NUCLEAR MEDICINE

CLINICAL AND TECHNOLOGICAL BASES

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Clinical and Technological Bases

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Nuclear Medicine

Foreword

With advancing technology many aspects of medicine have become dependent on the team approach, with persons from different disciplines bringing their skills together in support of the clinician to effect a systematic approach to diagnosis and treatment. Nowhere is this more true than in nuclear medicine. Clinicians, technologists, and scientists need to learn much of each other's disciplines in order to appreciate fully the contribution that each can make to the understanding of the problems.

Here is a book that presents all the fundamental information on nuclear medicine practice in a clear, straightforward manner, interweaving the clinical objectives, relevant physiology and metabolism, and practical details of diagnostic and therapeutic procedures in logical sequence.

The two authors have been experts in the field for many years. They complement each other superbly and the result is a book that should have wide appeal not only to the clinical, technical, and scientific staff and students in nuclear medicine departments, but to others who aspire to understand the tremendous potential of this relatively new medical discipline.

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Preface

This book is concerned with the basic principles underlying the diagnostic and therapeutic uses of radionuclides in medicine and the principles of procedure.

In some areas it could be described as a procedure manual, but its main objective is to help the nuclear medicine technologist grasp the principles of procedure. An understanding of principles (as opposed to following procedure by rote) equips the technologist for good routine practice, leads to the recognition of the significance of variables as they arise, and lays the foundation for the development of new procedures.

Broadly, the material covers:

- basic information in the areas of body systems, disease processes, radiobiology, patient care, aseptic procedure, laboratory practice, radiation hazards and protection, and radioactive measurement
- an analysis of the physiological and physical principles, and the technical features of radionuclide diagnosis and therapy
- details of common radionuclide procedures with emphasis on factors that may lead to erroneous results

The book does not attempt to cover physics, mathematics, chemistry, or radiopharmacy, but some reference is made to these subjects where appropriate.

Although the content is primarily intended for students of nuclear medicine technology, we hope that medical and scientific personnel who are not fully engaged in nuclear medicine practice may find sections of the book valuable.

The book is based on the lecture series we developed for the Royal Melbourne Institute of Technology Associate Diploma Course in Medical Nucleography. The course, of three years duration, was started in 1964 through the mutual cooperation of the Royal Melbourne Institute of Technology as the education body and the Cancer Institute which established the in-service training school, following the recommendation of its chief physicist, K. H. Clarke. The lecture series developed over a period of almost ten years, with the material evolving and expanding as a result of experience and the questions of the students.

We are indebted to those students in the earlier Radioisotope Technician and later Medical Nucleography courses, and to the radiographers (therapeutic and diagnostic) who contributed to the development of nuclear medicine technology, together with the physicists who laid the foundations and were copioneers in this field.

Other personnel who have contributed to the state of the art or to the validity of the statements in the text include fellow medical personnel, nursing

staff (clinical and tutorial), biochemists, medical laboratory technologists, and statisticians. Of course, the many authors of books and scientific papers we have read over the years have contributed to the development of our ideas.

For the actual production of material, we acknowledge with gratitude the contributions of the Royal Melbourne Institute of Technology for the printing of the original lectures, of Arrianne Martin, Arthur Wigley, and Doreen O'Reilly and staff for the artwork and photography, and very specially of Anna Faraci, Judy Gaida, Pauline Embury, and Audrey Hale for typing the manuscript. We are indebted to Phyllis Litwinka for her considerable work as the copy editor.

Finally, we recognize the Cancer Institute and the Royal Melbourne Hospital, where we personally gained our experience.

J. T. A.
M. J. M.

Nuclear Medicine

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Introduction

Nuclear medicine "arrived" on the world scene in the 1960s. For two decades previously, radionuclides were being used in medicine quite seriously and usefully, developing slowly and surely with increasing radionuclide availability and with each new advance in electronics and radiopharmaceutical manipulation.

Historically, the development can be roughly divided into decades.

The 1940s provided the era of Geiger counters and differential uptake of the biological radioactive elements ^{131}I and ^{32}P for therapy and diagnosis.

The 1950s saw the introduction of scintillation detectors and some manual scanning and the practice of tagging biological compounds with radionuclides, such as ^{51}Cr labeled red blood cells, and ^{60}Co labeled vitamin B_{12}.

In the 1960s, automatic rectilinear scanners emerged concurrently with the short-lived radionuclides which could be used in sufficient quantities to be detectable by such instruments. Pulse height analysis, allowing simultaneous measurement of multiple radionuclides, further widened the field, while radiochemical manipulation became an important area of investigation to extend the usefulness of scanners. In vitro laboratory tests with radionuclides were also developed in this period.

The present decade finds γ-cameras the major items, with whole body counting facilities and associated equipment for manipulation and analysis of the wealth of data now available. Laboratory investigations, such as radioimmunoassay, formerly part of the research field now have a major role in the diagnostic armamentarium in the 1970s.

It will be readily recognized that, throughout the development, there have been stages of research activity merging into clinical practice. Inevitably there have been difficulties in providing a patient-oriented setting and service because of the very nature of the equipment and associated investigations and because science-oriented personnel have devised the procedures.

In general, now, departments of nuclear medicine are well designed clinical areas—part of the patient scene along with other diagnostic and treatment services. Similarly it is recognized that staff in this field should be well versed in all aspects of patient care as well as in the technicalities of nuclear medicine.

Nuclear medicine technology (or nucleography) emerged as a new paramedical profession similar to radiography or medical laboratory technology in the early 1960s, and in some centers the nuclear medicine technologist has played a vital part in the clinical area.

Although the applications of radionuclides in medicine will change with new developments, the basic role and required skills of the technologist, as already developed, can be expected to persist.

1 *The Nuclear Medicine Technologist and the Patient*

THE NUCLEAR MEDICINE TECHNOLOGIST

Functions and Requisite Skills

A current work specification of the technologist in a nuclear medicine department gives an indication of the range of activities. (It is recognized that some of these procedures are performed by other personnel, e.g., radiopharmacists, physicists, and nursing staff, in some departments.)

Summary

Performs clinical investigations and therapeutic procedures using radionuclides, as requested or prescribed by medical personnel.

Work Performed

1. Arranges the patient's ward admission if necessary and any other associated appointments.
2. Instructs the patient as to appointments, preparation for procedures, and duration of attendances.
3. Arranges for the collection, receipt, and storage of radioactive materials.
4. Observing the correct handling procedure, receives, checks, and dispatches the material to the store, laboratory, or refrigerator as appropriate.
5. Accurately records all radionuclides received in the log book (responsibility being as for dangerous drugs).
6. Prepares the dose. This may consist of a simple check measurement for radioactivity content; accurate dispensing from bulk solution; elution of the dose from a parent radionuclide and radioactivity measurement and dispensing; or the labeling of the physiological material to be studied with the nuclide, e.g., labeling red blood cells with ^{51}Cr under sterile conditions. All preparations are made according to the appropriate principles of protection from radiation hazards.
7. Arranges the preparation of the patient for the procedure.
8. Makes out instructions to nursing staff regarding specific precautions to be taken with ward patients.
9. Administers or assists in administering the radionuclide.
10. Collects or arranges the collection of body fluid samples from patients.
11. Performs radioactivity measurements on the patient. This includes:
    a. setting the measuring equipment accurately to the appropriate operating factors for the particular investigation.

   b. setting up the patient in the appropriate position and marking areas for measurement using anatomical landmarks.
   c. positioning the detector accurately to produce significant and maximum information from the measurement.
12. Records all the information from the radioactivity measurements.
13. Progressively evaluates the information obtained and makes decisions regarding any extra measurements to be made for completeness.
14. Prepares samples and reference standard sources for radioactivity measurements. This may consist of a simple volumetric dispensing, accurate dilutions and dispensing, or separation or precipitation of blood fractions.
15. Performs radioactivity measurements on samples after determining the appropriate operating factors.
16. Makes the necessary calculations, analyses, and graphs to present the information from the measurements in a clinically significant form.
17. Presents the results of the procedure for evaluation to the medical officer in charge.
18. Attends to the dispatch of reports to the appropriate place.
19. Monitors all locations in which radionuclides have been handled.
20. Decontaminates all equipment and any furnishings unavoidably contaminated by patient activities.
21. Controls the disposal of radioactive waste (liquid and solid).
22. Arranges all procedures so as to afford maximum protection from radiation and contamination to patients, patients' associates, and hospital staff.
23. Maintains stringent laboratory organization to prevent cross-contamination of equipment or contamination hazard to personnel.
24. Keeps records of patient procedures, radionuclide movement, and equipment response.
25. Assists in the development of new techniques with experimental procedures and measurements.
26. Maintains trainee discipline and instruction.
27. Is responsible in all patient procedures for the maintenance of good hygiene standards and the observance of protection measures as well as correct ethical conduct towards patients.

It can be seen, from the duties listed, that skill must be developed in:

1. Laboratory work—efficiency in procedures, organization
2. Safe radionuclide handling—control within and outside the department
3. Patient care—efficiency, compassion, professional attitude
4. Use of equipment—how to use to best effect, understanding of limitations
5. Radioactivity measurement and calculation—understanding the aim and limitations, technique for requirement, application of corrections
6. Specific investigations—use of the principles 1–5, visualization of the whole aim, ability to modify technique

To achieve the required skills and fulfill the role, the trainee technologist must consciously draw on each teaching facility. Achievement, however, still depends on personal application and a sense of responsibility to work always to the best of one's ability.

Professional Attitudes

In addition to the skill, understanding, and technical ability acquired in training, the technologist needs to develop an appreciation of his or her place in the whole pattern of patient care. He must recognize the limitations as well as the functions and must have a strong sense of responsibility and integrity.

In the various professions, there are accepted codes of ethical behavior. A very strict code is necessary in the medical and paramedical professions, since they exist for the benefit of "people in need." These people must be able to depend on such professions for their physical welfare and confidently expect respect for their privacy. Thus a system of right conduct and the recognition of a moral responsibility are essential. Some of the characteristics necessary for the ethical conduct of the paramedical professions are:

- Responsibility and reliability—e.g., every duty however menial performed thoroughly
- Honesty and truthfulness—e.g., readiness to admit mistakes, remembering lives may be involved
- Obedience—e.g., intelligent, accurate obedience to doctor's instructions; taking orders from authority is not degrading
- Loyalty—e.g., avoid talk that could be harmful to the patient, the doctor, a colleague, or a hospital. Any matter of real concern must be taken to the proper authority
- Respect for the patient—e.g., the individuality, privacy, and dignity of the patient must be maintained

In these professions etiquette also is an important factor in the total patient care. In a hospital, good manners (common courtesy, respect, and understanding) contribute to the smooth functioning of the institution, and therefore to the standard of care.

Etiquette is reflected in manner of addressing patients and other staff, attitude to visitors to the department, conduct in other departments, punctuality, and general behavior and appearance. All actions and attitudes should aim at building up the trust and confidence of the patient. General etiquette and a professional appearance are perceived by the patient more readily than are technical skills.

Specific points of ethics and etiquette are considered in a résumé of the technologist's responsibilities to the patient, the doctor, other people within the department, other departments, the hospital and the community.

Responsibilities to the Patient

- Order and administer radioactive doses only on the signed authority of the medical specialist.
- Produce the required result (investigation or treatment) from the highest standard of work at every step.
- Ensure minimum discomfort and waiting periods commensurate with the requirements for a reliable result.
- Maintain the patient's confidence and trust in those attending him.

- Refrain from discussing the patient with anyone not concerned in the professional situation.
- Hold in confidence any personal information offered by the patient.
- Refrain from mentioning the patient's name outside the hospital (even if a family friend) without the patient's express permission to do so.
- Respect the patient's beliefs and customs.
- Always control one's emotions in front of the patient.
- Prevent injury, infection, or worsening of symptoms while in the department (further elaboration later in this chapter and in Chapter 4).

Responsibilities to the Doctor

- Carry out his instructions accurately and intelligently.
- Produce a dependable result on his patient. The exercise of his skill depends on high quality results.
- Progressively report results or observations of any changes in the patient's condition during the procedure.
- Properly use the radionuclides issued in his name.
- Maintain a respectful attitude in any conversation relating to him or to his patient.
- Refer the patient back to the doctor for the answer to any queries relating to results or treatment.
- Have the patient's records up to date and readily available to the doctor.

Responsibilities to Other People in the Department

- Work in harmony with professional and nonprofessional staff. The way people speak and act contributes to the atmosphere. The patient readily senses friction and loses confidence.
- Accept instructions in the proper manner.
- Issue instructions in the proper manner.
- Be respectful to senior people in front of others.
- Do not intrude on high level discussion.

Responsibilities to Other Departments

- Respect other workers including nonprofessional and junior professional staff. Skills and attitudes command respect as does position.
- Mix with other staff when possible and learn about their work.
- Coordinate with other departments for appointment times.
- Be attentive to visitors to the department, offering assistance, and if indicated, conduct them to the department head.
- Be courteous when visiting other departments. Always report to the head of the department. Leave the patient comfortable and the area tidy if work was done in another department.

Responsibilities to the Hospital

- Strictly observe hospital and department rules even if their significance is not understood. They may relate to legal responsibilities.
- Immediately report any accident to a patient to a higher authority, even though it may seem trivial or attended to satisfactorily.
- Ensure that requests for procedures are signed by the appropriate medical officer.
- Maintain acceptable records of all procedures, requests, radionuclide usage, and so forth.
- Consider costs in the care of equipment and efficient use of time.

Responsibilities to the Community

- Maintain the community's confidence in the hospitals and the medical specialists with whom you are associated.
- Any statements made by hospital employees are likely to be regarded as authoritative by people outside the field.
- Irresponsible statements may lead to a lack of confidence resulting in failure to seek treatment.

THE PATIENT

The technologist must have some knowledge of general patient care and the common nursing-type procedures that may be encountered in the nuclear medicine department. Some understanding of possible psychologic reactions of patients to sickness and the hospital situation is important. Sensitivity to the individual patient helps to engender his confidence and cooperation. There must be an awareness also of the limitation imposed by the physical manifestations of various conditions.

Patients coming to the department from wards may be unconscious or nauseated, or may need attention to catheters, or may require oxygen. Although there is often a trained nurse in the department, the technologist must be familiar with the care of the patients in these situations.

General Patient Care

In some scientific paramedical professions with their necessary accents on technological accuracies, it is possible to almost overlook the prime purpose, i.e., all exists for the benefit of the patient. The patient is the center, the reason for existence, not just a part of the overall scheme necessary for the end result. All procedures should be undertaken only for the patient's ultimate benefit. Sometimes unwanted side effects have to be accepted, e.g., absorbed radiation in nuclear medicine investigations, but such side effects are weighed against the anticipated benefits.

The nuclear medicine specialist bears the responsibility of assessing the acceptability of the proposed radiation effect in the light of the useful information he will receive about the patient's condition. The technologist must ensure

that the assessed risk is not exceeded in any way and, in fact, is minimized as far as possible. The patient must not suffer any physical injury as a result of his investigation. The protection of the patient from physical damage is discussed later in this chapter, and in the section on prevention of infection in Chapter 4.

A less obvious aspect of patient protection and care is the psychological one. Some understanding of human relationships is important to equip one to meet people's needs and deal with their reactions to illness and hospitalization. Some people have a natural awareness of other people's needs and an ability to express their care. This evokes the patient's confidence—a desirable situation. Other people need to learn about behavior, individual differences, and influences of pressure and environment to understand and cope with the various patient reactions.

Behavior

Behavior is often determined by feelings rather than rational thoughts. It is important to recognize the needs underlying the manifest behavior particularly of patients and, incidentally, also of colleagues, since relationships between staff affect the atmosphere to which the patient is exposed.

Reactions to Illness and Hospitals

Many factors contribute to a person's reaction to illness and to being a hospital patient. Natural fear and anxiety relating to the physical illness are only part of the complex emotional situation to which the patient must adjust.

In general, factors at work in a patient either long-term or on the first visit are pain with its associated fear and anxiety; interference with function, either organic or simply interference with the life pattern and work; separation from family, work, and interests; sudden change from independence to a state of dependency in an unfamiliar situation. The patient might experience any of the following emotions: fear of pain, disease, deformity, and death or of a new unfamiliar situation; anxiety about the illness and his future, about work and economic security, and about his family; embarrassment relating to loss of function or to dependency and submission to authority; loneliness because of separation from family, friends, and routine; and resentment that this should happen to him.

Many of these feelings are associated with needs for security, love, respect, and mastery of a situation.

Some people will readily adjust to the situation, while some will never fully adjust. This situation of stress and anxiety is a challenge to some, while in others it may cause a reversion to earlier patterns of behavior. During the process of adjustment, or in patients who fail to adjust, behavior is varied. The patient may be restless and tearful (reflecting fear and anxiety) apathetic and depressed (indicating hopelessness and lack of other interests), noisy and talkative (a form of bluff to cover fear), timid and apologetic (indicating fear), resentful and suspicious (arising from ignorance), tranquil and contented (can be a "too well-controlled" cover for true feelings), demanding (arising from his concept of the importance of his illness and his entitlement to special consideration).