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ABSTRACT

This study describes the duties and responsibilities of the medical physicist and estimates the number of medical physicists needed in the next decade. A questionnaire, sent to members of the American Association of Physicists in Medicine, was designed to cover: characteristics of medical physicists, nature of work in medical physics, distribution of effort, publications, administration and supervision, training of medical physicists, budget for medical physics, and regional medical programs. Following a tabulation of questionnaire results, a discussion concerning duties and responsibilities, estimate of manpower needs, certification and accreditation, and emerging areas of specialization for medical physicists are included. Recommendations suggest: (1) At least one full-time professional medical physicist is needed in each medical institution with more than 300 hospital beds. (2) Graduate training programs in medical physics shall terminate in a master or doctoral degree. In addition, experience shall be provided in clinical applications of pertinent subspecialities of physics. (3) Since projected needs would require doubling the number of medical physicists over the next 10 years, sufficient support of graduate training programs is essential. (4) Training programs in medical physics should be accredited. (5) Certification procedures for medical physicists need to be studied. (6) Courses on medical physics should be made available to premedical and medical students, as well as to paramedical students enrolled in schools of allied health sciences. (MJM)

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STATUS and FUTURE MANPOWER NEEDS of PHYSICISTS in MEDICINE in the UNITED STATES

by
The Joint Committee on Manpower Needs in Medical Physics
of
The American College of Radiology
and
The American Association of Physicists in Medicine

under
Contract PH 86-67-202
for
Division of Radioactive Materials and Nuclear Medicine

NOVEMBER 1973

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
FOOD AND DRUG ADMINISTRATION
Bureau of Radiological Health
Rockville, Maryland 20852

FOREWORD

The Bureau of Radiological Health conducts a national program to limit man's exposure to ionizing and nonionizing radiations. To this end, the Bureau (1) develops criteria and recommends standards for safe limits of radiation exposure, (2) develops methods and techniques for controlling radiation exposure, (3) plans and conducts research to determine health effects of radiation exposure, (4) provides technical assistance to agencies responsible for radiological health control programs, and (5) conducts an electronic product radiation control program to protect the public health and safety.

The Bureau publishes its findings in appropriate scientific journals and technical report and note series prepared by Bureau divisions and offices.

Bureau publications provide an effective mechanism for disseminating results of intramural and contractor projects. The publications are distributed to State and local radiological health personnel, Bureau technical staff, Bureau advisory committee members, information services, industry, hospitals, laboratories, schools, the press, and other concerned individuals. These publications are for sale by the Government Printing Office and/or the National Technical Information Service.

Readers are encouraged to report errors or omissions to the Bureau. Your comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

This publication contains the final report of the American College of Radiology in cooperation with the American Association of Physicists in Medicine on the Status and Future Manpower Needs of Physicists in Medicine in the United States. The work for this publication was conducted as part of the continuing radiological health education project of the American College of Radiology and supported by the Bureau of Radiological Health through contract PH 86-67-202. The primary purpose of this study was to provide a basis for describing the job responsibilities of medical physicists in the radiological health sciences.

Included in the report is an estimate of the manpower needs for physicists and the influence of these needs or medical physics training programs. This estimate, based on the ratio of physicists to patient radiologic procedures at the responding institutions, reflects the present under-utilization of the profession. If the recommendation of the report (one medical physicist for each 300-bed hospital) is generally adopted, a doubling of this ratio may be considered conservative in terms of the rapid expansion in medical services but still within the currently available capacity for training medical physicists. However, the potential of staff physicists to increase quality of patient care, reduce radiation dosage, and increase efficiency of operation cannot be realized without the support of hospital administrators, chairmen of radiology departments, and licensing and accrediting agencies. Also needed are collaborative working relationships with radiologic technologists and radiologic engineers in both hospitals and industry.

This report is a continuation of supportive manpower activities in medical physics initiated by the Bureau of Radiological Health with publication of the 1965 "Research Report on the Training of Radiological Physicists," prepared by H. M. Parker. I hope this report will be useful in further promoting the role and training of physicists in medical radiation.

Mr. William C. Stronach (ACR), Mr. William K. Melton (ACR), Dr. Peter Almond (President, AAPM), and Dr. Robert D. Moseley (University of Chicago) deserve special thanks for their support and encouragement. Miss Linda Clark of LMC Consulting Company provided valuable advice on questionnaire layout and workup of computer data. Dr. William Van de Riet, Postdoctoral Fellow in Radiation Physics at the University of Cincinnati, provided valuable aid in data analysis and graphic presentation. The efforts of all AAPM members and Regional Medical Program Directors who completed the questionnaires are appreciated.

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1. INTRODUCTION

In 1969 the American Association of Physicists in Medicine (AAPM) and the American College of Radiology (ACR) formed the Joint Committee on Manpower Needs in Medical Physics. The purposes of the Committee were to conduct an in-depth study of the present status of medical physicists, to develop information from which meaningful predictions on future needs of physicists in medicine might be derived, and to make recommendations to appropriate groups and governmental bodies.

The initial goals of this study are to describe the duties and responsibilities of the medical physicist, in this case primarily his work in various fields of radiological sciences. From these data one can determine his responsibilities and contributions to the needs of patients and then can determine the future needs of medical physicists. This survey will help to estimate whether more medical physicists are needed and if so, how many additional training programs are necessary, and in what particular areas in medical physics are the needs greatest.

Another goal of this study is to make a reasonable and conservative estimate of the number of medical physicists needed in the next decade. In making such an estimate a balance must be reached between the rapid growth of medical sciences (especially those relating to radiology) and improved techniques of communication (especially computers) that permit a more efficient use of physicists. In the next several years there will be strong trends toward economy of operation to reduce the cost of medical care.

1.1 DEFINITION OF MEDICAL PHYSICS

The term medical physics is not always interpreted consistently. Medical physics is defined as all applications of physics to any aspect of medicine. For the purposes of this study, medical physics includes the work physicists perform in the following well established areas of medicine: therapeutic radiology, diagnostic radiology, nuclear medicine, radiobiology, hospital health physics (radiation protection), and in the emerging fields of physiologic monitoring of patients, ultrasound, lasers, ophthalmology, thermography, information theory, and biomedical engineering.

See the Glossary of Terms in appendix A for an explanation of other related branches of physics.

1.2 METHODS OF STUDY

The study has proceeded along two lines. The principal line involves a questionnaire sent to each member of the American Association of Physicists in Medicine. Most of the data presented are derived from the information supplied by this questionnaire. Some 500 questionnaires were mailed out. The response was approximately 75 to 80 percent. In addition to this questionnaire, several physicists and radiologists have made informal site visits to establish in the minds of the committee the existing activities in this field.

In addition, a questionnaire was sent to the Directors of the Regional Medical Programs for Heart Disease, Cancer, Stroke, and Related Disease.

2. RESULTS

2.1 CHARACTERISTICS OF A MEDICAL PHYSICIST ACCORDING TO SURVEY

The median age of physicists is 40.5 years and about 75 percent of them are between 30 and 49 years of age (figure 1).

The ratio of men to women is 12 to 1, 75 percent hold at least a master's degree, while the remainder hold a bachelor's degree; 45 percent have either a Sc.D. or a Ph.D.; only 1.7 percent have an M.D.

Among bachelor's degrees, the major academic fields are as follows: physics - 68 percent; mathematics - 13 percent; engineering - 13 percent; and chemistry - 11 percent. The minor fields were: mathematics - 53 percent; chemistry-15 percent; and physics - 14 percent. Eighty-six percent of the physicists received a bachelor's degree from some institution within the United States.

Among physicists having higher degrees than the bachelor's, many have more than one such degree (table 1).

2.1.1 Certification

Twenty-seven percent are certified by the American Board of Radiology (ABR), 32 percent plan to obtain certification from this Board and 41 percent do not (152 individuals). Of these, 109 people work in a hospital in either radiotherapy or nuclear medicine. These two fields are the ones specifically covered by the American Board of Radiology certification program for physicists.

Twenty-two percent are certified by the American Board of Health Physics (ABHP), and another 22 percent plan to obtain such certification. The remaining 56 percent do not plan to seek ABHP certification.

Four percent are certified by other boards and 2 percent plan to obtain certification from such other boards.

2.1.2 Experience within the Field of Medical Physics

The median professional experience is 12.5 years; 34 percent have less than 9 years; 36 percent from 10 to 19 years; 23 percent from 20 to 25 years and 6 percent over 26 years. This experience distribution follows the age distribution quite closely. As indicated in figure 2, most practicing medical physicists have 20 years experience or less. This increase is the result of a number of

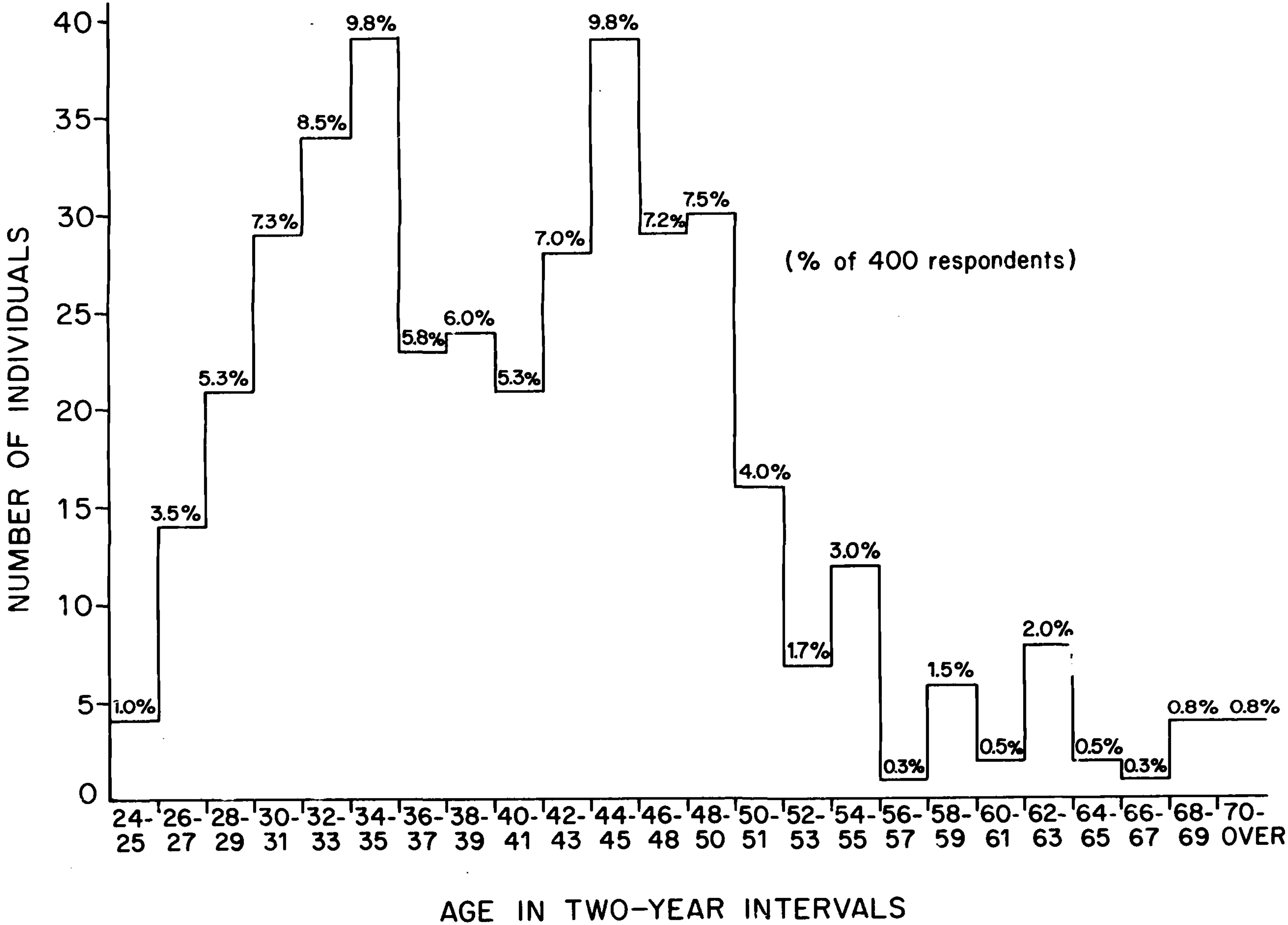

Figure 1. Distr..oution of medical physicists by age

Table 1. Distribution of medical physicists by advanced degrees

Academic field	Percent of medical physicists	
	Major	Minor
Physics	38.6	12.9
Medical Radiation Physics	19.2	17.8
Health Physics (Radiological Health)	11.8	10.2
Biophysics	10.1	6.5
Engineering	8.5	4.5
Mathematics	2.5	35.6
Chemistry	2.2	4.5
Other	7.1	8.0
Total	100.0	100.0

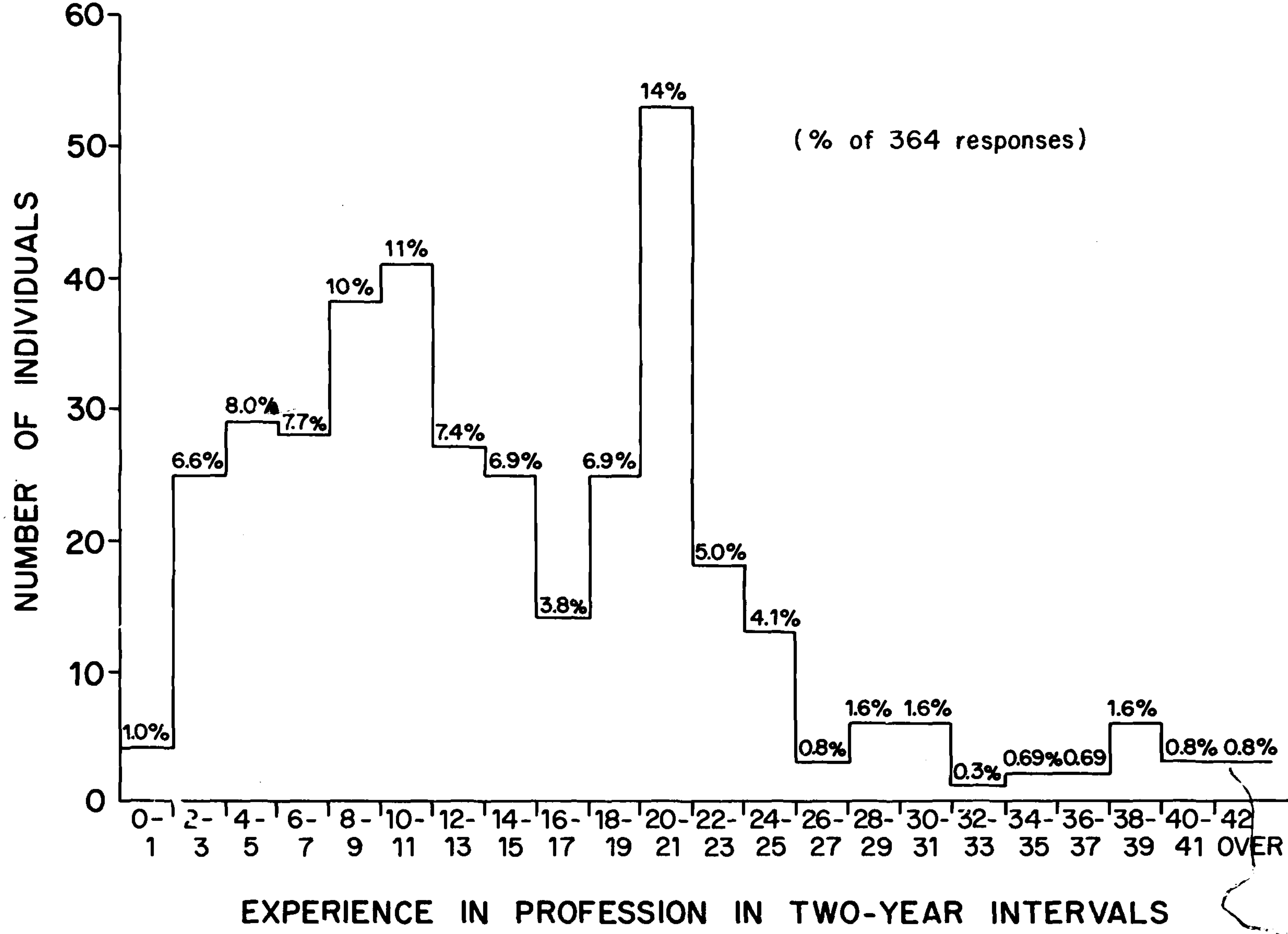

Figure 2. Distribution of medical physicists by professional experience

factors: 1) development and use in recent years of high energy accelerators for radiotherapy, 2) development of the nuclear reactor for the production of a broad spectrum of medically useful isotopes, 3) general increased concern about the potential hazards of radiation, 4) concern by physicians for better patient care, and 5) the development of training support by BRH, NIH, and AEC, some of which has as of 1971, been terminated.

2.2 NATURE OF WORK IN MEDICAL PHYSICS

Information on the major field in which most physicists work is given in table 2: 56 percent work in medical radiation physics, 18 percent in health physics, and the remainder are scattered through other scientific fields.

Information on the type of institution in which physicists work is presented in table 3: 31 percent of those replying to this question devote 91 to 100 percent of their professional efforts in hospitals associated with university medical schools. This group represents 63 percent of those who have a definite association with a hospital of a university medical school.

Half of the respondents to the questionnaire hold faculty appointments. Of this group, 47 percent are either associate or full professors.

Table 4 indicates that within an institution, 46 percent have their primary appointment in radiology, 11 percent are in departments of physics, 13 percent are in departments of medical physics, 7 percent in nuclear medicine and the remainder in such fields as biophysics, medicine, chemistry, public health, nuclear engineering, and biomedical engineering.

Of the 400 responding, 49 (or 12 percent) are employed by various branches of government. Within this group, 25 percent are with the Public Health Service, 12 percent with the United States Army, 10 percent with the United States Air Force and the remainder are with the National Bureau of Standards, United States Navy, and Atomic Energy Commission; 36 percent of this group also work for other agencies, presumably in State and local, county or municipal organizations.

2.3 DISTRIBUTION OF EFFORT

The survey shows that of the major divisions in radiology the principal effort is spent in therapeutic radiology, with the remainder divided about equally between nuclear medicine and diagnostic radiology.

Table 2. Distribution of medical physicists by major field of work

Major field	Percent of medical physicists
Medical Radiation Physics	55.5
Health Physics	18.0
Physics	8.9
Biophysics	8.4
Engineering	3.6
Mathematics	1.8
Chemistry	0.5
Other	3.2
Total	99.9

Table 3. Distribution of effort of medical physicists by type of employment (based on 400 responses)

Type of employment	Distribution of professional effort (percent)*										
	0 or no answer	1-10 per-cent	11-20 per-cent	21-30 per-cent	31-40 per-cent	41-50 per-cent	51-60 per-cent	61-70 per-cent	71-80 per-cent	81-90 per-cent	91-100 per-cent
University medical school hospitals	51.3	1.5	3.5	1.76	1.76	2.76	1.0	0.8	1.76	3.0	30.9
Medical school hospitals (not university)	95.0	3.3	.3	.5	.3	0	0	0	.3	0	.5
Primarily government supported hospitals	83.7	4.5	1.3	.25	0	1.51	1.0	.25	1.0	.75	5.8
Primarily government supported research	83.9	2.5	.5	.5	0	.75	.5	.5	1.0	.5	9.5
Private research laboratories	91.7	2.5	1.0	.25	.50	0	.50	.25	0	0	3.3
Federal, State or local health agencies	91.6	4.5	.5	.25	.75	0	.50	.25	.25	.75	1.8
Group private clinics	94.2	3.8	0	.75	.25	0	0	.25	0	.25	.5
Private consulting	86.9	7.3	3.3	0	.25	.25	.25	0	.25	.50	1.0
Private hospital	78.9	4.3	2.3	1.51	.25	1.0	.50	.75	.50	2.51	7.8
Other	66.2	7.3	4.5	1.7	.50	2.5	1.0	2.0	1.85	1.75	11.3

*Tabular entries are percentage of persons who spend the percentage of their effort shown in the column heading.

Table 4. Distribution of medical physicists by principal appointment in various departments (based on 324 responses)

Department	Responses (percent)
Radiology	46.3
Physics	10.8
Biophysics	3.1
Medicine	1.5
Medical Physics	13.0
Radiation Technology	1.9
Nuclear Medicine	7.1
Chemistry	0.3
Public Health	1.9
Nuclear Engineering	1.2
Biomedical Engineering	0.6
Obstetrics and Gynecology	0.0
Other	12.3
Total	100.0

Most of the work is related to patient service. In therapeutic radiology the service is often the determination of dose distributions for treatment planning. The second major effort is devoted to teaching medical physics to residents, medical students, graduate students, and technologists. The least amount of time is spent in research (tables 5A, 5B, and 5C).

Medical physicists have the following teaching responsibilities: 20.5 percent (361 respondents) teach medical students, 32.4 percent (364 respondents) teach graduate students, and 63.2 percent of the medical physicists (373 respondents) teach medical residents (including radiology residents). The majority of medical students are not exposed to medical physics. The average number of residents in general or mixed radiology taught per year is 13.2 residents per physicist.

An interesting fact is that the ratio of research to service increases as the number of physicists reaches three or four persons in a given department (figure 3).

The sharp increase in research opportunities and decrease in service needs occurs for departments with more than two physicists, based on full-time equivalents (FTE). These departments with more than two physicists do provide opportunity for intellectual research growth.

2.4 PUBLICATIONS

The number and types of publications of medical physicists indicate the importance of their work and the opportunities offered them to engage in creative scientific efforts. Of the 400 member respondents to the questionnaire who also hold a Ph.D., 43 percent indicated that they were principal authors of 344 scientific papers in 1967 (average of 2.0 papers per author). In the same year, 34 percent of those replying were associate authors of 234 scientific papers (average of 1.7 papers per author). In 1968, 42 percent of those replying were the principal authors of 359 scientific papers (average of 2.2 papers per author) and 34 percent were associate authors of 277 scientific papers (average of 2.0 papers per author). In 1969, 44 percent of those replying were the principal authors of 366 scientific papers (average 2.1 papers per author) and 40 percent were associate authors of 281 scientific papers (average of 1.8 papers per author); 16 percent of those replying to the questionnaire have written 106 books, 6 percent have been editors of 35 books and 26 percent of those replying have written 323 chapters of books.

The gradual and steady growth of scientific publications indicates the importance of this field. With a reasonable increase in the number of medical physicists the scientific output of the group will increase (figure 3).

Table 5A. Distribution of effort of medical physicists in therapeutic radiology

Percent of effort	Distribution of physicists in therapeutic radiology (253 responses)* (percent)	Distribution of physicists by task* (percent)		
		Service (206 responses)	Training (204 responses)	Research (170 responses)
0 - 9	10	4	10	21
10 - 19	13	3	13	22
20 - 29	14	9	28	25
30 - 39	11	6	14	10
40 - 49	13	11	11	9
50 - 59	11	23	15	9
60 - 69	10	16	2	1
70 - 79	7	11	4	1
80 - 89	7	11	2	1
90 - 99	4	6	1	1
Totals	100	100	100	100

*The tabular entries in the last four columns are percentages of the total number of persons responding who spend the indicated percent of their effort, per task, as given in column 1.

Table 5B. Distribution of effort of medical physicists in diagnostic radiology

Percent of effort	Distribution of physicists in diagnostic radiology (213 responses)* (percent)	Distribution of physicists by task* (percent)		
		Service (139 responses)	Training (149 responses)	Research (97 responses)
0 - 9	31	10	4	28
10 - 19	32	10	5	20
20 - 29	21	26	12	16
30 - 39	9	8	9	9
40 - 49	2	5	9	4
50 - 59	2	25	26	14
60 - 69	1	1	9	3
70 - 79	1	7	10	3
80 - 89	1	5	12	2
90 - 99	0	3	4	1
Totals	100	100	100	100

*The tabular entries in the last four columns are percentages of the total number of persons responding who spend the indicated percent of their effort, per task, as given in column 1.

Table 5C. Distribution of effort of medical physicists in nuclear medicine

Percent of effort	Distribution of physicists in nuclear medicine (225 responses) (percent)	Distribution of physicists by task* (percent)		
		Service (158 responses)	Training (170 responses)	Research (129 responses)
0 - 9	21	7	5	20
10 - 19	36	10	11	15
20 - 29	18	19	25	16
30 - 39	6	4	12	13
40 - 49	8	10	10	8
50 - 59	3	25	18	14
60 - 69	1	6	5	6
70 - 79	5	9	5	4
80 - 89	0	7	7	2
90 - 99	2	3	2	2
Totals	100	100	100	100

*The tabular entries in the last four columns are percentages of the total number of persons responding who spend the indicated percent of their effort, per task, as given in column 1.

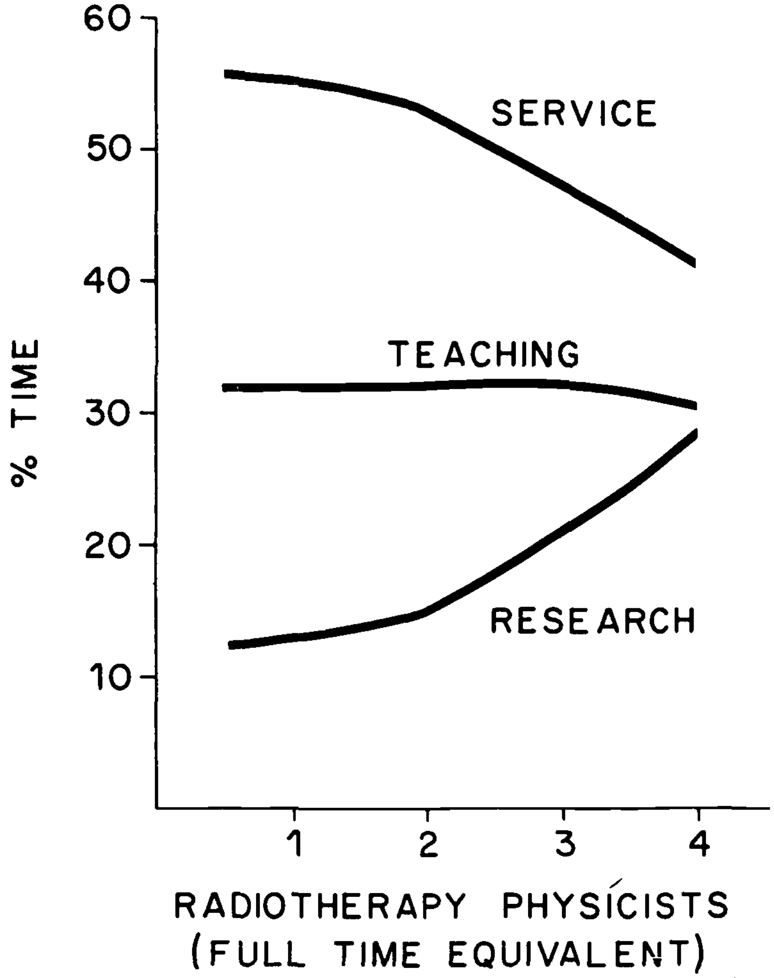

Figure 3. Percentage of time spent on research, teaching, and service vs. number of physicists in department

2.5 ADMINISTRATION AND SUPERVISION

Another indicator of the importance of a scientific field is the number of individuals supervised by the scientific group leader. Table 6 indicates that among medical physicists, 48 percent have sole (31 percent) or shared (17 percent) supervision of other physicists. Other personnel supervised by medical physicists include health physics technicians, 28.7 percent under either sole or shared supervision; and electronics technicians, 26.8 percent under either sole or shared supervision.

2.6 TRAINING OF MEDICAL PHYSICISTS

The Joint Committee did not attempt to study the curricula of the various undergraduate physics departments. Most medical physicists have had undergraduate majors in physics and mathematics with minors in mathematics (See section 2.1) suggesting that undergraduate preparation usually encountered is adequate.

Of the bachelors degrees, 86 percent were received in the United States. Private schools were favored slightly over city, State, and Federal colleges or universities. A majority, 52 percent of our members, attended schools where the undergraduate population was 2,500 or larger. This is understandable since the faculty of a larger school is usually more diversified, thus encompassing more areas of expertise.

Information was also obtained on the major and minor fields of study for advanced degrees (master's or doctorate) of AAPM membership (table 1). This diversity of major fields for advanced degrees may indicate the diversity of opinions on an appropriate graduate curriculum for medical physicists. One institution may consider that the medical physicist should have a strong major in conventional physics and present a thesis in straight physics or on some aspect of medical physics. Another institution may prefer that the graduate curriculum de-emphasize "pure" physics and include courses in biological and medical fields. No attempt is made here to resolve these two views, but one should realize that these differences in outlook do exist.

Graduate training programs are listed by the AAPM,* giving information on institutions where training is available for master's or doctor's degrees in the following categories: Medical radiologic physics, including radiologic health; general medical physics; and biophysics, including radiobiology. The September 1968 and December 1969 Quarterly Bulletins of the AAPM also give detailed information on several programs.

*Listing available from: Administrative Secretary, AAPM, The American Institute of Physics, 335 East 45th Street, New York, New York 10017.

Table 6. Distribution of medical physicists by types of personnel supervised (based on 400 respondents)

Types of personnel	Percent of medical physicists*	
	Sole supervision	Shared supervision
Other physicists	31.0	17.0
Radiation therapy technicians	4.0	23.5
Health physics technicians	17.2	11.5
Electronics technicians	10.8	16.0
Dosimetrists	6.5	8.2
Computer programmers	6.0	6.0
Machinists	7.3	12.5
Other personnel	27.5	22.7

*The sum of each of the two columns exceeds 100 percent because of the multiple administrative responsibilities of the supervisory physicists.

In appendix B of this report training programs are listed by length of study, degrees offered, and for professional certification by the American Board of Radiology and for postdoctoral training. The departments listed as giving training in medical physics are not necessarily the departments awarding the degree.

2.7 BUDGET FOR MEDICAL PHYSICS

Two areas of inquiry concerning the budget in medical physics were explored. One was the degree of participation in the negotiation process of budget proposals and the other was the source of income for the physicist himself.

Among 396 persons who responded to the question of negotiating on budget proposals for their department or division, 65 percent stated that they do participate in the negotiation process. Of those, 131 negotiate with their department chairman, 52 with the hospital administration, only 10 with the dean, and 53 with persons other than those listed.

Of those replying, financial support for medical physicists comes from institutional and hospital funds in 80 percent and from grants and contracts in 20 percent.

2.8 REGIONAL MEDICAL PROGRAMS

On October 6, 1965, Public Law 89-239 was established authorizing some 55 Regional Medical Programs (RMP). The purpose of this Act and of the programs and operational projects established under it is to assist the nation's health resources in making available to all persons the best possible care for heart disease, cancer, stroke, and related disease.

The initiative and decision to carry out a program comes from each local community and from its health leaders, rather than from Federal or RMP direction. The activities are carried out with and among existing institutional and personnel resources. The objective of the program is not to create another mechanism for funding individual intramural projects; rather, it seeks through operational projects based on regional cooperative arrangements, to bring the benefits of scientific advances in medicine to people wherever they live within a given region.

One valuable regional activity is that of medical physics. A number of important programs especially in therapeutic dose planning have been funded.

Table 7 shows responses to the questionnaire by regional and, where they exist, sectional offices. No assumption was made that just because a response was not received, a region does not now have nor

Table 7. Survey data from regional medical programs

(1)	Number of inquiries sent to regions and sections	70
(2)	Number of responses from regions and sections	56
(3)	Number of regions	55
(4)	Number of regions that responded	45
(5)	Number of regions without grants (none awarded, none pending, and none anticipated within 5 years)	24

anticipate having a medical physics program. Thus item (5) includes only the number of negative responses. (For example, a response was not received from Texas although Texas does have a program generally believed one of the most outstanding in the country.)*

The number of grants involving medical physics actually funded as of October 1969 included 1 planning grant and 14 operational grants. In addition, there were 11 pending grants, all of them of the operational type. Sixteen replies stated that grant requests involving the employment of medical physicists were anticipated some time during the next 5 years.

The various categories of activity of medical physicists working or pending under Regional Medical Program grants are shown in table 8. By and large, the present use and future demand for physicists is greatest in the category of therapeutic radiology. A given position does not necessarily mean that the funding or the work requires a full time physicist. For the present, the number of funded positions is short by only three persons. The pending and anticipated positions for employment is 18.

The total number of physicists in all categories presently funded is 20, with 14 of the posts filled. The total pending or anticipated posts is 23. Closely allied with the physicist in therapeutic radiology is the dosimetrist. Here we see an indication of a shortage with only five positions filled of ten funded. One respondent stated categorically that a shortage does exist. A few computer programmers are needed and the need has been essentially filled.

The duration of the funded programs is mainly for a period of 3 to 4 years. Of 25 replies only one indicated that a program was being funded for less than three and only four for more than 5 years. On the other hand, many grants can be extended. Of 24 replies on the question of whether the program is to be made self-supporting, 21 were affirmative.

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*R. J. Shalek, "Cooperative Programs in Medical Physics," Second International Conference on Medical Physics, Boston, Mass., August 11-15, 1969. The University of Texas, M. D. Anderson Hospital and Tumor Institute, Houston, Texas.

Table 8. Distribution of activities and positions in medical physics available in regional medical programs, 1969

Positions	Number of positions funded	Number of positions filled	Number of positions pending or anticipated
<u>Medical physics</u>			
Physicists in therapeutic radiology	12	9	18
Physicists in nuclear medicine	1	1	2
Physicists in diagnostic radiology	2	2	0
Health physicists	1	1	1
Physicists and/or biomedical engineers	3	1	2
Other physicists	1	0	0
Totals	20	14	23
<u>Allied fields</u>			
Computer programmers in therapeutic radiology	3	2	4
Dosimetrists in therapeutic radiology	10	5	5
Totals	13	7	9

3. DISCUSSION

3.1 DUTIES AND RESPONSIBILITIES

Most medical physicists providing physics services for hospitals are members of one of the clinical departments, usually Radiology or Radiation Therapy and/or Nuclear Medicine. Smaller hospitals (less than 300 beds) usually obtain physics services from outside consultants Intermediate size hospitals, depending upon the Radiology or Radiation Therapy and Nuclear Medicine work load may employ only one physicist. In large university affiliated hospitals a number of physicists may work together as a team often comprising an administrative division of the Radiology Department. In a few medical centers employing a large staff of physicists and physics technicians, separate departments of medical physics exist. The larger clinical teaching centers which can afford the administrative arrangement whereby a number of medical physicists work together as a team can more readily establish training centers for future medical physicists.

The work and activities of the medical physicist stem from the nature of medical physics itself. The latter can be described as an applied branch of physics, concerning itself with the use of the methods and mode of thinking of the physicist as applied to the problem of diagnosing and treating human disease. Some areas of specialization for the medical physicist have gained visibility. These include the use of ionizing radiation in diagnosis, therapy and nuclear medicine (radiological physics); the medical use of ultrasound and infrared; and bioelectrical investigations of the brain and heart.

The medical physicist usually finds his time about equally divided in three areas of work: consultation with physicians, teaching, and research. In working with physicians the medical physicist is a member of a team concerned with patient problems or with the use of equipment for diagnosing or treating patients. For the radiological physicist the consultation may relate to radiation therapy treatments, procedures in nuclear medicine, or the problem of information retrieval in diagnostic radiology. Medical physicists have prime responsibility for teaching basic science to residents and medical students and for creating graduate degree programs for training other medical physicists. Another and more recent teaching responsibility is to train physicians for academic careers by providing a strong basic science program, usually at the M.S. level. The research role of the medical physicist is much like that of investigators in the traditional sciences, with the added proviso that he (the medical physicist) is working in inter-disciplinary areas. Thus a broad range of problem areas is encompassed including work in cancer, heart disease, and mental illness. Medical physicists use the general techniques available to all researchers including computers and information theory. Medical physicists publish in many journals depending on the scientific specialty involved but typical examples of various research areas may be found in a journal dedicated to this field entitled "Physics in Medicine and Biology." This journal is jointly sponsored by the American Association of Physicists in Medicine, The British Hospital Physicists Association, the Medical and Biological Physics Division of the Canadian Association of Physicists, and the International Organization of Medical Physics.

The specific responsibilities that medical physicists have vary considerably depending upon the institution and administrative arrangements. Most of the responsibilities that a medical physicist can be expected to assume are included in the following outline and illustrated by the flow diagrams following each radiological specialty.

3.1.1 Medical Physics Services

Radiation Therapy (figure 4)

1. Periodic calibration of all radiation therapy equipment.
2. Determination of the radiation dosimetry characteristics for the various types and energies of radiation used (superficial and medium energy x-ray machines, cobalt-60 teletherapy units, high energy accelerators such as linear accelerators, Van-de-Graaff units, and betatrons).
3. The assay, calibration and leak testing of brachytherapy sources (radium needles and capsules, radioactive gold seeds, radioactive iridium and tantalum wires, cesium-137 sources, and californium-252 sources).
4. The calculation of radiation dose distributions in patients undergoing treatment, often with the aid of computerized dosimetry programs. Monitoring or measuring the dose delivered to the patient at selected sites.
5. The calibration, intercomparison, and maintenance of radiation dosimetry systems (ionization chambers, electrometers, thermoluminescent dosimetry systems, chemical dosimetry systems).
6. The design of radiation therapy installations and the calculation of shielding specifications.
7. The design and construction of special devices used in conjunction with radiation therapy.

Nuclear Medicine (figure 5)

1. The calibration of radioisotope assaying equipment.
2. The assay of radioisotopes administered to patients.
3. The intercomparison and maintenance of radioisotope assay or counting standards.
4. Testing the reliability and monitoring the reproducibility of radioisotope counting equipment.
5. Determining the performance characteristics of patient radioisotope scanning and imaging equipment.
6. Helping to evaluate the efficacy of nuclear medicine procedures.

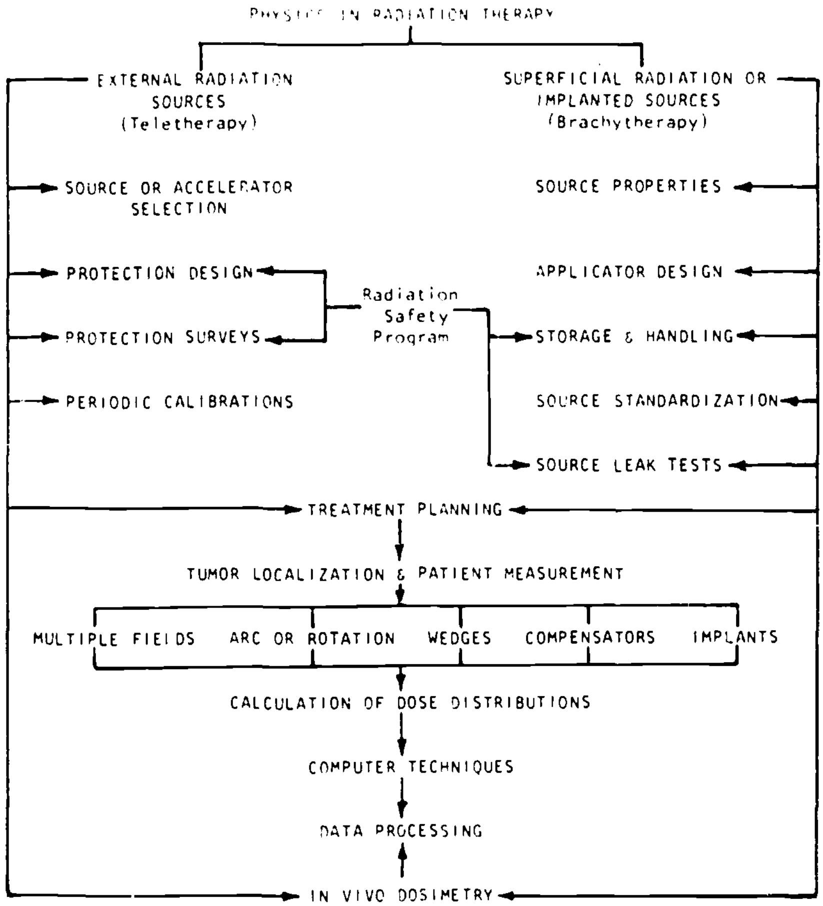

Figure 4. Medical physics services in radiation therapy

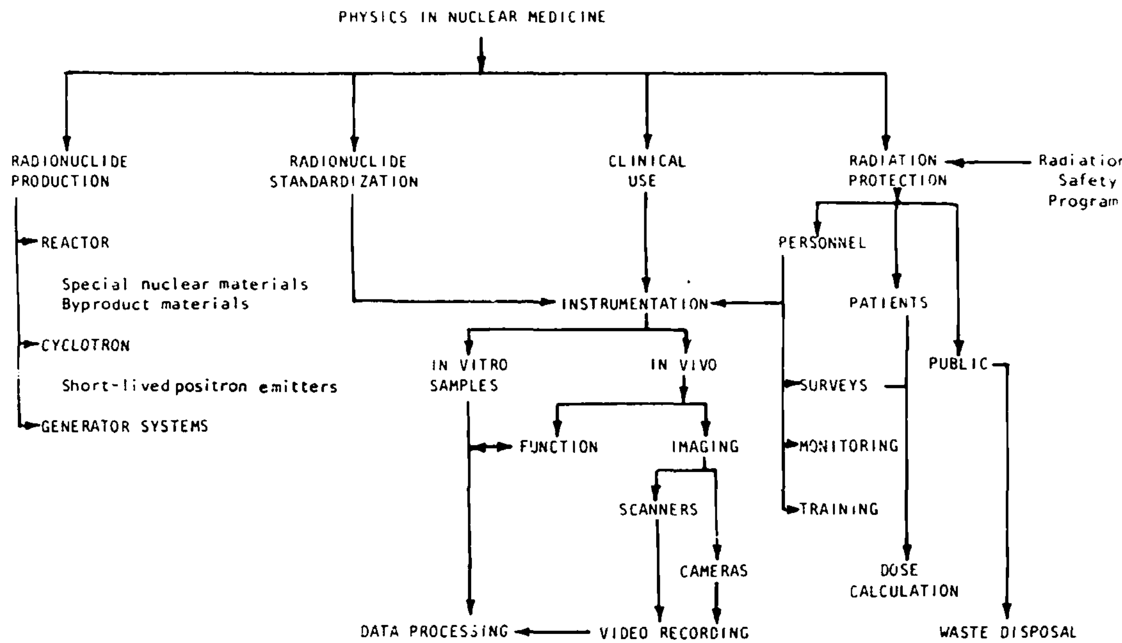

Figure 5. Medical physics services in nuclear medicine

Diagnostic Radiology (figure 6)

1. The calibration of x-ray equipment used for diagnostic purposes.
2. Evaluating the performance of new diagnostic equipment and the parameters that determine the diagnostic quality of the imaging system of special purpose equipment (mammography, image intensifying fluoroscopy, tomographic equipment, etc.)
3. Providing physics and engineering services in connection with newer diagnostic procedures and equipment such as isotope scanning devices for bone mineral determination, thermography equipment, and ultrasonic equipment.
4. Technical assistance in the evaluation of the efficacy of the various diagnostic procedures, and dose reduction to the patient.
5. The design of diagnostic x-ray facilities and the calculation of shielding specifications.

Radiation Safety Services (figure 7)

1. Radiation safety surveys of all radiation facilities in radiology, radiation therapy, nuclear medicine, and other departments.
2. Radiation monitoring of hospital personnel with appropriate radiation dosimeters. Maintenance of personnel monitoring records.
3. Leak testing of all sealed radioisotope sources.
4. Maintaining records of the receipt, inventory, transfer, and disposal of all radioactive materials.
5. Establishing and monitoring radiation safety procedures and techniques to assure proper quality control.
6. Evaluating all license applications for the use of radioactive materials for the Institutional Radioisotope Committee.
7. Establishment of safe procedures and hazard control in the use of lasers, microwaves, and other potentially hazardous radiations.

3.1.2 Medical Physics Teaching Activities (including formal and informal lectures, review sessions, laboratory sessions). These activities include teaching:

1. Medical students.
2. Nurses.
3. Student radiologic technologists and nuclear medicine technicians and technologists.
4. Residents, particularly in radiology, radiation therapy and nuclear medicine.
5. Graduate students in the basic medical sciences.
6. Graduate students and trainees in medical physics.

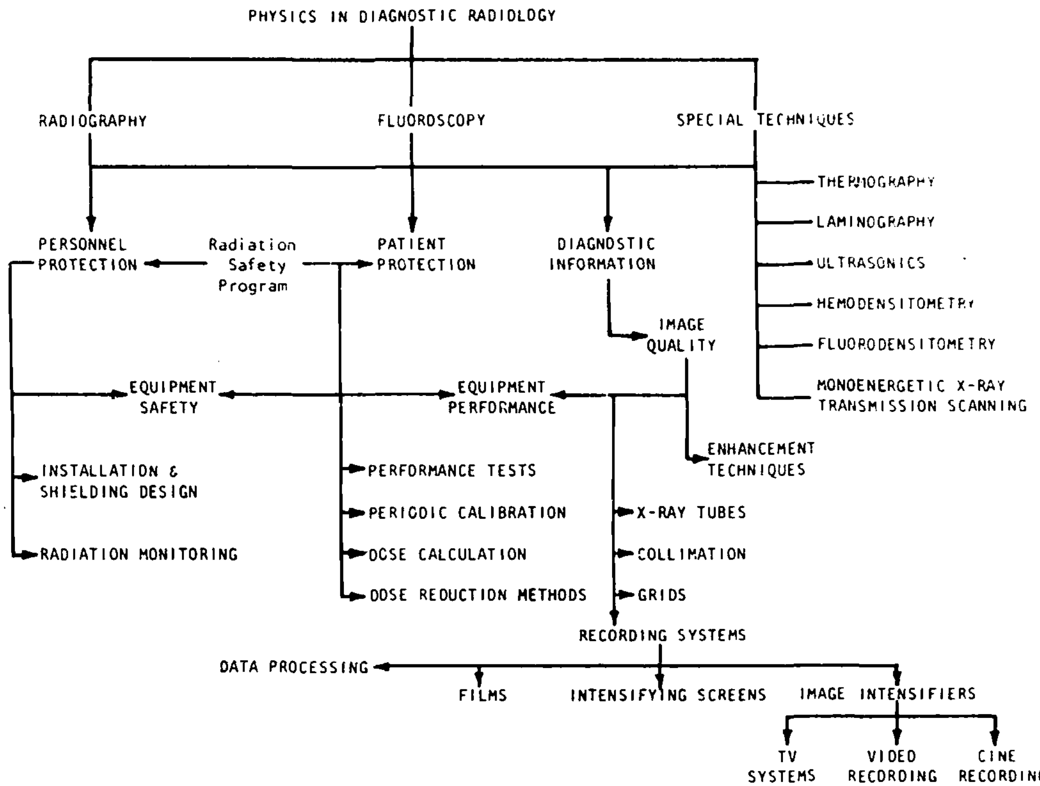

Figure 6. Medical physics services in diagnostic radiology

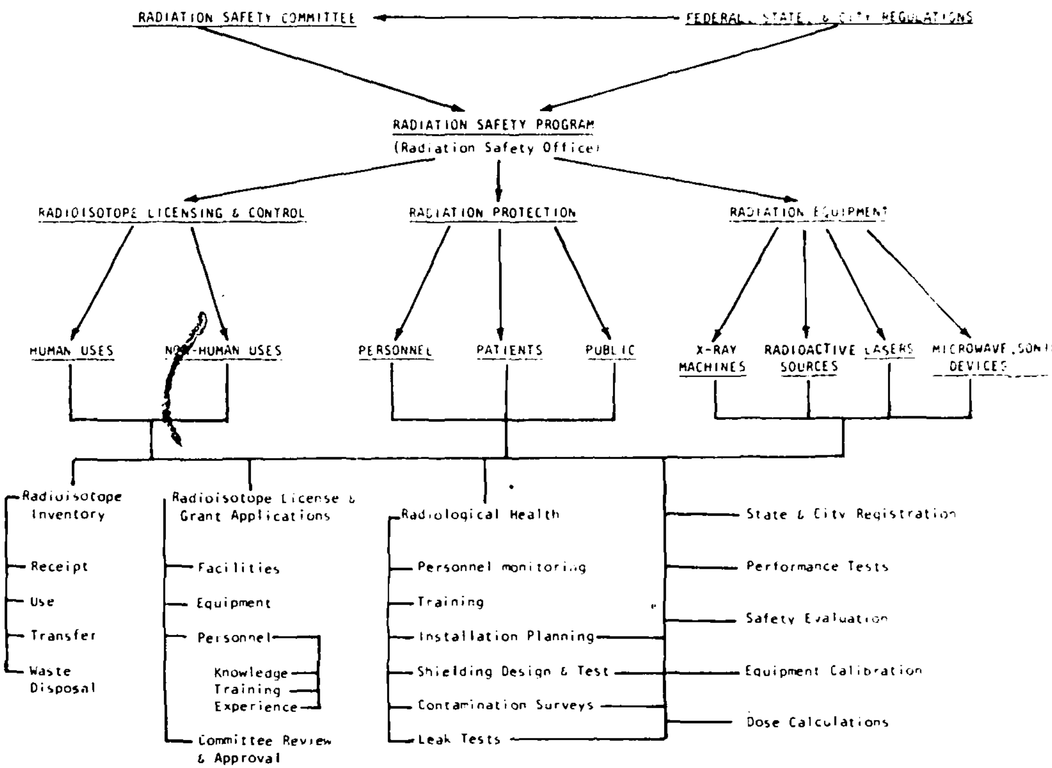

Figure 7. Medical physics services in radiation safety

3.1.3 Research and Development Activities in Medical Physics

Because of the multidisciplinary nature of medical physics, much of the research and development is a cooperative effort with medical specialists, biologists and radiobiologists, engineers, physiologists, biochemists, and other physicists. Among the broad areas of investigation are the following:

1. Development of dosimetry techniques for applications in clinical medicine, radiation biology, and radiation protection.
2. Development of new equipment and techniques for the early diagnosis and therapy of cancer, heart disease, etc.
3. Investigations in the biological effects of radiation (ionizing, microwaves, coherent light, ultrasound).
4. The application of physical techniques (e.g. electron spin resonance and nuclear magnetic resonance) in cancer research.
5. Development of methods for automating diagnostic and therapeutic procedures and information retrieval.
6. Development of methods for dose reduction from roentgenologic and nuclear medicine procedures.

3.2 ESTIMATES OF MANPOWER NEEDS OF MEDICAL PHYSICISTS

A relatively accurate estimate of the needs in medical physics for the decade 1970-1980 would be a useful figure. Calculations deriving such a number from several independent approaches are given in appendix E. Requirements derived separately from diagnostic radiology, nuclear medicine, and therapeutic radiology and adjusted by the number of hospital beds gave remarkably similar estimates of 877-1240 physicists needed using both median and mean values. Hence the committee estimates that 1,000 medical physicists will be needed by the end of this decade, about double the number currently working. The growth rate on this basis will be about 7 percent per year. These estimates will permit an orderly and reasonable development rate that is economically justifiable.

3.3 CERTIFICATION AND ACCREDITATION

Several decades ago, a number of radiologists and physicists believed that examination, certification and registry of radiologic physicists working in radiology was an important goal and the American Board of Radiology (ABR) was the logical organization to undertake the responsibility. Thus, the ABR was requested in June 1947 to undertake a program of certification. The first examination in radiologic physics was conducted in June 1949.

The current stated purposes of the ABR certification program are:

1. To elevate the standards and advance the cause of radiologic physics by encouraging its study and improving its practice.
2. To determine the competence of specialists in radiologic physics and to arrange, control and conduct investigations and examinations to test the qualifications of voluntary candidates for certifications to be issued by the Board.
3. To grant and issue certificates in the field of radiologic physics to voluntary applicants and to maintain a registry of holders of such certificates; and
4. To serve the public, physicians, hospitals, and medical schools by preparing and furnishing lists of physicists who shall have been certified by the Board.

The certificate itself indicates that its holder has completed certain requirements of study and training that the Board considers the minimum for an adequate foundation in the field, and has passed certain examinations designed to test his competence in the field of radiologic physics.

It has always been understood that a certificate in Roentgen-ray and Gamma-ray Physics, Medical Nuclear Physics or the combined program, Radiological Physics qualifies the physicist to act in an advisory capacity regarding the physical aspects of radiation therapy, radiodiagnosis and nuclear medicine to radiologists who are practicing clinical radiology.

Information on the requirements for certification by the American Board of Radiology, and application forms for the certification examination can be obtained from the American Board of Radiology, Kahler Center Building, Rochester, Minnesota 55901.

Another certification program of interest to medical physicists is the one of the American Board of Health Physics (ABHP). This program is directed exclusively toward certification in Health Physics (Radiation Protection). AAPM is formally associated with the American Board of Health Physics through an AAPM appointee to the ABHP. Information on the requirements of ABHP is available from Mr. H. Wade Patterson, Chairman, American Board of Health Physics, Lawrence Radiation Laboratory, Health Physics Department, Berkeley, California 94720.

Various programs of accreditation in the medical specialties -- radiology, surgery, internal medicine, etc. -- have been developed over the years. Surveillance of these programs by visiting committees of the Advisory Board of Medical Specialties help institutions that provide training by indicating areas of weakness and strength. This approach has helped to upgrade the training provided in the relevant medical fields. At the present time there is no comparable accreditation program for medical physics training programs. Medical physics can be concerned with a number of different medical specialties, and thus an accreditation program would be a complex undertaking.

3.4 EMERGING AREAS OF SPECIALIZATION FOR MEDICAL PHYSICISTS

Traditionally, medical physicists working in hospitals and medical institutions have been closely associated with applications of ionizing radiations to the treatment of cancer. This is still the dominant area of work of medical physicists today (table 5). However, the situation is changing; medical physicists are finding other fields within medicine to which they can apply their knowledge and skills. For example, during the last decade a sizable number of medical physicists have found employment in nuclear medicine. This is a rapidly growing field requiring much physical instrumentation. The special knowledge and training of physicists can contribute greatly to the proper operation of these instruments, the calibration techniques which assure that radiation doses delivered to patients are correct, the use of the proper radionuclides, and the radiation safety aspects of the laboratory which protect both patients and employees. Of course the physicist is also well qualified to make contributions both in research and teaching related to nuclear medicine. Undoubtedly the employment of physicists in fields related to radiation therapy and nuclear medicine will continue to grow.

3.4.1 Opportunities for Medical Physicists in Diagnostic Radiology

Within the field of radiology, the largest subdivision is diagnostic radiology.* However, it engages the smallest number of physicists (table 5). It does appear, however, that there is a trend toward employing more physicists in the field of diagnostic radiology. The following factors will tend to accelerate this trend:

1. A large body of new technology developed in connection with our space program, the television industry, high-energy physics research, etc. has become available. Physicists are needed to incorporate these developments into diagnostic radiology.
2. The increased cost and complexity of radiographic equipment are such that many radiologists desire to have their own experts available for the selection, evaluation and development of equipment. At present many radiologists depend to a large extent on representatives from various manufacturers of x-ray equipment for their technical advice.

*Note: Many physicists work in both fields.

3. The demand for radiologic services is increasing. Automation is one way of meeting this demand, and it is becoming an important factor in diagnostic radiology. Physicists are needed to develop automated systems of filming, processing and record storage.
4. Computers are beginning to play an important role in diagnostic radiology. Currently, they function chiefly in patient handling and data storage. Computer physicists can assist in expanding the role of computers to include tasks such as differential diagnosis and image scanning.
5. Members of the medical profession in general, and diagnostic radiologists in particular, are becoming more aware of the fact that the major portion of man-made radiation received by the population comes from diagnostic x rays, and that it would be prudent to reduce this radiation if it can be done without sacrificing the information content of diagnostic image receptor systems.
6. The American Board of Radiology is now giving examinations in the physics of diagnostic radiology. Physicists are needed to teach courses to prepare residents for these examinations.
7. Currently, Federal support for technologic developments in diagnostic radiology is being provided by the Bureau of Radiological Health, The National Institute of General Medical Sciences of NIH, and the National Science Foundation. Because of the significant contribution of medical radiation to the total population dose in relation to all other controllable sources, it is essential that this support be increased.

3.4.2 Applications of Medical Physics Involving Non-Ionizing Radiation

Medical physicists have always played an important role in radiation safety for patients as well as employees in medical centers. It is not surprising that this role has been extended to new areas, for example, the safety aspects for users of microwave energy from ovens. Microwave ovens are becoming commonplace in hospitals for simple, rapid heating of food for employees and patients. Medical physicists are active both in evaluation of the degree of hazard and in inspection and correction of the hazards where they are present.

A number of medical physicists are now spending a large percentage of their time working in the field of sound. Most of these are concerned with ultrasound and its diagnostic applications in medicine. Ultrasound can be used, for example, to map body structures, and to measure the rate of blood flow in arteries, the amount of opening of the mitral valve of the heart, and the movement of the pharyngeal wall. The instrumentation required is quite complex and medical physicists are playing an important role in the development and evaluation of satisfactory ultrasonic instruments for medical applications. It is quite possible that the demand for physicists in the general field of audiology will increase.

3.4.3 Application of Medical Physics to Heat and Temperature

Physicists have known for a long time that body temperature can be measured by means of the infrared radiation emitted by the body. Applications of this principle are currently being studied in several medical centers. The technique used, commonly known as "thermography," involves the detection of the infrared radiation from the patient's skin which is recorded on a map of the patient as varying shades of gray. The warmer spots usually appear as lighter shades. The technique holds considerable promise in regard to the early detection of breast cancer and other malignancies and also in showing areas of local inflammation. It is also useful for showing the general distribution of blood flow. A number of medical physicists are now spending a fair amount of their time on problems of thermography and its diagnostic applications.

Low-temperature physics also is a growing field in its applications to medicine. The use of low temperature for anesthetic purposes is promising in certain selected cases. Cryosurgery or the use of very low temperatures for destruction of cells, also appears to have a small but important range of medical applications. The production and measurement of low temperatures is an area in which a medical physicist can make a useful contribution in this growing field.

3.4.4 Applications of Medical Physics Involving Computers

There is hardly a practicing medical physicist who does not use a computer in some way in his day-to-day duties. The use of modern high-speed computers for calculations of radiation distributions in therapy is now routine. There are many other applications of computers to medicine. The increasing complexity of computers is such that this is rapidly developing into a subspecialty of medical physics.

3.4.5 Other Areas

The general progress in medicine that we have witnessed over the past few decades will continue at an equal or greater rate, and many new applications of physical principles will become important in preventive medicine as well as in the diagnostic and therapeutic aspects of medicine. The following brief list of topics suggests some of the areas that may develop during the coming years.

1. The quantitative measurement of transillumination in the diagnosis and evaluation of hydrocephalus in infants.
2. The development of in vivo techniques for the measurement of bone quality which will be useful in the diagnosis and evaluation of therapy in the very common condition of osteoporosis in elderly women.

3. The application of modern solid-state physical techniques to the study of body components, e.g., the application of electron spin resonance (ESR) and nuclear magnetic resonance (NMR) in cellular metabolism.
4. The use of electric and magnetic fields in medicine. This might also include an application of ion physics.
5. The applications of infrasound and low-frequency vibrations to the body.
6. The identification and control of carcinogenic environmental agents.

Also, medical physicists will undoubtedly play a greater role in the general field of patient monitoring, now often referred to as biomedical instrumentation, or sometimes as biomedical engineering.

Traditionally, medical physicists have been associated with departments of radiology because of their responsibilities in the area of radiation therapy. As a result, a number of new applications of physics to medicine are often found in departments of radiology. For example, ultrasound and thermography are usually in radiology departments although they have no connection with x rays. Some of the topics previously mentioned will be of definite interest to other clinical areas such as orthopedic surgery, pediatrics, neurology, and surgery. As a result of this increased diversity of physics applications and the associated increase in the number of medical physicists needed in hospitals, increased growth of departments of medical physics is likely much as has occurred in Great Britain and in the Scandinavian countries. These departments, if called departments of applied physical science in medicine, could then conveniently include biomedical engineers and computer experts as well.

4. RECOMMENDATIONS

1. At least one full-time professional medical physicist is needed in each medical institution with more than 300 hospital beds.

2. Graduate training programs in medical physics shall terminate in a master or doctoral degree. In addition experience shall be provided in clinical applications of pertinent subspecialties of physics.

3. Since projected needs would require doubling the number of medical physicists over the next 10 years, sufficient support of graduate training is essential. This goal is particularly important in this time of declining funding for the training programs of the National Institutes of Health, Bureau of Radiological Health, and Atomic Energy Commission.

4. Training programs in medical physics should be accredited. Necessary standards for this field and criteria for accreditation should be developed.

5. Certification procedures for medical physicists need to be studied. This recommendation is especially important because of the diversity of fields in which medical physicists now work.

6. Courses on medical physics should be made available to pre-medical and medical students, as well as to paramedical students enrolled in schools of allied health sciences.

APPENDIX A

GLOSSARY OF TERMS*

Biophysics - radiologic physics was formerly included in this field, which now conventionally applies to basic studies of the physics of life processes.

Health physics - that subdivision of radiologic physics that relates to any aspect of radiation protection; radiation protection physics, or protection physics.

Medical nuclear physics - physics applied specifically to nuclear medicine.

Medical physics - all applications of physics to any aspect of medicine.

Nonradiologic medical physics - any portion of medical physics other than radiologic physics.

Professional Medical Physicist - one who has the M.S., degree in physics or medical physics and possesses certification by the American Board of Radiology, or has the Ph. D. degree in physics or medical physics. Such persons should have had experience working at a medical institution.

Radiation physics - should properly mean the study of the physical properties of radiation. It is conventionally restricted to studies of ionizing radiation. Some centers use it synonymously with radiologic physics.

Radiodiagnostic physics - physics applied specifically to radiodiagnosis.

Radiologic physics - physics applied to any aspect of radiology, including radiation protection.

Radiologic sciences - all phases of science applied to radiology or radiation protection.

Radiophysics - a variation synonymous with radiologic physics.

Radiotherapy physics - physics applied specifically to radiotherapy.

*In part from H. M. Parker, "Research Report on the Training of Radiological Physicists. A Study of British and Swedish Methods and Their Relevance in the United States." (Contract No. PH 86-66-8) Bureau of Radiological Health, Rockville, Maryland 20852 (November 23, 1965).

APPENDIX B

GRADUATE PROGRAMS THAT INCLUDE MEDICAL PHYSICS

1. MASTER'S DEGREE PROGRAM (1 YEAR)

Lawrence Radiation Laboratory
University of California
Berkeley, California

Health Physics
Stanford University
Stanford, California

Department of Physics
Dr. W. W. Cross Cancer Institute
Edmonton, Canada

Department of Radiology
University of Florida
Gainesville, Florida

School of Medicine
Division of Nuclear Medicine
University of Miami
Miami, Florida

Georgia Institute of Technology
Atlanta, Georgia

Technological Institute
Northwestern University
Evanston, Illinois

Department of Radiology
Wayne State University
College of Medicine
Detroit, Michigan

Department of Radiotherapy and
Radiological Research Laboratory
Columbia Presbyterian Medical Center
Columbia University
New York, New York

Radiation Safety and School of
Public Health
University of North Carolina
Chapel Hill, North Carolina

Radioisotope Laboratory
General Hospital
University of Cincinnati
Cincinnati, Ohio

Department of Radiology
Ohio State University
Columbus, Ohio

X-Ray Science and
Engineering Laboratory
Oregon State University
Corvallis, Oregon

Dept. of Radiation Health
University of Pittsburgh
Pittsburgh, Pennsylvania

Radiotherapy and
Cancer Division
Puerto Rico Nuclear Center
San Juan, Puerto Rico

Department of Physics
M.D. Anderson Hospital
Univeristy of Texas
Houston, Texas

Department of Radiology
University of Wisconsin
Madison, Wisconsin

2. MASTER'S DEGREE PROGRAM (2 YEARS)

Department of Radiology
University of California
Los Angeles, California

Donner Laboratory
University of California
Berkeley, California

Ontario Cancer Institute
University of Toronto
Toronto, Canada

Radiation Safety and School of Public Health
University of North Carolina
Chapel Hill, North Carolina

Department of Radiology
University of Colorado Medical Center
Denver, Colorado

Department of Radiology and Department of Environmental Engineering
University of Florida
Gainesville, Florida

Department of Radiology
University of Chicago
Chicago, Illinois

Department of Radiology
University of Illinois Medical Center
Chicago, Illinois

Technological Institute
Northwestern University
Evanston, Illinois

Department of Radiology
University of Kansas Medical Center
Kansas City, Kansas

Department of Therapeutic Radiology
University of Kentucky Medical Center
Lexington, Kentucky

Department of Radiological Science
School of Hygiene and Public Health
Johns Hopkins University
Baltimore, Maryland

Physics Research Laboratory
Massachusetts General Hospital
Boston, Massachusetts

Radiation Therapy Center and School of Public Health
University of Michigan
Ann Arbor, Michigan

Department of Radiology
College of Medicine
Wayne State University
Detroit, Michigan

Physics Department
Central Michigan University
Mount Pleasant, Michigan

Dept. of Physics and Astronomy
University of New Mexico
Albuquerque, New Mexico

Sloan-Kettering Institute for Cancer Research
New York, New York

Radiation Therapy Center
Strong Memorial Hospital
University of Rochester
Rochester, New York

Radioisotope Laboratory
General Hospital
University of Cincinnati
Cincinnati, Ohio

Radiation Therapy
College of Medicine
Ohio State University
Columbus, Ohio

Dept. of Radiological Sciences
University of Oklahoma
Oklahoma City, Oklahoma

X-ray Science and Engineering Laboratory
Oregon State University
Corvallis, Oregon

Department of Radiation Therapy and Nuclear Medicine
Hahnemann Medical College and Hospital
Philadelphia, Pennsylvania

Department of Radiology
Hospital of the University of Pennsylvania
Philadelphia, Pennsylvania

Stein Research Center
Thomas Jefferson University
Philadelphia, Pennsylvania

Radiotherapy and Cancer Division
Puerto Rico Nuclear Center
San Juan, Puerto Rico

Department of Nuclear Engineering
Texas A & M University
College Station, Texas

Southwestern Medical School
University of Texas
Dallas, Texas

Department of Physics
M. D. Anderson Hospital
University of Texas
Houston, Texas

Radiology Department
Univ. of Texas Medical School
San Antonio, Texas

Department of Radiology
Univ. of Utah Medical School
Salt Lake City, Utah

Radiology Department
Univ. of Washington
Seattle, Washington

Department of Radiology
University Hospitals
University of Wisconsin
Madison, Wisconsin

3. TRAINING FOR CERTIFICATION BY AMERICAN BOARD OF RADIOLOGY

Department of Radiology
University of California
Los Angeles, California

Environmental Health and Safety
University of California
San Diego, California

Box 372
Naval Hospital
San Diego, California

Department of Radiology
University of Colorado Medical Center
Denver, Colorado

Department of Radiology
University of Florida
Gainesville, Florida

Department of Physics
Emory University
Atlanta, Georgia

Georgia Institute of Technology
Atlanta, Georgia

Department of Radiology
University of Chicago
Chicago, Illinois

Dept. of Therapeutic Radiology
Univ. of Kentucky Medical Center
Lexington, Kentucky

Dept. of Radiological Science
School of Hygiene and Public Health
Johns Hopkins University
Baltimore, Maryland

Department of Radiology
Wayne State University
Detroit, Michigan

Radiation Department
Meadowbrook Hospital
East Meadow, New York

Department of Radiotherapy
Columbia-Presbyterian Medical Center
Columbia University
New York, New York

Department of Medical Physics
Memorial Hospital
New York, New York

Department of Radiology
New York University
New York, New York

Department of Radiology
Strong Memorial Hospital
University of Rochester
Rochester, New York

Radioisotope Laboratory
General Hospital
University of Cincinnati
Cincinnati, Ohio

Department of Radiation Therapy
Ohio State University
Columbus, Ohio

Radiation Center
Oregon State University
Corvallis, Oregon

Department of Radiology and Department
of Radiation Therapy and Nuclear Medicine
Hahnemann Medical College
Philadelphia, Pennsylvania

Radiology Department
Hospital of the University
of Pennsylvania
Philadelphia, Pennsylvania

Department of Radiology
Thomas Jefferson Univ. Hospital
Philadelphia, Pennsylvania

Radiology Department
Southwestern Medical School
University of Texas
Dallas, Texas

Department of Physics
M. D. Anderson Hospital
University of Texas
Houston, Texas

Radiology Department
Univ. of Texas Medical School
San Antonio, Texas

Department of Radiology
Univ. of Utah Medical School
Salt Lake City, Utah

Department of Radiology
University of Wisconsin
Madison, Wisconsin

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4. Ph.D. DEGREE PROGRAM

Lawrence Radiation Laboratory
University of California
Berkeley, California

Department of Radiology
University of California
Los Angeles, California

Environmental Health and Safety
University of California
San Diego, California

Department of Radiology
Stanford University
School of Medicine
Stanford, California

Dept. of Medical Biophysics
University of Toronto
Toronto, Canada

Georgia Institute of Technology
Atlanta, Georgia

Radiological Physics Division
Argonne National Laboratory
Argonne, Illinois

Department of Radiology
The University of Chicago
Chicago, Illinois

Department of Radiology
University of Illinois Medical Center
Chicago, Illinois

Technological Institute
Northwestern University
Evanston, Illinois

Department of Radiology
University of Kansas Medical Center
Kansas City, Kansas

Department of Radiological Science
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APPENDIX C

ESTIMATE OF NEEDS FOR MEDICAL PHYSICISTS

In our estimate of needs for medical physicists, three types of data have been collected. These data are described in sections (1), (2), and (3) below.

1) In the course of the study we used the following categories to compile information obtained from AAPM members on the patient load per year per full-time-equivalent (FTE) medical physicist: (a) number of new radiation therapy patients; (b) number of nuclear-medicine procedures; (c-1) number of general examinations in diagnostic radiology; and (c-2) number of special procedures (for example, use of a catheter) in diagnostic radiology. The frequency distributions in the above categories are widespread. Table 9 lists the mean and median values for the above categories.

2) Data have also been assembled, for the hospitals of various AAPM members, on the number of new radiation therapy patients per year divided by the number of beds in the hospital. The mean and median of these data as well as data on the number of nuclear medicine procedures, and general examinations and special procedures in diagnostic radiology, are listed in table 10.

3) A listing of health care institutions was published in the Journal of the American Hospital Association, Volume 43, Part 2 (p. 493, August 1, 1969). A summary of the listing as a function of number of beds is given in table 11.

The figures of table 11 exclude mental hospitals, tuberculosis hospitals, and clinics which do not have a resident physician on their staff. For the purposes of our needs estimate we shall assume that the 2,058 hospitals having less than 300 beds will not require the services of a full-time professional medical physicist at this time.

A necessary figure for the needs estimate is a measure of the number of beds in U.S. hospitals. The number of beds is determined by taking the sum of the following, from table 11: 622 hospitals times 500 beds per hospital, 227 hospitals times 450 beds per hospital, and 403 hospitals times 350 beds per hospital. This figure gives a total of 554,200 beds.

Since many hospitals do not have a medical physicist, it seems reasonable to recommend that those without a physicist employ as their first one a professional medical physicist (see appendix A. Glossary of Terms). For the needs estimate (tables 12 and 13), therefore, we shall use the data for "1" FTE medical physicist from table 9 (see block enclosure).

Table 9. Various patient procedures per year for different numbers of full-time-equivalent (FTE) medical physicists per institution

Mean values

	Number of FTE medical physicists			
	0.5	1	2	3
a. New radiotherapy patients per year/FTE	1,238	691	371	349
b. Nuclear-medicine procedures per year/FTE	6,517	3,717	1,706	1,136
c. Diagnostic radiology				
1. General examinations per year/FTE	137,000	63,000	31,000	--
2. Special procedures per year/FTE	2,914	3,033	583	--

Median values

	Number of FTE medical physicists			
	0.5	1	2	3
a. New radiotherapy patients per year/FTE	1,156	600	350	283
b. Nuclear-medicine procedures per year/FTE	6,040	3,000	1,815	1,210 (estimated)
c. Diagnostic radiology				
1. General examinations per year/FTE	165,000	58,000	31,000	--
2. Special procedures per year/FTE	2,200	1,608	600	--

Table 10. Mean and median number of various patient procedures per year per bed

	Number of AAPM members answering question	Mean	Median
a. Number of new radiation therapy patients per year per bed	177	1.54	0.95
b. Number of nuclear medicine procedures performed per year per bed	178	6.13	5.00
c1. Number of general examinations done in diagnostic radiology per year per bed	150	104	95
c2. Number of special procedures in diagnostic radiology per year per bed	149	2.76	1.90

Table 11. Number of beds in hospitals in the United States

<table>
<tr><th colspan="2">Number of hospitals in the United States</th><th>Actual number of beds</th><th>Number of beds assumed in calculating need for medical physicists</th></tr>
<tr><td>622</td><td></td><td>500 or more</td><td>500</td></tr>
<tr><td>227</td><td></td><td>400 - 499</td><td>450</td></tr>
<tr><td>403</td><td></td><td>300 - 399</td><td>350</td></tr>
<tr><td>669</td><td rowspan="2">2,058</td><td>200 - 299</td><td>-</td></tr>
<tr><td>1,389</td><td>100 - 199</td><td>-</td></tr>
</table>

Table 12. Estimate of need for medical physicists in hospitals, based on median data

Field	From table 11	From table 10	From table 9	
a. Therapy	554,200 beds x	0.95 therapy patients / bed, year x	1 physicist / 600 therapy patients/year	= 877 physicists
b. Nuclear medicine procedures	554,200 beds x	5.00 nuclear procedures / bed, year x	1 physicist / 3,000 nuclear procedures/year	= 922 physicists
c. Diagnostic radiology 1. General examinations	554,200 beds x	95 general exams / bed, year x	1 physicist / 58,000 general exams/year	= 903 physicists
			Average	= 900 physicists

Table 13. Estimate of need for medical physicists in hospitals, based on mean data

Field	From table 11	From table 10	From table 9	
a. Therapy	554,200 beds x	1.54 $\frac{\text{therapy patients}}{\text{bed, year}}$ x	$\frac{\text{1 physicists}}{\text{691 therapy patients/year}}$	= 1,240 physicists
b. Nuclear medicine procedures	554,200 beds x	6.13 $\frac{\text{nuclear procedures}}{\text{bed, year}}$ x	$\frac{\text{1 physicists}}{\text{3,717 nuclear procedures/year}}$	= 915 physicists
c. Diagnostic radiology 1. General examinations	554,200 beds x	104 $\frac{\text{general exams}}{\text{bed, year}}$ x	$\frac{\text{1 physicists}}{\text{63,000 general exams/year}}$	= 915 physicists
				Average = 1,023 physicists

APPENDIX D

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Accession No.

U.S. Department of Health, Education, and Welfare, PHS, FDA, Bureau of Radiological Health - DHEW Publication (FDA) 74-8014 (Nov. 1973) 54 pp. (limited distribution)

ABSTRACT: The work for this publication was conducted as part of the continuing radiological health education project of the American College of Radiology; it was supported by the Bureau of Radiological Health through contract PH 86-67-202. (over)

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