Nuclear Medicine and Medical Education

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During recent years, the importance assumed by nuclear energy in every aspect of life sciences has imposed a reappraisal of the place assigned to it in medical education. At the end of 1960, the Congressional Committee of the U.S. Senate, under the chairmanship of Senator Hubert H. Humphrey (1), published a report dealing with the magnitude, organization and distribution of programs on radiation research in life sciences. Senator Humphrey established nine categories in this subject, *e.g.*, radiobiological research, radiation genetics, radiation protection, education, training and information. According to the Congressional Committee, education and training constitute per se another category of research, and should be supported accordingly. In 1959, of the total budget of $47,485,600—allocated in the U.S.A. to radiation research in life sciences—education and training occupied the seventh place with 7.85 percent of the total amount. In comparison, the report mentions for the same year $2,400,000 in Japan and $1,272,000 in Canada; in Japan, 3.4 percent of this amount is devoted to education and training.

Since 1960, many reports have been published concerning the financial assistance given to research in radiobiology (2,3). It is not the purpose of this article to discuss the adequacy of official or private support of radiobiological research, but chiefly to assess the importance of teaching and educational opportunities in nuclear medicine.

**Terminology and Definition of Nuclear Medicine**

It is universally admitted that today nuclear medicine represents a reality and not a transient fashion in medicine. What is less accepted is the name of this discipline, a factor that sometimes leads to confusion in terms or in purpose. The term *Nuclear Medicine* is a misnomer and has not met with unanimous approval; the only valid argument in its favor is that of accepted use, and its

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appeal to the imagination of the young physician aware of his ties with the nuclear age. This phenomenon is by no means unique, for other ambiguous terms have caught the fancy of the public; for example, the term "Molecular Biology" might imply to the non-initiated that it deals with the biology of molecules and not with the study of biological phenomena at the molecular level. Space Medicine is another redundancy, for it is obvious that every biological manifestation must occur in space; yet it is self-evident that it deals with medical and biological problems encountered during extra-terrestrial activities of man.

The other names used instead of Nuclear Medicine, e.g. Isotopic Medicine or Atomic Medicine, are even worse. The first term places the accent on radioisotope methodology, which is far less than the area covered by nuclear medicine; as for the latter, it is even more inaccurate than molecular biology, for obvious reasons.

If the semantic problem raised by nuclear medicine is a matter of taste, loose definition of the area covered by this discipline is more serious, for it leads to confusion and overlapping zones of related disciplines. At present, it is understood that nuclear medicine deals with the following matters:

— fundamental and clinical applications of radioactive isotopes, either introduced systemically into a living system or organism, or applied in vitro as a radioactive compound or as a stable element that is activated into a radioactive isotope (activation analysis).

— effects of ionizing radiation upon living cells or organisms, whether experimentally or from a clinical or public health point of view.

This definition invests nuclear medicine with a broad spectrum of interest almost as wide as that of medicine itself; it also represents some modern lines of interest in medicine. Indeed, the enormous amount of information gathered in each of the classical divisions has rendered almost impossible any dialogue between the representatives of different medical specialties. This obstacle could be overcome by the creation of liaison disciplines whose role is to unit the classical depth disciplines through the agency of a methodology or a concept applicable to both areas. Thus, nuclear medicine can be also defined as a, “liaison specialty uniting the fundamental sciences to the clinical specialties through the use of radiation methodology; this latter point signifies that both radioactive atoms and ionizing radiation are used for the needs of nuclear physicians.” This definition is similar to that proposed in other papers (4,5) and is essential for the establishment of further concepts in medical education. Indeed, a liaison discipline should not constitute a separate entity within a medical school, for it then loses its impact on the student. It should offer the new information distributed throughout the other disciplines initially through the professors of nuclear medicine, and then through the members of the respective departments. Thus, the newly acquired concepts will fuse into the other data of the classical discipline, without the necessity for creating specialists in nuclear medicine in every department.

SYNONYMIES AND OVERLAPPING AREAS WITH RELATED DISCIPLINES

Once the area covered by nuclear medicine is defined, the other disciplines that are partly synonymous or whose field overlaps, must be analysed. In the
first category, one must define the purpose of radiobiology and of health physics. Radiobiology is a part of biophysics and deals with the effect of electromagnetic radiation in the living cell; it has lately been extended to corpuscular radiation. It differs from nuclear medicine, for the field of the former also comprises non-ionizing radiation, and ultra-violet rays, etc. In addition, the chemical nature and the biological role of the atom carrying the radiation is not taken into consideration. Radiobiology is chiefly fundamental in scope, while nuclear medicine, besides being fundamental, is performed with a continuous view to its clinical applications. In general, distribution studies with labeled compounds are not considered to pertain to radiobiological research, as stated in the purposes of the recent congresses of radiation research; yet, this is essential in nuclear medicine, for all diagnostic and therapeutic applications are based upon the information afforded by distribution studies.

Health Physics encompasses all the physical, chemical and biological aspects of the utilization of radiation or radioactive elements, with the purpose of establishing adequate protection against radiation damage: physics of tissue damage, dosimetry, contamination of the environment, ecological studies, radiation protection, etc. It is an important discipline in view of the impending development of industrial utilization of nuclear energy, and its sphere of action considerably overlaps that of nuclear hygiene; it has no direct contact with the clinical applications of radioactive material, or with the other major applications of nuclear energy in public health: radiation sterilization of food and drugs, epidemiological studies with radioisotopes, etc.

The distinction made between nuclear medicine and nuclear biology is chiefly one of purpose: indeed, the latter is the mother discipline, encompassing the fundamental and practical studies in biology, made with the aid of the radioactive atom or ionizing radiation; the former deals with human applications. It starts with a problem developed from human pathology and ends in the same area, even if the solution of the problem was found in collaboration with other disciplines.

The intimate link between nuclear medicine and radiology is based on historical as well as on technical reasons. Clinical application of radioactive isotopes took advantage of the knowledge of radiation dosimetry acquired by radiotherapists; also, radiologists were placed in a better position to appreciate the wealth of possibilities offered by labeled compounds. The Society of Nuclear Medicine was founded by a group of medical and nonmedical scientists, most of them connected with radiological sciences; their action stemmed from the conviction that nuclear medicine should be based on a thorough knowledge of biochemistry and physiology, besides the physics of radiation. The American Journal of Roentgenology recognizing this situation added the word Nuclear Medicine to the title of the journal in 1956. In 1961, the Board of Examination in Radiology introduced a special examination in nuclear medicine. Efforts are being made towards full recognition of nuclear medicine by the same Board of Certification, provided that a definition will be accepted to avoid overlapping and misunderstanding. There is a large twilight-zone between radiotherapy and nuclear medicine. In fact, it would be more logical to leave the entire therapy
to the radiotherapist, whose knowledge of dosimetry is more adequate than that of the nuclear physician. Usually, the dividing line is drawn at the internal radiation treatment: the radioactive compound distributed after metabolic incorporation is the appanage of nuclear medicine, the other procedures fall within the realm of radiotherapy.

Undoubtedly, nuclear medicine will help in opening new vistas in research and training for radiologists, mainly for those connected with large teaching centers. In a recent article (6) Dowds complains of the penury of interest of young radiologists in academic and research activities. He suggests that “to survive, radiology must encourage and promote specialization in various areas”.

Perhaps this view is too gloomy, for radiology is as vigorous as ever; nevertheless, it stresses the fact that the development of nuclear medicine will contribute to attract radiologists to academic and research centers.

In fundamental sciences, radioactive isotopes have brought a wealth of information and have revolutionized basic concepts. Thus, the dynamic concepts of turnover, metabolic pool, biological half-life, etc., have been created almost entirely with the aid of stable or radioactive isotopes; this is the reason for the intimate fusion between nuclear medicine and biochemistry, physiology or molecular biology. Other disciplines rely heavily on radiation procedures, such as genetics, bacteriology and immunology. The interpenetration is less impressive in the clinical branches, in which the radioactive isotopes occupy a steadily increasing role.

Even with all the uncertainties mentioned before, one hopes that the concept of Nuclear Medicine-lasion specialty will emerge with reasonable clarity after this analysis. It is imperative to know in more detail the content of this general concept and to analyze the best means of integrating the indispensable information in the curriculum.

LEVELS OF TEACHING NUCLEAR MEDICINE

The teaching of nuclear medicine should be offered at the three levels available in a medical school: undergraduate, graduate and post-graduate. However, since the graduate studies in nuclear medicine and biology are dependent on the full recognition of this discipline as a full-fledged specialty, this is not the moment to dwell upon the timeliness of a degree in a discipline that is not universally recognized as such.

POST-GRADUATE TEACHING

The Post-graduate studies in nuclear medicine are offered either by universities or hospitals, or by the education division of the institutions working in the field of nuclear energy. Owing to the diversity of interests of the students of nuclear medicine, the type of course can be either "general" or specialized for a limited field of application. There are many institutions offering regular training courses to physicians from different specialties. Lists of the post-graduate courses are being published regularly by the special bulletins of the I.A.E.A. or by other institutions. More than 30 training centers are listed for the United States and Canada. The Oak Ridge National Laboratory has a considerable number of pre-
clinical and clinical courses of one or two weeks duration. This is specially
provided for physicians who seek official license for the clinical use of radioactive
isotopes.

A different philosophy is advocated by the Isotope School of the British
Atomic Energy Research Establishment. The course with special reference to
medicine lasts five weeks and comprises two parts: the first three weeks are
dedicated to fundamental problems of nuclear physics, chemistry and instru-
mentation; the last two weeks are devoted to a review of the common uses of
radioisotopes in clinical medicine. This latter part is held in conjunction
with a large group of the London hospitals, by their respective clinicians, or
radioisotope specialists. At the end of the five-week period (170 hours) a cer-
tificate of attendance is given, but this does not constitute a certificate of com-
petence to use radioactive isotopes in medicine.

The sole disadvantage of the specialized courses offered by the above
institutions is that they disrupt the activity of the student who has to travel from
remote countries to register for the course. This difficulty has been partially
solved by the International Atomic Energy Agency, whose division of training
and education organizes regional courses in various areas of the world. Thus, a
regional course of clinical applications of radioactive isotopes took place in
December 1964, in Manila, for students chiefly from South East and Far East
Asia.

The other alternative is that of weekly courses offered for a longer period of
time to students in the vicinity of the institution, as is the case of some courses
offered by medical schools in large centers. There are numerous courses of this
type in the United States and in Canada; the one organized by the author at
McGill University and presently being held at the University of Montreal has
been functioning uninterruptedly since 1953. The courses offered by the Atomic
Energy of Canada are of the specialized training type rather than of the general
medical type as offered by Oak Ridge and British AERE. However, during re-
cent years a oneweek course of Health Physics has been organized at Chalk
River, Canada, and is open to physicians and non-physicians interested in radia-
tion protection.

UNDERGRADUATE LEVEL

In 1958, the Society of Nuclear Medicine started the organization of teaching
symposia devoted to the various aspects of education in nuclear medicine. On
this occasion, I wrote the following regarding the introduction of nuclear medi-
cine at the undergraduate level, "...The boundaries of this new discipline are
too hazy and we must await a delimitation (4)."

Now, seven years later, most of the boundaries of nuclear medicine have
been delimitated, and it is our duty to introduce the fundamentals of nuclear
medicine as part of the regular curriculum of medical students. At present, this
introduction has not been made uniformly, as shown in the inquiry made by
Sears (7) in 106 medical schools on the North American continent.

There are two problems to be solved, both of which are of importance in
these times of soul-searching for new formulas in medical education. What is
essential to be taught in nuclear medicine at the preclinical and clinical level? Where should the necessary information be offered?

There are two answers to the second question, each having its advocates and opponents. Some suggest the creation of a separate department of nuclear medicine within the clinical period of medical training, while others favor incorporating the required information into the framework of the program of the already existing departments. My personal conviction derives from the principles expressed earlier in this article. As a liaison discipline, nuclear medicine should be introduced in the early stages of medical teaching, the largest part at the level of fundamental disciplines, where it will have far more impact on the student than in the second part of their studies. Also, in this manner, the number of hours devoted to the teaching of nuclear medicine concepts could be larger than when offered as a clinical specialty, at which time the majority of students are already oriented as to their future and tend to devote as little time as possible to lectures.

During the academic years 1962-64 the Faculty of Medicine of the University of Montreal introduced, on an experimental basis, a number of lectures devoted to nuclear medicine. The largest part of the 22 hours of lectures and 15 laboratory hours was held in the department of Physiology (12 lecture-hours and two full laboratory periods of six hours each). During the present academic year, the program of nuclear medicine is distributed within the following disciplines:

<table>
<thead>
<tr>
<th>Title of course</th>
<th>Department</th>
<th>Content</th>
<th>Lecture hours</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Nuclear</td>
<td>Physiology</td>
<td>Fundamentals</td>
<td>12</td>
<td>2 = 12 hours.</td>
</tr>
<tr>
<td>Radiopathology</td>
<td>Bacteriology</td>
<td>Radiation disease</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Radiopathology</td>
<td>Pharmacology</td>
<td>Toxicology of radioactive</td>
<td>1</td>
<td>1 = 3 hours.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>compounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Hygiene</td>
<td>Public Health</td>
<td>Contamination of the environment</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

This program contains the essentials which should be integrated within the basic sciences. In other medical schools, the above subjects could be offered in the department of biochemistry or pathology instead of physiology, but the subjects remain unchanged. It must be stressed that this facilitates the task of the department of radiology, whose limited number of lecture hours could be thus devoted to more specific subjects than to a review of the fundamentals supposedly known by the third year medical student.

In answering the second question, one could suggest the following topics:

- fundamentals of nuclear physics: structure of nuclides, disintegration, radiations, definition of units, interaction of radiation with matter, ionization.
- fundamentals of radiochemistry and radiobiology: trace elements, precursor-finite product relationship, turnover, metabolic pools and spaces established with labeled compounds, isotopic effect.
— fundamentals of radiobiology and radiopathology: effects of radiation on the cells, tissues and systems; acute and chronic radiation disease; radiation disease and immune processes, radiation and cancer, genetic effects of radiation.

— fundamentals of nuclear hygiene: toxicology of radioactive compounds, contamination of the environment with radioactive compounds: fallout, radioactive wastes, nuclear accidents; protection against radiation, limits of tolerance, natural level of radioactivity.

The laboratory periods have one period devoted to the familiarization with the basic counting equipment, and some elementary experiments on attenuation of radiation, necessary to the understanding of radiation protection. A second period is offered in connection with the physiology of blood, and entails experiments performed by each student on ferrokinetics, plasma volume determination with labeled albumin and red cell volume determination with $^{51}$Cr. Demonstrations are made on voluntary subjects on clinical applications of the accepted radioisotope procedures (Schilling tests, survival of red cells). Finally, a third full day is entirely devoted to thyroid studies with radioactive compounds: metabolic cycle of mineral iodine in animal and man, uptake and scanning procedures in voluntary subjects, hormonal utilization tests with labeled $T_3$ and $T_4$. The latter part is presented as a demonstration for a limited group of students.

The laboratory period in pharmacology deals with the distribution pattern of a radioactive contaminant according to the route of administration, chemical form, specific activity, etc. It also makes the link between the physiological applications and the problems treated in radiopathology and hygiene.

Thus, the students receive a certain amount of clinical information, which has a better impact when offered together with the fundamental subjects.

The clinical part of the program is not developed at present, for lack of hospital facilities on the university campus. Also, it is more difficult to select the subjects of purely clinical character which have not been covered in the basic sciences, and which could be considered essential for the clinician. Therapy with radioisotopes is treated in the department of radiology, and some aspects of cancer diagnosis and treatment within the department of surgery; however, one feels that the clinical aspects are less important for the medical student, unless he chooses the laboratory of nuclear medicine as a stage of rotating internship. Optional periods of two months are offered to the medical students in the fourth year, who become familiarized with radioisotope applications. The six months to one year period do not enter this category, they are part of the training periods for residents in radiology or internal medicine.

This program is by no means complete or final; it will be changed during the forthcoming years, in order to satisfy the demands of a complex and crowded curriculum. However, the results are already visible, and medical students are better prepared to accept the clinical applications of the radioactive atom and the ionizing radiation as an everyday medical practice and not as an exotic activity restricted to the few large medical centers.

The author would be happy to share this educational experience with other colleagues who are involved in the introduction of nuclear medicine at the under-
graduate level in the medical school, and perhaps to work towards the establishment of a complete program to be submitted to the committees of undergraduate curriculum.

REFERENCES


Tulane Symposium
on
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The symposium will feature discussion by an outstanding guest faculty on computer techniques in scanning and on newer techniques in scanning, including the application of computer technology.

Further information may be obtained from Mrs. Susan Crain, University College, Tulane University, New Orleans, Louisiana 70118.

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