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ABSTRACT

Radiology today is a major clinical specialty of medicine in terms of the number and complexity of patient examinations, and the financial resources, physician manpower, and supporting personnel required for performing its functions. It reached its present status because it provides accurate methods of diagnosis for so many diseases. However, this progressive expansion in radiological patient service and nuclear medicine has not been accompanied by a similar growth in manpower. Compared with the impressive amount of ongoing clinical activity in these specialties, the effort and support of research in these fields have been meager. To strengthen these areas of concern, it is recommended that: (1) greater research support be provided for new radiological methods and new developments in instrumentation; (2) increased emphasis be put on support for improved educational methods for instruction in radiological sciences; (3) greater emphasis be put on research in improving the efficiency of radiological examinations; (4) research be conducted in the areas of the development of newer methods for radiation detection and new radioactively-labeled compounds for medical application; (5) recruiting efforts be maximized to draw promising young men into the field. (HS)

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RESEARCH TRAINING IN RADIOLOGY

Report of the Radiology Training Committee
National Institute of General Medical Sciences

RESEARCH TRAINING IN RADIOLOGY

REPORT OF THE RADIOLOGY TRAINING COMMITTEE

NATIONAL INSTITUTE OF GENERAL MEDICAL SCIENCES

NATIONAL INSTITUTES OF HEALTH

BETHESDA, MARYLAND 20014

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FOREWORD

Research programs of the National Institute of General Medical Sciences support the acquisition of new biomedical knowledge broadly applicable to the solution of health problems. The Institute also administers a national program of research training to help meet our country's health manpower needs.

Support for training is provided largely by awarding grants to universities to assist well-qualified students complete programs of study in selected fields of science. Besides supporting the training of young men and women in many disciplines, training grants help to provide the special academic environment in which research training must take place.

In the awards process, training grant applications are reviewed and evaluated by appointed committees of scientist advisors. Altogether, the Institute has 16 such advisory groups whose members are chosen because of their eminence in particular fields of science and who represent valuable resources of information about new directions in research, both basic and applied, and broad, general trends in areas of foremost concern.

To use fully these resources - the Institute has asked its committees to assess and report periodically upon the status of research and training in their fields. These reports, updated at frequent intervals, may be indicative of the health and vigor of research in an entire field or, at times, in specific areas of great interest.

The Radiology Training Committee of the National Institute of General Medical Sciences has in this report assessed its research manpower needs in diagnostic radiology and nuclear medicine.

The need for this report has arisen in good part from the considerable publicity which has been given to the apparent increase over the past few years of supply over demand of persons highly trained to conduct research. Although originally prepared as a communication to the NIH on manpower, it seemed to the Institute staff that the information would be of value to the scientific community.

I again commend the Committee for an excellent report. It has been valuable, as many past reports have been, to the staff and programs of the National Institutes of Health. It should be useful to many others who are concerned also with progress in the health sciences.

DeWitt Stetten, Jr., M.D., Ph.D.
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MAGNITUDE OF THE MANPOWER SHORTAGE IN CLINICAL RADIOLOGY

The impending crisis in health care delivery in the United States can be met only if shortages in health manpower can be overcome. According to the Carnegie Commission Report,(8) the most serious shortages of professional personnel in any major occupation group in the United States are in the health services. The critical shortage of both professional and non-professional personnel in clinical radiology has been documented in previous publications, particularly since the Report to the Surgeon General, USPHS by the National Advisory Committee on Radiation of 1966.(16)

Although the medical applications of ionizing radiations began about 75 years ago, their major impact on medicine for both diagnosis and treatment was not realized until the 1940's. At that time, several major technological advances were achieved including image amplification, the development of "special radiological procedures," and the development of high energy X or gamma radiation sources for radiotherapy. The "special procedures" that have extended the diagnostic capabilities of radiography include special instrumentation (such as tomography, cine-radiography and rapid serial filming) and special visualization by injecting contrast media through catheters selectively placed in blood vessels and elsewhere in the body. After World War II, a wide variety of radioactive materials became available for medical purposes. Concurrently, the technology of scintillation detectors rapidly advanced. As a consequence, the science of nuclear medicine was born and quickly became one of the fastest growing of the medical disciplines. Today, the applications of the radiation sciences in clinical medicine are divided into three major subspecialties -- radiological diagnosis, therapeutic radiology, and nuclear medicine. As the number and complexity of diagnostic X-ray procedures increase, diagnostic radiology is undergoing further subspecialization into such fields as pediatric radiology, cardiovascular radiology, and neuroradiology.

Today, diagnostic radiology has emerged as one of the major forces in modern clinical medicine. A survey by the USPHS in 1964[21] revealed that 115 million X-ray examinations (excluding dental X-rays) were carried out in the U.S., equivalent to 1.2 diagnostic X-ray procedures (or 1 diagnostic X-ray visit) for every 2 individuals in the population each year. A study of consecutive hospital admissions by Morgan[12] revealed that for every 100 new hospital admissions, 160 X-ray diagnostic examinations are performed, and 2/3 of all in-patients are examined radiologically. Of these, 75% had one or more medical diagnoses established or confirmed by radiological methods. As a consequence of its growing importance in medicine, radiology has become highly attractive to medical students in recent years. Since 1965, there has been a sharp increase in the number of graduates from American medical schools entering training in radiology. By 1968, 8% of graduates of U.S. and Canadian medical schools entered radiology residency training;[12] only in the fields of internal medicine, general surgery, and psychiatry were more students enrolled. Moreover, directors of radiology training programs believe that the average candidate applying for residency training is now of higher caliber than in previous years.

The work capabilities of the clinical radiologist have been under study for many years. In a detailed survey by Donaldson in 1951,[6] it was found that one radiologist could be expected to handle 6,000 patients per year, equivalent to 7,200 radiological procedures per year. Subsequent studies have shown little evidence of improved efficiency in the utilization of a radiologist's time. The reasons for this are manifold. Each procedure requires a knowledge of the patient's clinical condition, individual interpretation and reporting of radiographs, and frequently, individual consultations with the patient's referring physician. Indeed, the number of patient examinations carried out by a clinical radiologist has steadily decreased within recent years. The expanding proportion of special radiological procedures which require more professional time for both technical performance and interpretation is responsible for this trend. To illustrate, a survey of 17 large university hospitals in 1966 [16] revealed that special procedures represented slightly less than 3% of all diagnostic studies but required 25% of the radiologists' time. From this, it can be calculated that one full-time radiologist can carry out only 850 special procedures per year, i.e., each special procedure requires an average time of 2.33 professional hours. It was further shown that 72% of the total radiologist manpower was required for diagnostic radiology, 16% for therapeutic radiology and 12% for nuclear medicine.

The growth rate of the number of radiologists in relation to the volume of clinical radiological services in the U.S. was assessed in 1966 in the NACOR Report [16] and recently updated by Morgan. [12] The consumption of X-ray film (based on the film manufacturers' figures) is growing at an annual compound rate of 6.8% and currently may be as high as 10%. (Figure 2) The number of raiological procedures nationally is growing at a rate in excess of 5% per year. Allowing for the increase in man hours required for special procedures, the growth rate in radiological work effort is actually 6.7% per year in radiological diagnosis. The overall growth rate in radiological patient services is 7% per year, compared with an annual growth in the number of radiologists of approximately 5.7%.(Figure 1) Consequently, if these trends continue, any shortages in radiological manpower which now exist will become more acute in future years.

The NACOR Report expressed concern that an acute shortage of clinical radiologists already existed in 1964. Subsequent publications[2, 15, 18] confirmed this contention with one notable exception ---- Knowles[10] believed there was insufficient evidence to indicate a current shortage of radiologists while conceding that regional shortages, and a universal shortage of academic radiologists, did exist. His argument was based on a USPHS study of 6 medical groups providing prepaid medical services which needed only 4.4 radiologists per 100,000 population. Knowles recognized, however, that the population served by these medical groups was a highly selected one. This study, therefore, cannot be applied to the general population. None of the available estimates for current requirements in radiological manpower can assess the need for radiological services to the relatively large segment of the population which now receives inadequate medical care. Should a new health system be implemented to provide an acceptable level of medical care to the entire population, the demands for radiological services would undoubtedly increase, but to an unpredictable extent.

Calculation of the number of diagnostic radiologists required by the nation by 1980 cannot be based solely on projections of population growth, particularly if a national health insurance system becomes effective.

In 1930, there was only one radiologist per 122,000 population, whereas in 1950, there was one per 42,000 population, and in 1970, one per 19,300 population. Moreover, an adequate prediction of the radiological manpower needed cannot be based on a fixed percentage of the total of 450,000 physicians projected by the U.S. Department of Labor for 1980.(19) Past experience has shown that the proportion of physicians specializing in radiology has steadily increased as the utilization of radiological services has progressively risen. Thus, in 1950, only about 1% of all physicians were radiologists;(6) whereas, in 1970, more than 3% of all physicians were radiologists.(5) (Table I) In the future, this percentage is apt to rise further; consequently, the estimation of radiological manpower should be based on projections of the types and numbers of radiological examinations to be performed for the total population.

Statistics from the AMA(5) (Table I) indicate that in 1969 there were only 10,041 radiologists. Of this group, 9,375 were involved in patient care, including 2,159 residents in radiology. The NACOR Report forecasts that between 20,000 and 25,000 radiologists will be needed in the USA by 1975 and that the number of training positions in radiology would have to be increased to more than 4,500. Similar projections based on the volume of anticipated radiological examinations presented in Table II predict that by 1980 almost 30,000 diagnostic radiologists will be needed. It was calculated that 147 million medical diagnostic X-ray examinations were performed during the year 1969, and it is estimated that over 17,000 diagnostic radiologists should have been available to adequately perform this work. Obviously, a shortage of radiologists existed during the year 1969, and a sizable but unknown fraction of the total number of diagnostic radiological procedures were conducted without supervision by a radiologist. Furthermore, X-ray films at some institutions were reviewed by radiologists only at periodic intervals, resulting in delays in diagnostic evaluation.

The field of nuclear medicine has a manpower problem of exceptional magnitude because its development has been so recent and its technological advances have been so rapid and so quickly incorporated into clinical practice. A survey conducted by the Stanford Research Institute for the National Center for Radiological Health, USPHS,[22] revealed that approximately 2.7 million patient procedures using radioactive materials were carried out during the year 1966. A comparison with a previous study by the same institute for the AEC in 1959 showed that in the 7 year interval between the two surveys, the number of administrations of radioactive material for medical purposes had increased fourfold. The NACOR Report[16] and Morgan's recent publication[12] indicate that the growth rate in clinical procedures employing radioactive materials is continuing at 15% per year, a rate that is more than twice that of diagnostic radiology. According to a survey conducted by Beierwaltes in 1962,[4] 79% of all hospitals with 100 or more beds had a functioning clinical radioisotope unit. Another report of Quinn in 1968[14] indicated that a hospital of 400 or more beds required a full-time physician in nuclear medicine. At that time, there were 818 hospitals with 400 beds or more out of a total of 7,160 hospitals in the USA. The total manpower need in nuclear medicine at that time was estimated to be 1,200 physicians of which only 500 were available. Quinn therefore indicated an immediate shortage of 700 full-time physicians in nuclear medicine. Recently, the Joint Commission on Hospital Accreditation has ruled that hospitals must provide a clinical service in nuclear medicine for accreditation. Experience to date[9] has shown that one full-time physician can conduct a maximum of approximately 3,000 clinical nuclear medicine procedures per year. Estimates of the present and future manpower needs in nuclear medicine in Table II predict that by 1975, over 3,000 physicians will be needed in this field, and over 6,000 by 1980. These are in agreement with a previous estimate by Beierwaltes.[4]

The realistic projection of these manpower needs and resources to 1980 would suggest that there will be insufficient radiological manpower to supply the radiologic needs of the country if there is no change in the pattern of practice. These patterns of practice should then be modified to utilize para-medical personnel insofar as possible to expedite the work of the radiologist.

Development of the manpower needed for adequate radiologic coverage in the future should then depend on

1) Increasing numbers of medical graduates by expanding older medical schools and inaugurating new ones, with the expectation that the fraction of 8-10% entering radiology will be continued. If the number of medical graduates can be increased by approximately 50% as recommended by the Carnegie Commission Report[8] by 1978-1980, a maximum of from 1,200 to 1,700 radiologists may complete training each year.

2) Strengthening radiology training programs to provide adequate instruction for the increasing number of trainees. This has implications for academic radiology as discussed in Section II.

3) Training and employment of increasing numbers of para-medical personnel to aid the radiologist.[2]

4) Fullest use of automated equipment and computers to make both radiologic and para-medical personnel more efficient. Automated exposing, processing, film viewing, report preparation, and information retrieval should be extended and improved.

5) Investigation and utilization of improvements in design of medical centers in general and radiology departments in particular to provide the most effective use of space, equipment, and personnel in providing radiologic care.

6) Appropriate advance radiologic consultation and control to reduce the number of unnecessary examinations.

7) Expansion of supporting services in radiological physics, engineering, and radiopharmaceuticals.

Only with this multipronged attack on the manpower problem can the nation's health needs for radiological services be achieved.

MANPOWER SHORTAGE IN ACADEMIC RADIOLOGY

Numerous publications[1,2,3,7,12,15,18] dealing with the manpower problem in radiology universally proclaim that the shortage of "teachers of radiology" is more profound than the shortage of "practicing radiologists." Even the Knowles" report,[10] which claimed that the shortage of general radiologists was insufficiently documented, recognized that the shortage of academic radiologists was indeed acute. At that time (1968-69) Knowles believed that the teaching hospitals in the USA required at least double the existing 1,000 full-time faculty in radiology merely to fulfill the service demands of these hospitals. From 1961-1969, there was a 74 percent increase in academic radiologists, higher than in any other discipline. Nonetheless, the AMA statistics[11] reveal that the number of unfilled faculty positions in radiology doubled between 1961 and 1969. The AMA recorded 1,288 full-time faculty members in radiology for the year 1969-1970, with 105 budgeted, unfilled positions.

Service Responsibilities

It is generally recognized that the average academic diagnostic radiologist should not have to perform as much clinical work as the practicing radiologist because of other duties. According to Rigler,[18] the optimal number of diagnostic examinations per academic radiologist per year is 5,000. The survey of academic radiology conducted by Ross in 1969,[15] however, revealed that each faculty member in diagnostic radiology averages 8,000 clinical studies per year. The 1970 survey conducted by Dr. Eugene Klatte[9] for the Society of Chairmen of Academic Radiology Departments showed that an academic diagnostic radiology department averages 12,600 examinations per staff radiologist per year. A partial listing of positions available in academic radiology recently published[13] showed that out of 85 accredited medical schools, 22 percent are in need of radiologists at the professorial level and 8 percent are in need of division or section heads. This listing is obviously incomplete but, nevertheless, reflects the present need for more academic manpower. One may conclude that the existing number of academic radiologists should be doubled even to meet present academic needs.

The activities in academic radiology are more complex than those of private practice because they include teaching at both the undergraduate and postgraduate levels and research in addition to clinical duties. Currently, the available time of an academic radiologist is overcommitted to patient care because of the growing importance of radiological procedures in the evaluation of patients and the tremendous increase in the number of X-ray examinations requested. Because patients with difficult or unusual clinical problems tend to be referred to academic centers, the recent trend to develop subspecialized facilities and radiologists in cardiovascular radiology, neuroradiology, pediatric radiology, and nuclear medicine is greater in teaching hospitals than in community hospitals. Special radiological procedures requiring considerable time by the radiologist for this technical performance are more frequently performed at university hospitals. A recent study of Abrams revealed that 8 percent of diagnostic procedures performed at the Peter Bent Brigham Hospital are special procedures that require approximately 35 percent of the total clinical work effort.[Table III] In the past, the major teaching effort has been devoted to the training of residents in radiology, chiefly by regular daily radiological conferences and by individual instruction.

According to Rigler,[18] 80 percent of all residents in radiology are being trained at university or affiliated teaching hospitals.

Teaching Responsibilities

Only within recent years has radiology emerged as an important discipline in the undergraduate curriculum of most medical schools. This change has resulted from curricular revisions including more electives in radiology during the senior year, the incorporation of the clinical disciplines in the early years of the curriculum, and the development of "systems teaching," of which radiology is a part. Thus, the teaching program for medical students has been extended from merely basic clinical radiology to include radiological anatomy, physiology, and pathology, and a better coordination with other clinical disciplines is being achieved. According to the 1971 SCARD (Society of Chairmen of Academic Radiology Departments) survey,[9] an academic radiology department now provides clerkships of five-week duration in radiology for approximately 55 medical students per year in addition to 280 formal lecture hours and 550 hours of interdepartmental teaching conferences. In addition to the medical student curriculum, most academic departments are also responsible for the teaching programs in radiologic technology. Diagnostic radiology is particularly suitable for self-instruction methods of teaching including video tape, 35mm. reproduction, and computer terminals since many of the concepts in this field are visual in nature. Considerable effort in the development of these teaching aids in the near future appears warranted. Academic radiology has a responsibility in continuing education because the practicing radiologist feels the need for a periodic renewal of his knowledge and new techniques. This is evident in the growing number of refresher courses being offered which constitute another teaching burden for the academic faculty.

Research Responsibilities

Fifty percent of the available time should be devoted to teaching and research. Because of the immediate pressures of patient care and numerous teaching responsibilities, the total effort of the academic radiologist devoted to radiological research is disturbingly small. The AMA study of the distribution of physicians in 1969[5] revealed that only 1.3 percent of all radiologists are in research positions compared with 3.8 percent for all physicians and 6.8 percent for medical specialties. In fact, the percentage of radiologists in full-time research is lower than for any other specialty of medicine. Knowles emphasized that most radiologists in academic departments not only lack the time to carry on research, but also lack facilities and necessary training.

Shortage of Academic Radiologists

One of the principal reasons for the critical shortage of young academic radiologists is the large gap in income between the academic and private radiologist. According to Knowles, in 1969 the salaries of academic radiologists generally ranged from $25,000 to $50,000 per annum, whereas the practicing radiologist usually made over $60,000 per annum, and many earned more than $100,000. Another reason for the shortage is that academic radiologists have been poorly supported by their own medical schools. The academic institutions, now under great financial pressure, are unwilling or unable to provide the facilities for radiological research. According to Dowdy,[7] administrators of financially distressed universities and hospitals have frequently looked upon radiology as an income-producing resource and have provided insufficient support for research and training. Furthermore, because academic radiologists have devoted insufficient time in the past towards research and research training, they have failed, unlike other clinical disciplines, to take advantage of available research and training grant financial support. Once an academic shortage becomes established, it is self-perpetuating because the faculty members remaining in an inadequately staffed department have little or no time for academic pursuits, become disillusioned and leave the academic center for greater financial rewards. Because of the current financial difficulties of academic institutions and the effective reduction in research and training funds, the incentives for academic radiologists to enter private practice have never been greater.

In nuclear medicine, the shortage of academic physicians is probably even more serious than that of diagnostic radiology. The 1971 SCARD survey revealed that a typical U.S. medical school has only two full-time physicians in nuclear medicine and that the clinical examinations which they are required to do (2,700 procedures/year/faculty member) leave little or no time for academic activities. This is particularly unfortunate in a young, developing field where the need for a sustained research effort and the training of more physicians is great. Because of the shortage of training personnel, it is estimated that at the present time about 10 percent of the hospitals associated with medical schools have been unable to recruit an experienced full-time physician in nuclear medicine.

A projection of the demands for academic manpower in diagnostic radiology and nuclear medicine in future years will depend on the criteria used. Abrams[1] several years ago stated that a six-fold increase in the number of academic radiologists was required. If the goals of the Carnegie Commission on Higher Education are to be met for 1980, there should be about 16,000 medical graduates per year, or a 52 percent increase compared with 1970. If one assumes that 2,600 academic radiologists were needed in 1969-70 rather than the actual figure of 1,300, then 3,900 would be required by 1980 to maintain a constant faculty-to-student ratio. It is more likely, however, that the number of academic radiologists will be dictated to a much greater extent by the growth of the clinical activities in university hospitals. Clinical service in radiology at university hospitals will probably increase at an annual rate of between 7 and 8 percent within the next decade resulting in a compounded increase of approximately 100 percent within the decade. Using this criterion, the number of academic diagnostic radiologists, which should have been 2,600 in 1970, should increase to 5,200 in 1980.

In nuclear medicine, it can be conservatively assumed that the need for full-time faculty increases will at least be as great as in diagnostic radiology. Hence, between 800 and 1,000 full-time academic physicians in nuclear medicine will be required by 1980. Thus, the total increase in academic radiologists needed for the next decade is estimated at 5,000. It is obvious that these must be trained, at least initially, in the present academic departments. To ensure the proper balance between patient care, teaching, and research, these trainees must have opportunity to study teaching techniques and to develop basic research skills. They must be protected from inundation by increasing clinical loads, with resultant discouragement of their academic careers.

Immediate steps must be taken to begin to provide for needed increase in numbers of academic radiologists, including

1) Expansion of existing academic training programs with increasing support at both federal and institutional levels.

2) Appropriate apportionment of faculty time -- approximately 50 percent to patient care (which may include some residency instruction), 30 percent to research, and the remainder to formal teaching.

3) Opportunities for trainees to study educational techniques for undergraduate and graduate teaching.

4) Opportunities for trainees to develop basic science backgrounds and to acquire basic research skills.

5) Adequate stipend levels during training and adequate salary scales for faculty.

NEED FOR RESEARCH IN DIAGNOSTIC RADIOLOGY AND NUCLEAR MEDICINE

Methods for diagnosis of disease are equally as important as methods of treatment, and for many conditions such as cancer, early diagnosis confers a greater likelihood of cure. Among the diagnostic modalities used, radiology is pre-eminent. The usefulness of radiation in medical examinations has resulted in diagnostic radiology's growth to the sixth largest clinical specialty in terms of numbers of clinicians, and fourth largest in terms of entering trainees. Much of the future progress of medicine will depend on the development of more sensitive and more selective methods of diagnosis. Research in diagnostic radiology is dedicated to these ends and will therefore remain a significant factor in the improvement of medical care.

In the past, the resources and effort devoted to research in radiology by the medical and allied professions and by industry have been relatively small. The effort of radiologists has been expended largely in providing service rather than increasing the efficiency and quality of this service. The limited university-based research in radiological instrumentation in turn has failed to stimulate research and development by the X-ray industry. Thus, only 3 percent of industrial earnings have been spent on research and development compared with some 10 percent in the growth industries. Despite this relative lack of research, the increasing impact of diagnostic radiology on medical practice can be attributed largely to successful past research, particularly related to the development of image intensifiers, new contrast media, and catheterization techniques. Thus, for example, most of the therapeutic triumphs in cardiovascular surgery in recent decades were made possible by the precise localization of abnormalities by angiocardiography, in coronary artery surgery by coronary arteriography, and other neuroradiological methods.

Present research in diagnostic radiology is diversified. It is both technological and biological in scope, for a radiologist is basically a physician applying a technology to human biological problems. These two areas interact with one another, for technological development stimulates medical applications and new medical knowledge creates a demand for technical development safely to exploit it. The central theme of radiological and nuclear medicine research is exploration of the morphology and physiology of organ systems by "non-destructive" imaging or measurement with various radiation sources and detectors. The radiologist uses this approach to investigate anatomical structures and record the progress of pathological states, and for objective evaluation of the effects of drugs and other forms of therapy. He uses not only X-rays, in increasingly versatile ways, but nuclear, infrared, and ultrasonic radiation as well.

The major categories of research endeavor in diagnostic radiology have been discussed in detail in a previous report of the Radiology Training Committee.[3] These include technological developments in instrumentation and contrast media and diagnostic applications of radiologic techniques to other clinical fields, such as medicine, surgery, pediatrics, etc. Research of two different types is needed: (1) coordinated team efforts directed towards recognized specific goals of high priority, and (2) research designed and pursued by individuals to explore original ideas and exploit new technologies. It is through the latter that personal inspiration and dedication can achieve unpredictable major scientific advances.

Research in Diagnostic Radiology

One of the areas of highest priority is immediate improvement in efficiency of radiological practice. This is particularly urgent to reduce the magnitude of the manpower shortage for radiologists, to predict the future effectiveness of paramedical radiological assistants in assuming some of the radiologist's duties, to reduce the general costs of medical care, and to prevent any unnecessary radiation burden on the population. Many facets are involved in such an effort. These include objective studies of the long-term value of each type of radiological examination, with a view towards simplifying lengthy studies and eliminating unnecessary or unproductive procedures and repeated examinations. Such research would clarify the indication for radiological examinations, prevent their indiscriminate use, and modify the increasingly large investments being made for medical X-ray installations.

Research in instrumentation in diagnostic radiology is particularly promising at the present time because of the intimate relationship of the specialty to electronic developments. The product of diagnostic radiology is usually an anatomic image, and today the recording, transmission, and display of images is increasingly electronic. The contributions of this technology, therefore, can be expected to be greater to radiology than to almost any other specialty.

In the technological area, the principal problems generally recognized as requiring future attention relate to increasing the speed and efficiency of the diagnostic process and increasing the range of diagnostic images available in terms of quality and patient dose. Research is needed, for example, on:

a) recording systems providing immediate display of X-ray images;

b) high resolution recording systems utilizing miniature films or other high-density information storage techniques;

c) computerized systems for rapid retrieval of stored radiologic images;

d) computerized systems for recording and transferring radiological reports into individual patient records;

e) computer analysis or assistance in the interpretation of X-ray images;

f) systems for enhancing or modifying images;

g) X-ray tubes with higher thermal capacity and smaller focal spots, allowing examinations with better spatial resolution of anatomic detail or higher temporal resolution of dynamic processes;

h) low-dose technology and its medical usefulness;

i) systems analysis of diagnostic radiology departments to reduce inefficiency and automate many repetitive functions such as patient scheduling, film transport, and adjustment of control variables for radiographic exposures;

j) the further development of contrast media. Thus far, radiopaque agents have been developed for successful visualization of the gastro-intestinal tract, the biliary tract, the bronchial tree, the urinary system, and vascular system. There is a great need to improve the agents used for intravascular injections to reduce or eliminate their toxicity. Moreover, new types of contrast media should be devised to reveal the structure of other organ systems which are not visible on conventional radiographs. For example, it is now theoretically possible to develop a contrast medium in the form of small microspheres capable of demonstrating the reticuloendothelial organs such as the liver and spleen. Surprisingly, few individuals are engaged in research in this area.

In the clinical area, research is especially needed in the following:

a) further improvement in selective catheter procedures for diagnosis and treatment. Examples: magnetic pods in catheter tips to facilitate passage into smaller blood vessels; catheter methods for biopsy and exfoliative cytology; catheter-delivered drug therapy as for acute gastro-intestinal bleeding and for advanced tumors; catheter reparative procedures such as transluminal angioplasty, percutaneous patent ductus repair, and percutaneous hepatic vascular shunting;

b) more interdisciplinary research with other clinical specialties to investigate the early manifestations and modes of progression of disease processes in patients. For instance, alterations in the physiology of the lower esophagus have been studied by correlation of intraesophageal pressure measurements and cineradiography. Redistribution of renal blood flow demonstrable by renal arteriography has been correlated with alterations in renal function in different diseases of the kidney. In pediatrics, the development of pyelonephritis has been found associated with ureteral reflux demonstrable by cystourethrography. Imaginative comparative studies of this type can lead to further insight into the origin of disease processes;

c) the use of high-speed cineradiography and ultra-short radiographic exposures need further exploration in angiocardiography, coronary arteriography, and in laryngo-pharyngeal studies of speech disorders;

d) clinical applications of ultrasound and infrared imaging need more extensive evaluation.

Diagnostic X-ray and radioactive tracers will continue to contribute to our basic knowledge of physiology and pathology because they are powerful non-destructive tools for assessing normal and abnormal function of inaccessible body structures. They are ideal modalities for studying the effects of various drugs on blood flow or specific organ functions (pharmacodynamics). These studies are applicable to animal experimentation and to clinical investigations. Much has been learned, for example, about drug effects on bowel motility from gastrointestinal fluoroscopy. Correlation of dynamic events as recorded radiographically, together with physiologic parameters, has added new knowledge to the study of many organ systems. Correlation of microradiography with angiography and histology also has proven to be extremely valuable in the understanding of the microcirculation and its alterations in diseases such as acute and chronic renal disorders and rejection of renal transplants. Much of the information gained from this work has been applied to humans. This technique should receive much attention in the future.

There is a great need for educational research, for more efficient instruction in diagnostic radiology at various levels of sophistication for technologists, medical students, residents in radiology, clinicians in other specialties, and radiologists. Because so much of the knowledge of this field is visual in content, instruction requires a sizable library of high fidelity reproductions of radiographic images. The field is ideal for modern audio-visual techniques of self-instruction. Exploitation of these methods in radiology, however, is still in its infancy. With greater support and effort, such techniques as time-sharing computer terminals, video tapes of lecture-demonstrations, carrousels of 35 mm.

slides, and sound recordings should be developed, and their effectiveness compared with older methods of instruction. In the future, a nation-wide system of self-instruction in radiology may become feasible.

Research in Nuclear Medicine

Nuclear medicine is rapidly becoming a discrete specialty, and the need for research in this field deserves special treatment, distinct from the needs of diagnostic radiology. It owes its genesis almost entirely to the research efforts of university centers and similar research institutions. The contribution of industry to the development of this specialty is negligible. Thus, nearly all concepts behind current imaging equipment, and the recent advances in radiopharmaceutical development stem from university centers. The results of this research have been directly translated into patient care, with great success during the last decade. This success underlies the unusually rapid growth of the practice of nuclear medicine and its present need for manpower.

Future research in this young and dynamic field is mandatory and has application to almost every facet of medical diagnosis. Important research areas discussed previously[3] include:

a) the development and utilization of short-lived isotopes. These will be produced by medical cyclotrons, other high energy accelerators, generator systems and reactors;

b) the development of new radioactively labeled compounds (radiopharmaceuticals) that will localize in different organs or tissues of the body for demonstration of the morphology and function of these organs. Such developments include the formulation of radiopharmaceutical "kits." These consist of prepackaged, presterilized, reagents that permit the rapid preparation of short-lived radioactive compounds without any special chemical equipment. This is important to provide widespread availability of these materials for many types of diagnostic studies to the entire patient population, including small community hospitals;

c) the development of new radiation detectors such as semi-conductors;

d) the development of equipment for new types of examinations using radioactive material; a good example is the recent introduction of tomographic imaging devices;

3) the utilization of computers for handling dynamic physiologic studies and for improving the quality of radioisotopic images;

f) interdisciplinary research with other fields of medicine; an example is the recent development of a device for measuring radioactive gases from bacteria present in the blood, thus speeding up the detection of septicemia;

g) the use of external detectors for radioactive inert gases for the assessment of regional ventilation in different areas of the lung, and for the measurement of regional blood flow in various organs. The latter is important for the comparison of blood flow between the two kidneys, and for the detection of localized abnormalities in cerebral blood flow, particularly in patients with stroke;

h) radioimmunoassay systems for application in many fields including cancer detection;

i) the use of radioactive trace elements to explore the metabolic fate and excretion of trace elements in the body, including environmental contaminants;

j) autoradiography to gain further knowledge about the tissue and cellular localization of radioactively labeled metabolites, drugs, and other compounds.

It is important to recognize that in the past, major developments in diagnostic radiology and particularly in nuclear medicine have stemmed from research performed at universities. Such departments are best suited to carry out this work and to teach research techniques and methodology to future academic radiologists. Research is a necessary ingredient of advanced academic teaching programs. Involvement in such research helps the teacher to constantly update the informational content presented to students and maintains the vitality of any medical specialty.

NEED FOR RESEARCH TRAINING IN RADIOLOGY

The need for expansion of research in diagnostic radiology, nuclear medicine, and diagnostic radiation physics and engineering has been amply documented, both in the literature[1, 3, 12, 16, 18] and in the previous Section of this report. Current research manpower, however, is insufficient to mount any significant expansion in effort. Enough trained, competent investigators simply do not exist in radiology to support the necessary expansion. Indeed, the percentage of research project money going to these fields is one of the lowest in clinical medicine, despite some improvement in recent years. A large infusion of research funds <u>without associated training support</u> would not solve the research manpower shortage, nor would it markedly increase basic or clinical research productivity. Additional research project funds would help the few existing competent investigators to increase their productivity. It is probable also that more research-oriented physicians would be attracted into radiology. There is a risk, however, that massive amounts of such money would be wasted on ill-conceived and poorly designed projects unless potential young investigators in radiology acquire an expertise in research methods and appropriate training in the sciences essential for radiologic research.

In order for the quantity and quality of research to be augmented significantly, it is necessary to increase the number of investigators entering diagnostic radiology, nuclear medicine, and related basic sciences. This could be achieved by:

1) attracting well-qualified investigators from other specialties to collaborate in radiologic research projects;

2) attempting to entice such investigators to transfer from their

own area of specialization into radiology departments;

3) training a cadre of young radiologic investigators, to form the nuclear for research-oriented medical school radiology departments. These three alternatives are not mutually exclusive, and indeed, all are considered desirable and necessary.

Collaborative radiologic research has been among the most productive, particularly in clinical areas. Determination of indications, accuracy, and diagnostic yield of examinations can be done best by combined studies between radiology and other clinical disciplines. Conversely, radiologic and isotopic methods have been extensively used to study the efficacy of various clinical therapeutic measures. Such studies can only be done by collaborative means. Basic radiologic-physiologic research is also a fruitful area for this type of combined effort. Many important areas of investigation, however, are not suitable for collaborative study. Among these are studies designed to develop new techniques, new equipment, more advanced radiopharmaceuticals, imaging systems, and fundamental physical research.

Many departments of radiology have been successful in augmenting their research staffs either by offering joint appointments or full-time positions to investigators who are primarily trained in other fields. Such individuals can have a salutary effect upon the research effort of a radiology department and can be the focal point about which an investigative program evolves. They also may be a valuable asset in research training. The number of trained investigators in other disciplines who are willing to become solely affiliated with departments of radiology are few, however, and those holding joint appointments are frequently unable to devote sufficient time to radiology projects. Their interests and expertise are usually along channeled lines, dictated by their primary area of interest, and they are not in a position to take additional research responsibilities.

The third alternative, that of creating and supporting programs specifically designed to training investigators in radiology, could be expected to have the greatest impact. It goes to the very heart of the problem -- the research manpower shortage in radiology, nuclear medicine, and medical physics. This was recognized by Congress in 1966 with the expansion of the NIGMS Radiology Research Training Programs. The programs were instituted to create a nucleus of young, competent radiologic investigators who would not only make valuable research contributions themselves, but who would attract other research-oriented medical students and trainees into the field. In other words, the program was designed to train individuals who would not only produce their own research, but who would attract and train other investigators, thus generating a geometric proliferation of research-trained radiologists. These individuals would alter the overall image of radiology as presented to medical students -- from that of a hospital-based, service-limited specialty to that of a complete academic discipline. This in turn, would attract some outstanding students with academic orientation to enter the field.

Record of the Radiology Training Program of NIGMS

Since the allocation of funds to the NIGMS to further diagnostic capabilities in radiology a small on-going research training program already underway has grown rapidly as shown in Table IV. Of the 22 active programs at the present time, 14 are in diagnostic radiology and 8 are in nuclear medicine. About two-thirds of the entering trainees have already had more than 3 years of relevant postdoctorate experience and thus qualify as special trainees. Since the beginning of the program, a total of 211 trainees have been appointed for 6 months or more. Eighty-five of the trainees are currently still in training. Seventy-three individuals have completed the traineeship and are in academic positions in universities throughout the country. Fifty-nine of these are the level of assistant professor or higher, and 14 are instructors. Thirty-one individuals who received 6 months or more support from the program are in primarily non-academic jobs. A significant proportion of these hold clinical appointments in university departments of radiology or nuclear medicine and thus do some teaching. Seventeen are currently in the military service. The majority of these will either return to complete their academic training or plan to enter academic radiology.

Thus, out of a total of 126 physicians who received 6 months or more support from the program and have finished their training, 73 are in academic positions, and some of the 17 who are in the military will be assuming academic positions upon completion of their service obligations. The current status of five former trainees is unknown. Several of the 31 physicians who entered private practice have active part-time teaching roles in university department.

As could be anticipated, difficulties were encountered early in the program: these revolved around the recruitment of academically-oriented trainees, lack of sufficient numbers of research-oriented teachers, and insufficient research grant support and consequent research activity in departments of radiology. These difficulties were expected. Had they not been encountered, the whole traineeship program would not have been necessary. In the past 3 years, however, a dramatic change has occurred. An ever-increasing number of young men oriented toward research and interested in a career in academic radiology have been applying for the program. This group includes the top graduates from medical schools through the country. Many of them have already demonstrated proficiency in research prior to applying for the program, and some have had one or two years of training in other disciplines.

Research orientation of departments of radiology have been strengthened by the addition of young staff men who have received training from the program. These individuals, in addition to adding depth and sophistication to university radiology departments, attract more bright young medical students and other trainees into the program. Thus, it appears that the research training program in radiology is beginning to fulfill its objectives after only a few years of existence. The impact of the program is only beginning to be appreciated, and it will be several years before its full effects become evident.

Critique of the Programs and Suggestions for Improvement

Since each institution designs its program on an individual basis, there is considerable variation in organization, size and content of program, research orientation, and length of the traineeship offered. A critique of the overall program must of necessity then be of a general nature and does not necessarily apply to all programs. A review of the programs, however, indicates the following:

1) Selection of Trainees: More care should be given to selecting trainees who have high research potential and orientation, and

who are dedicated to a career in academic radiology. Programs that are unable to attract such trainees should not be supported from this source. Particular care should be taken to avoid converting the training program into an "enriched residency."

2) Formal Research Training: More opportunity and encouragement should be provided for the trainees to take formal courses in research methodology, statistics, experimental design, advanced mathematics, and basic science background material. These courses most frequently are not offered by a department of radiology, but are available elsewhere in a majority of medical schools. Formal arrangements should be made for the trainees to attend such courses early in their program, so that this background can be applied by them in their research projects.

3) Closer Liaison with Basic Science Departments: Since radiology has long been regarded as a clinical specialty, liaison with basic science departments in many institutions is meager. Close working relationships with basic science departments is of great value in the training program. Cooperative projects, sharing of facilities, and close consultation with basic science departments is lacking in many programs and should be encouraged.

4) Lack of Research Grant Support and Research Activities: Obviously, an active ongoing research program in the department sponsoring an academic training program is essential. Since there is a severe shortage of research-oriented radiologists, many of the programs are deficient, both in the quantity and the variety of research activity in the department. Every effort should be

made by these departments to recruit staff who will actively engage in research and who will be capable of obtaining research grant support.

5) Duration of Training: Although the majority of the diagnostic radiologic training programs are of 4 years duration, the support for the nuclear medicine programs has been limited to 2 or 3 years. The formation of the Board of Nuclear Medicine as a conjoint Board of Radiology, Pathology, and Internal Medicine will soon be accomplished. The Board will require at least one year of training in one of the three specialty areas (radiology, pathology, and internal medicine) and in addition, two years of training in nuclear medicine. This new organization will have a significant impact on formal training in nuclear medicine. In order to prepare individuals for an academic career in nuclear medicine, a multidisciplinary preparation will be mandatory. Accordingly, a four-year program with interdisciplinary emphasis is recommended. This program might combine internal medicine, diagnostic radiology, and nuclear medicine. As the formal structure of an individual program evolves, four years of training rather than the current two years is recommended.

6) Earlier Exposure of the Trainee to Research: Every effort should be made to involve the trainees in research activities as early as possible in their traineeship. This could take the form of formal courses in basic science, and various aspects of research methodology. Active participation in ongoing research projects and planning of original projects should also be encouraged as

soon as the trainees enter a program.

7) More Stringent and Frequent Review of Ongoing Programs:

a) Although new applications seeking NIGMS support for training programs are subjected to a stringent peer review, and many are disapproved, periodic review of ongoing programs should be intensified. b) Currently the peer review system is utilized for initial applications, applications for renewal of training support, and under those circumstances in which administrative factors make review necessary, such as a change of program director. Since the inception of the radiology training programs, five institutions have had their applications for renewal disapproved or their programs terminated. This action, however, was usually taken at the review of the competing renewal application.

NEED FOR FEDERAL SUPPORT FOR RADIOLOGICAL RESEARCH TRAINING

Previous Sections have established manpower needs in radiology in general, the existing manpower shortage in academic radiology, and the need for research and research training in radiology. Academic radiological centers are chief sources for postgraduate training of radiologic manpower and are the only source for teaching of radiology to undergraduate medical students. They are also the principal sites of effective radiologic research, both in the laboratory and patient care phases of radiology. In the face of increasing demands for patient care and for research in diseases of national concern, federal support is urgently needed to strengthen the centers of academic radiology. There is need for expansion, rather than limitation, of such support. As discussed in Section IV, the radiology residency research training programs have begun only recently to provide trained manpower for academic radiology. Of necessity, training for academic radiology will take at least one year longer than the training for community radiological practice. In particular, training for academic radiology should include training in research and teaching in addition to clinical experience. The cost of such additional training should not be borne by increases in patient hospital fees.

The federal support of stipends for training in academic radiology has evolved as an effective method for achieving this goal. Alternative mechanisms have been proposed for training support and these should be examined in detail.

a) Loan Program

It has been proposed that a loan program could satisfactorily substitute for the existing research training grants. The fallacy of this argument is that many research trainees already carry heavy educational debts and have reduced incomes during their training period. Few would choose to borrow money and incur further debts to extend their training period in order to gain research competence when the alternative of a high income in private or community practice is readily available. Actually, by choosing a career in teaching and research, a young academic radiologist must commit himself to a sizable reduction in income throughout his academic life compared with his potential income in practice. A loan program would therefore only accentuate the already large gap in life-long earnings between the academic and practicing radiologist. Academic radiology should not place itself in the position of allowing economic pressures to induce trainees to abandon the longer training program because of fear of further indebtedness.

b) Research Grant

Superficially, it would appear feasible to provide research training by having the trainees participate in the research grants of their senior teachers. Although valuable experience may be gained in this way, it must be realized that such a program would provide only a focus on a very narrow field of interest. These research projects are goal-oriented and are relatively inflexible. The basic science course work and formal training in laboratory procedures would be difficult to include under research project supports. The proper training of individuals for research requires a major investment in time by the senior investigators aside from their research efforts, and this time must be supported financially. Similarly, the support for increasingly independent investigation by the trainee would also prove difficult. In addition, there are probably not enough ongoing research projects in diagnostic radiology to provide sufficient training for the increasing number of academic trainees which are needed. Although other sources are available for research grants, such as the American Cancer Society and the Picker Foundation, these sources are very limited.

Because of the necessity for a broader base of research training which provides appropriate basic science opportunities and exposure to many research techniques, the individual research grant does not appear to be a feasible mechanism for support of training. This can better be achieved through the research training programs which have now evolved.

c) Supply and Demand

It has been postulated that the economic basis of supply and demand would funnel the necessary number of physicians into academic radiology. This is not feasible for the foreseeable future for the following reasons:

1) The existing operation of supply and demand has resulted in understaffing of academic centers in favor of private practice.

2) Academic medical centers are too limited in their economic resources to respond to existing shortages by offering sufficient financial rewards to encourage trainees to obtain academic training without stipend support.

3) Severe shortages of academic radiologists exist now, and the need for correcting them cannot wait for the prolonged response of a theoretical "free market" mechanism.

4) The "supply and demand" theory with economic determinants would greatly favor the continuance of the present trend of manpower expansion

in private practice and community hospitals while further depleting the academic medical centers.

It has been suggested that federal subsidy should not be used to promote the training of physicians who will later have high incomes by virtue of their subsidized training. Few individuals, however, will have sufficient personal and family resources to support a period of research training in addition to college education, medical school, and specialty training. Furthermore, the ultimate effectiveness of nationally co-ordinated health programs will depend primarily on incrasing the number of adequately trained personnel. The value to society of these individuals as the need increases is ample justification for the continuation of federal support of training stipends.

It has also been suggested that the use of federal support of stipends for training of people who later will man "income-producing" departments is inappropriate. As the practice of radiology becomes more complex, the costs of equipment and supporting personnel are mounting. Radiologists in academic centers find more demands on their time for teaching and research. Hence, departments of radiology are not the "income-producing" departments that they have been in the past. This is becoming evident from more accurate cost accounting procedures now being carried out. The transition to more academically oriented departments will of necessity require more operating funds. It is unrealistic to assume that federal support of training is not necessary to provide the trained base of manpower which can operate academic departments of radiology with appropriate attention to their obligations of teaching and research and expanded programs of patient care.

In view of the weaknesses of other methods and the demonstrated need for expanded financial support, any withdrawal of funds for training will greatly handicap the academic centers of the country as they face an era of unprecedented demand in all areas of their expertise: patient care, teaching, and research. The ongoing momentum of the radiology research training programs must be strengthened rather than weakened, if the medical care needs of the country are to be met effectively.

SUMMARY AND RECOMMENDATIONS

Radiology today is a major clinical specialty of medicine, in terms of the number and complexity of patient examinations, and the financial resources, physician manpower, and supporting personnel required for performing its functions. It has reached its present status because it has provided accurate methods of diagnosis for so many diseases. Its continued growth can be attributed partly to increasing utilization of radiological examinations for patient care. More importantly, new clinical applications of radiological methods, including the use of radionuclides and nuclear techniques are being evolved at an ever-increasing rate. This progressive expansion in radiological patient service has not been accompanied by a similar growth in manpower. The previous sections of this report have reaffirmed the national shortage of radiologists, and the critical shortage of "teachers of radiology" already documented in the literature. Similar statements are true for specialists and teachers of nuclear medicine. Compared with the impressive amount of ongoing clinical activity in these specialties, the effort and support of research in these fields have been meager.

The NIH mechanism of financial support for research and research training, which has utilized an objective peer review system for evaluating and establishing priorities, has been generally successful. However, project funds, awarded on the basis of excellence tend to remain largely inaccessible to an area of endeavor which is weak on a national level -- such as research in diagnostic radiology -- and the "area of weakness" is perpetuated. It is only within recent years that some medical school departments of radiology have been able to mount a significant research program and successfully compete for project funds. It is vitally important that this previously neglected area of research be strengthened in the future. Past research support has been too highly restricted to categorical disease states or organ systems. In the future, it is recommended that greater research support be provided for new radiological methods and new developments in instrumentation which are frequently applicable to many organ systems or disease states. Furthermore, there should be increased emphasis on support for improved educational methods for instruction in the radiological sciences rather than limiting awards to the acquisitions of basic biological knowledge. There should be greater emphasis on research in improving the efficiency of radiological examinations, or "systems analysis" in radiology, including automated methods for storage and retrieval of radiological images and for transferring and recording radiological data. The utilization of computers for these activities should be thoroughly explored. In nuclear medicine, the development of newer methods for radiation detection, and new radioactively-labeled compounds for medical application would appear to be particularly important avenues of research. Although there must be targeted research and training efforts in areas of high priority, it will also remain important to preserve individual project support that is not restricted to particular fields of medicine.

Current economic forces, including reduced federal and institutional budgets, and high incomes of practicing radiologists and nuclear medicine specialists will tend to magnify the already critical shortage of academicians in these fields. Recruiting and retaining young, outstanding academicians will remain the major challenge of radiology in the foreseeable future. These men will have the major responsibility for training future clinical radiologists, and for virtually all of the training of undergraduate students and research workers in radiology. Following the establishment of NIGMS training grants in radiology only a few years ago, some recent progress has been made in the training of young academic radiologists with capabilities in both research and clinical areas. This has been a significant start in alleviating the dearth of academic radiologists. Such progress could not have been achieved through loan programs or research support limited to individual projects. The NIGMS training programs can be further improved particularly by more formal training in research methodology, experimental design and statistical evaluation, and a closer liaison with basic sciences. It is essential that these programs not only be continued but expanded to achieve the goal of adequate staffing for all departments of radiology in the medical schools of the United States with competence in all phases of radiology.

APPENDICES

TABLE 1 *

FEDERAL AND NON-FEDERAL PHYSICIANS

IN UNITED STATES AND POSSESSIONS

BY SPECIALTY AND ACTIVITY

DECEMBER 31. 1969

UNITED STATES AND POSSESSIONS

		MAJOR PROFESSIONAL ACTIVITY									
		PATIENT CARE					OTHER PROFESSIONAL ACTIVITY				
				HOSPITAL BASED PRACTICE							
SPECIALTY	TOTAL PHYSICIANS	TOTAL	OFFICE BASED PRACTICE	Interns	Resi-dents	Full-Time Physician Staff	Medical Teaching	Adminis-tration	Research	Other
TOTAL PHYSICIANS	324,942	270.737	188.166	12.533	39.283	30.755	5.149	12.107	12.375	2.598
GENERAL PRACTICE	58.919	57.845	52.804	342	1.055	3.644	57	508	281	228
MEDICAL SPECIALTIES	71.886	62.592	42.449	3.045	9.780	7.318	1.734	2,277	4.914	369
A	1.706	1.496	1.380		57	59	24	23	157	6
CD	5.970	4.710	3.659		429	622	260	177	767	56
D	3.870	3.604	2.829		570	205	59	60	136	11
GE	1.916	1.454	1.070		203	181	104	44	308	6
IM	38.258	33.837	22.116	2.158	5.834	3.729	660	1.242	2.337	182
PD	17.098	15.217	10.181	887	2.419	1.730	443	543	814	81
PDA	372	323	263		41	19	8	5	35	1
PDC	456	295	159		51	85	53	12	95	1
PUD	2.240	1.656	792		176	668	123	171	265	25
SURGICAL SPECIALTIES	82.912	79.005	56.772	1.414	14.415	6.404	963	1.058	1.650	236
GS	28,603	27.247	17.612	1.263	5.843	2.539	312	423	537	84
NS	2,484	2.327	1.573		520	234	47	26	77	7
OBG	18.084	17.124	13.208	151	2.458	1.277	218	391	395	46
OPH	9.578	9.166	7.373		1.343	450	72	72	239	29
ORS	9.227	8.900	6.229		1.893	778	104	76	115	32
OTO	5.272	5.047	3.790		886	371	66	49	95	15
PS	1.503	1.441	1.094		250	97	21	12	25	4
CRS	666	647	607		25	15	2	5	8	4
TS	1.857	1.685	1.187		281	217	48	34	85	5
U	5,638	5.421	4.099		886	436	73	60	74	10
OTHER SPECIALTIES	89.249	71.295	36.141	7.732	14.033	13.389	2.395	8.264	5.530	1.765
AM	1.319	843	472		108	263	11	363	58	44
AN	10.434	9.743	7.106		1.497	1.140	361	130	179	21
CHP	1.898	1.521	985		276	260	101	154	107	15
DR	1.540	1.392	804		283	305	47	33	28	40
FOP	197	98	77		9	12	12	35	10	42
N	2.850	2.191	1.128		645	418	161	77	403	18
OM	2.746	2.037	1.938		24	75	7	551	45	106
P	20.328	17.510	9.862		3.506	4.142	395	1.643	667	113
PTH	9.826	7.438	2.862	203	2.124	2.249	439	507	814	628
PM	1.415	1.237	524		244	469	23	96	43	16
GPM	819	300	190		60	50	61	308	100	50
PH	3.075	816	516		115	185	90	1.853	176	140
R	10.041	9.375	5.529		2.159	1.687	192	130	134	210
TR	786	721	390		169	162	16	14	32	3
OTHER SPECIALTY	8.753	3.887	2.442		656	789	379	1.907	2.396	184
UNSPECIFIED	13.222	12.186	1.316	7.529	2.158	1.183	100	463	338	135
INACTIVE	19,895									
ADDRESS UNKNOWN	2,083									
EXCLUDES TEMP.FOREIGN	3,784									

* From AMA (Reference No. 5)

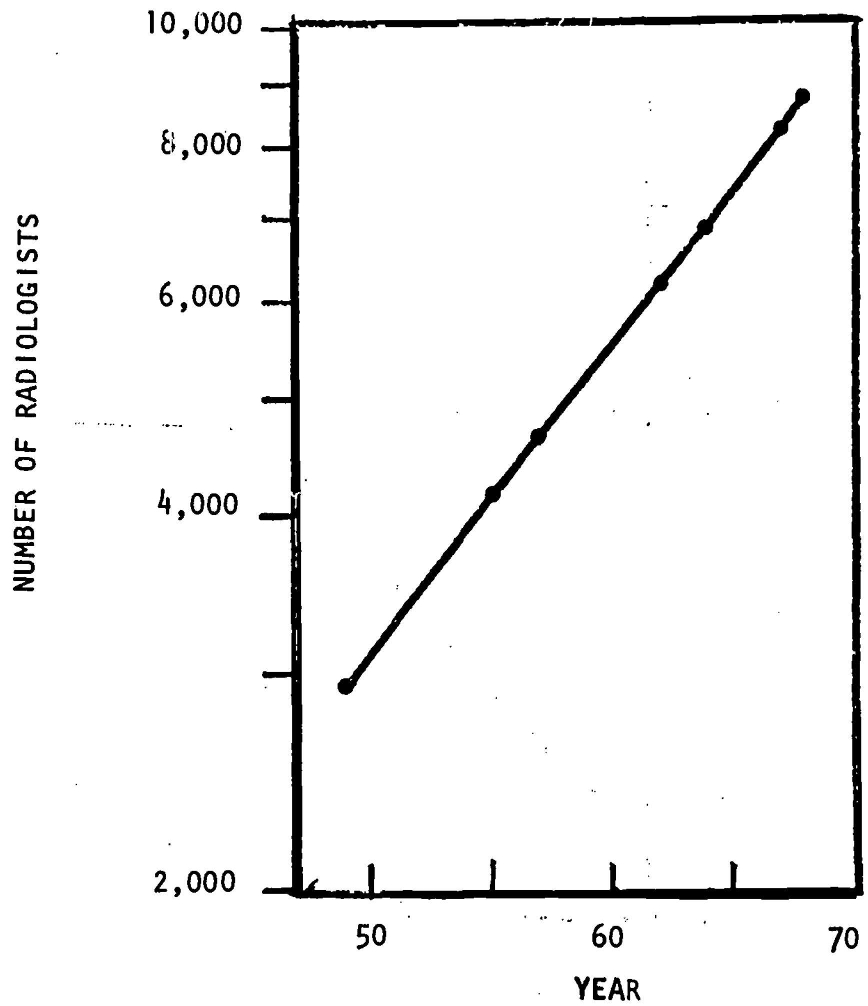

Figure 1. Number of clinical radiologists, exclusive of residents in training, in practice in the United States.

FROM MORGAN (reference 12)

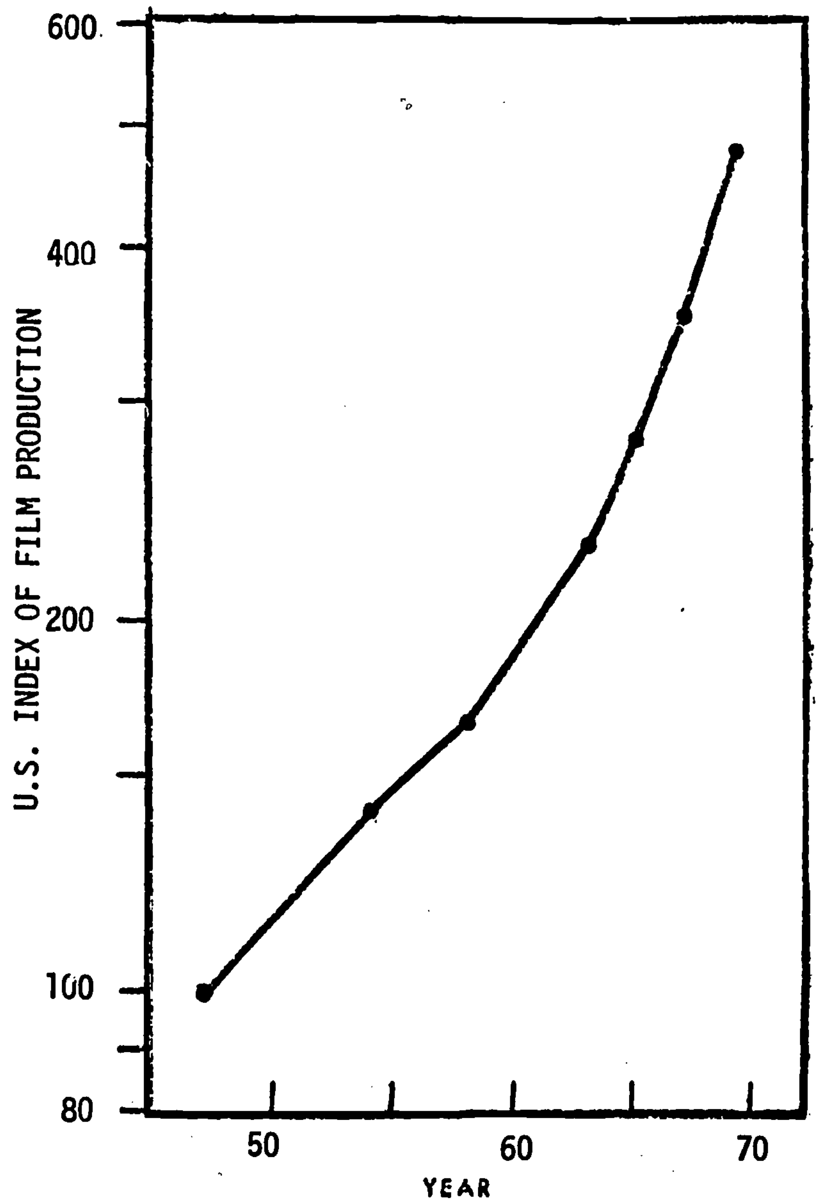

Figure 2. Index of consumption of medical X-ray film in the United States.

FROM MORGAN (Reference 12)

TABLE II

ESTIMATES OF PHYSICIAN MANPOWER NEEDS IN DIAGNOSTIC RADIOLOGY AND NUCLEAR MEDICINE IN U.S.

	---------Diagnostic Radiology---------			---------Nuclear Medicine---------		
Year	1 U.S. Population (millions)	2 No. of Medical X-ray Examinations (millions)	3 No. of radiologists required	4 No. of Procedures (millions)	5 No. of physicians required	Total No. of Physicians required
1964	189	115**	13,600	-	-	-
1966	-	-	-	2.7+	900	-
1968	-	-	-	3.6	1,200	-
1969	202	147	17,300	4.1	1,370	18,670
1970	203*	154	18,200	4.7	1,570	19,770
1975	215	197	20,200	9.5	3.170	23,370
1980	227	251	29,600	19.1	6,270	35,870

1) U.S. Census Bureau Figures excluding overseas military
* actual census

2) Number of Medical Diagnostic X-ray examinations, excluding dental X-rays.
** survey figure quoted in "Report of the Medical X-ray Advisory Committee on Public Health Considerations in Medical Diagnostic Radiology (X-rays)," October, 1967 USPHS Bureau of Disease Prevention and Environmental Control, National Center for Radiological Health.
Projections based on annual growth rate of 5%.

3) Calculation based on 10,000 regular diagnostic procedures per radiologist, 1,000 special procedures per radiologist, assuming 2% of all examinations are special procedures.

4) + Number of clinical nuclear medicine procedures (in vivo and in vitro) from Survey of Stanford Research Institute. Projections based on annual growth rate of 15%.

5) Calculations based on 3,000 procedures per full-time equivalent physician. 1968 estimate corresponds with Quinn's estimate.

Footnote: The above estimates are based on the assumptions that (1) all diagnostic procedures will be supervised by qualified diagnostic radiologists or nuclear medicine physicians, and (2) that the current annual increase in the number of radiological procedures nationally will continue at the same rate. The special needs of academic radiology departments are not considered in this table. The influence of extended insurance programs will undoubtedly increase the number of examinations while improved efficiency and elimination of unnecessary studies may partly counteract this trend. The manpower needs cannot be predicted with great accuracy; however, all projections indicate that good medical care will necessitate at least a doubling of the current number of radiologists within the next decade.

TABLE III

ABRAMS' TIME STUDY OF DIAGNOSTIC RADIOLOGICAL PROCEDURES, 1970

(PETER BENT BRIGHAM HOSPITAL)

Examination	% of Total Load	Average Time for Technical Procedure, in hours	% of Total Technical Manpower Time
Chest	40	.2	17.5
Skull	5	.5	5.5
Spine and pelvis	8	.4	7
Extremities	14	.3	9
Upper GI	6	.5	6.5
Colon	3	.7	4
Abdomen	7	.3	4
IVP	5	1.0	11
Special Procedures	8	2.0	35

TABLE IV

NIGMS RADIOLOGY TRAINING PROGRAM

Fiscal Year	No. of Active Grants	No. of Awards 1/	Council Recommended Amounts 2/		Funds Awarded		Funds Expended		Approx. No. Stipends	
			Total	Stipends	Total	Stipends	Total	Stipends	Pre	Post & Spec
1964-65	4	4	195,138	71,033	195,138	71,033	157,930	44,901	5	6
1965-66	4	4	243,189	76,600	214,776	214,776	175,215	40,817	2	6
1966-67	16	16	1,239,989	358,750	1,169,568	348,239	964,466	274,222	4	37
1967-68	20	18	1,401,381	539,300	1,492,813	647,400	1,118,134	457,466	3	55
1968-69	22	20	1,729,658	774,400	1,751,495	950,858	1,561,292	676,010	3	99
1969-70	23	18	1,840,894	947,300	1,541,836	872,975	1,431,740	678,804	1	94
1970-71	22	21	2,191,242	1,083,850	1,806,408	1,032,900			3	106
1971-72	23	22	2,356,799	1,285,673	1,853,298	1,129,525			3	115

1/ Figures do not include supplements

2/ Direct costs only

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