy of 140 kv, thus providing the foundation for external roentgen teletherapy. By 1922, 200 kv x-ray tubes were available for "deep therapy."[10]

During this same period, radium has been used in containers in the uterus (Margaret Cleaves, 1903[9]) and interstitially (Robert Abbe, 1905[1]). Later it was developed as a teletherapy source (Finzi, 1911[8]; Kelly, 1920[8]; Regaud,[8]; Forssell[8]; Cutler[8]; Quick, 1955[19]).

Clinical radiation therapy was born in 1922, when Regaud, Coutard and Hautant presented evidence to the International Congress of Otology in Paris,[21] that advanced laryngeal cancer could be cured without disastrous, treatment-produced sequelae. Thus, for the first time the method was used by physicians (radiotherapists) interested in its development rather than by surgeons who considered ionizing radiation as a minor adjuvant to be used as a caustic agent.

During this period of French and Scandinavian influence, the treatment philosophy was to avoid tissue necrosis and sloughing through distribution of radiation in time and through use of sources with short wavelengths.[7] By 1934, Henri Coutard[11] had developed a *protracted-fractional method* which remains the basis of current radiation therapy. A few radiotherapists, primarily in France, Scandinavia, and England, had developed techniques for the treatment of patients with cancers of the larynx and cervix *prior* to the definition of a unit of radiation dose in 1928. These techniques, with minor variations, are valid today!

The next period of development was physical. Ionizing radiation was quantitated and qualitated. These units and measures (roentgen = radiation quantitated by measurement of ionization of air; rem = roentgen equivalent mammal; rep = roentgen equivalent physical; rad = radiation absorbed dose; half value layer = a measure of quality; interstitial dose schemes of Paterson-Parker and Quimby) were standardized throughout the world. Treatment planning and delivery became accurate and reproducible.

The leaders in this growth phase were the British. Use of British-developed treatment techniques and dependence on British-trained physicists and dosimetrists continues throughout the world today.

There was coincident enrapture with apparatus, as if cancer cures were as close as the development of ever more "powerful" radiation sources.

X-ray generators operating at 800–1,000 kv were installed for medical use as early as 1932.[5] These were followed by cyclotrons, synchro-cyclotrons, betatrons, bevatrons, linear accelerators, and nuclear reactors. Cobalt-60 and cesium-137 succeeded radium-226 as isotopic teletherapy sources. Yet cancer cures remained elusive.

Today, major interest has returned to the biologic responses induced by ionizing radiation and to the biology of cancer in the human. Recent explosive growth of radiobiology at times has resulted in a failure of communication between basic-science–oriented and clinically oriented workers, with consequent inattention to problems of immediate clinical importance and even to production of data conflicting with long-established empirical observations. Development of an understanding of radiobiological responses and correlation with the necessary knowledge of human cancer biology should be the major thrust during the foreseeable future.

CURRENT STATUS

"Radiation therapy as a specialty has been accepted very reluctantly and is still far from being generally accepted throughout the country. Most of the radiation therapy was and much still is performed as an annex to x-ray diagnosis by the general radiologist, although in Great Britain, France, and the Scandinavian countries, radiation therapy has long been accepted and practiced as an independent specialty."[7] As early as 1938, Forssell stated[16] "Roentgen diagnostic and radiotherapy demand different scientific training, and the investigation of each belongs to different spheres of medicine. The conditions necessary for their practical utilization are also very different. . . . Radiotherapy's task of treating about two-thirds of cancer patients alone or in cooperation with surgery has, even from a mere practical point of view, made it impossible for one and the same man to satisfactorily direct both the roentgen diagnostic work and the radiotherapy of a large hospital, if he is not a genius."

Yet as late as 1955 the transcript of the Annual Conference of Teachers of the American College of Radiology[2] included the following statement: "In our system of free enterprise, it is readily apparent that the bulk of radiologic practice will continue to be carried on by radiologists who must assume the responsibility for both diagnosis and therapy. Any other method would require transportation of many patients to centers large enough to support *adequate specialized therapy* *equipment and personnel.*" This seems a curious position in an age when people travel hundreds of miles for recreation and thousands of miles for committee meetings, and perhaps partially explains why as late as 1948 a delegation from the British Empire Cancer Campaign found only three institutions in North America (including one in Canada) practicing radiotherapy equivalent to that practiced in England.[4] This gap between prevalent and optimally obtainable cancer treatment was noted by Steiner in 1952[28] and still exists today.

Regardless of the inherent scientific integrity of any medical specialty, its success depends upon its disciples. In 1960, Kaplan[18] estimated that, by 1970, 1,400 to 1,700 therapeutic radiologists would be required to adequately care for the U.S. population with cancer. The number of full-time, active radiotherapists in the U.S. increased from 111 in 1959 to 295 in 1968,[12] but remains less than 400 at present. Therefore, the potential for growth in the immediate future exceeds the recent rapid growth.

The number of trainees in "straight" radiotherapy was 25 in 1960, 84 in 1968, and is estimated to be 150 in 1970.[13] In 1969, 29 therapeutic radiologists were certified by the American Board of Radiology. Therefore, the number of newly qualified radiotherapists only slightly exceeds the attrition rate and makes little inroad on the existing demand. A major problem for therapeutic radiologists is choice of a job from among many offered. This situation is the basis of a form of "occupational musical chairs" which involves all radiotherapists.

Although the number of institutions offering this training has increased from 29 to 66 in the decade 1960–1970, only about one-half of the available positions are filled. This healthy growth of trainees in radiation therapy has been accompanied by a proportional increase in straight diagnostic radiology trainees, thus reducing the number of general radiologists tempted to do radiotherapy.

Although the American Board of Radiology has offered certification since its inception in 1934, the American Medical Association has certified training programs independent of diagnostic radiology only since April, 1969. The first Department of Therapeutic Radiology in a U.S. medical school was established only a few years ago. By July, 1970, 15 to 20 such independent departments should exist.

Such developments as independent training and certification and the establishment of vigorous departments in U.S. medical schools will be followed by more widespread recognition of therapeutic radiology as a legitimate medical specialty. This can only result in a period of quantitative and qualitative growth unknown to date.

ATTEMPTED ANSWERS

There are multiple indicators that the foreseeable future for therapeutic radiology is one of continuing rapid growth. Today's requirement for a four- to fivefold increase in the number of radiotherapists to manage patients with cancer may be intensified by the rapid reduction in the training of general radiologists, the limited number of radiotherapy trainees, and an inherent appeal of the method whenever adequately demonstrated.

In the unlikely but hoped for event that unforeseen curative agents become available during our lifetime, therapeutic radiologists, because of their unique background in clinical oncology, will be the best qualified to master new techniques and continue their involvement with the cancer patient. If "cancer preventatives" are developed, radiotherapists can become medical administrators.

Inasmuch as increased understanding of radiation use and increased complexity of application have led to the development of a special physician, the radiation therapist, it is unlikely that other physicians will usurp the function of the radiation therapist as the methods become even more complex. Indeed, today few surgeons use radioactive materials for implantation, and the number of gynecologists applying radium is decreasing, because today's gynecology trainee realizes his limitations.

Much of the data on short- and long-term radiation effects in humans was provided by early radiologists as inadvertent experimental objects. These physicians, martyrs to ignorance, suffered from an increased incidence of skin cancer, leukemia, cataract, and perhaps life shortening. Today's radiation therapist should receive little exposure to ionizing radiation, certainly less than the diagnostic radiologist doing fluoroscopy. With good practices based on current knowledge, risks should not exceed those to any physician.

Future changes are not easily predictable. However, it is unlikely that new radioactive agents or equipment will result in revolutionary changes. As in surgery, there is much work to be done in understanding, refining, and applying existing methods. However, ever-increasing knowledge of basic biology might revolutionize the specialty. For example, if cancer cells could be synchronized and irradiated when most sensitive, or if chemicals could selectively sensitize cancer cells to irradiation, today's methods might be quickly outmoded. Training programs can anticipate such unforeseen developments by encouraging the trainee to be a life-long student.

The private practice of all medical specialties is rapidly changing. The private practice of therapeutic radiology, never well developed, is no exception. Requirements of expensive facilities and a large number of patients always have encouraged location in medical centers and organization in groups inclusive of specially trained physicians, physicists, dosimetrists, technicians, and nurses. Trends toward physician group practices in other specialties may make these activities similar to what has been commonplace in radiation therapy.

It is important to emphasize that therapeutic radiology can legitimately compete economically in today's marketplace, despite the high cost of facilities. Many excellent private groups attest to this in all parts of the U.S.

Cancer programs in the U.S., as in other countries, have been influenced by government at all levels. The National Cancer Institute, the first institute in the National Institutes of Health, has been constructively involved in meaningful programs in cancer prevention, detection, treatment, training, and investigation. This participation has contributed to the health of our citizens through encouragement of all cancer workers.

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3

FUNDAMENTALS OF CLINICAL RADIATION THERAPY

TECHNICAL MODALITIES

The technical modalities used for clinical radiation therapy may be divided into three major groups (Tables 3–1 and 3–2):

1. *External (transcutaneous) irradiation:* Irradiation from sources at a distance from the body (x-ray; teletherapy with radium-226, cobalt-60, or cesium-137).
2. *Local irradiation:* Irradiation from sources in direct contact with the tumor.
   a. *Surface irradiation with applicators* loaded with radioactive material (molds for the treatment of certain oral and skin tumors).
   b. *Intracavitary irradiation* with radioactive material (most commonly radium-226, cobalt-60, cesium-137) in removable applicators which are inserted into body cavities, such as uterus, vagina, or maxillary sinus.
   c. *Interstitial irradiation* by removable needles containing radium-226, cesium-137, or cobalt-60; by nonremovable "seeds" of radioactive gold-198 or radon; by small radioactive iridium-192 sources in nylon suture; or by radioactive tantalum-182 wire.
   d. *Direct roentgen therapy* to epithelial lesions by means of cones (ie., transvaginal, intraoral).
3. *Internal or systemic irradiation:* Irradiation by radioactive sources (i.e., ^{32}P, ^{131}I) administered intravenously or parenterally.

During the past three decades, improvement in facilities for external irradiation has made the use of local techniques less important. In our own practice, local techniques are limited to intracavitary treatment of certain gynecological cancers (cervix, vagina, uterus) and some carcinomas of the bladder, to interstitial and mold treatment of some carcinomas of the tongue and floor of the mouth, and to occasional transoral and transvaginal roentgen therapy.

External Irradiation

For irradiation of neoplasms from external sources, roentgen rays generated at voltages between 85 kv and 35 mv and gamma rays from radium-226, cobalt-60, cesium-137 currently are used clinically. The energy (and penetrating power) of