CRC

MANUAL of NUCLEAR MEDICINE PROCEDURES

3RD EDITION

J. W. Keyes, Jr.,
Editor

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INTRODUCTION TO THE THIRD EDITION

Our hope in assembling this new manual, as in previous editions, is to provide a useful working reference for the clinical nuclear medicine laboratory. The methods described have all been tested and are in use in our laboratories. Although they may not represent the only or even the easiest way to do a procedure, they are known to give satisfactory results.

The changing character of nuclear medicine procedures and equipment has dictated some significant changes in this edition. In many cases the material presented is less in the detailed "cookbook" form of the previous editions and more in the form of guidelines around which more detailed procedures can be built in the user's own laboratory. As before, we have assumed that this book will be used by, or under the direction of, someone who is familiar with the operation of radionuclide imaging equipment. The appearance of new equipment such as the whole-body scanning cameras, the hybrid whole-body scanners, and a new generation of nuclear medicine computers has necessitated carrying this assumption one step further. The user must now integrate the procedural guidelines provided here with the specific operating instructions for his or her own equipment to develop an integrated working protocol.

It is assumed that the user is familiar with the sources of radionuclides and radiopharmaceuticals and the safe handling of these compounds. Nuclear medicine laboratories, like all facilities which handle radioactive substances, operate under stringent regulations administered by the federal government and/or appropriate state agencies. It is therefore assumed that the user of this manual will be operating under an appropriate license. As radiopharmaceuticals are also classed as drugs, nuclear medicine also must conform to regulations of the FDA and other regulatory bodies pertaining to drugs. A number of the radiopharmaceuticals listed in this manual are classed as "investigational" at the time of this writing. While these are so indicated, it is possible that some or all of these agents may be reclassified as accepted and approved during the useful life of this manual. Users should ascertain for themselves the current status of these compounds. Those laboratories wishing to perform studies with compounds still classed as investigational must, of course, satisfy the necessary legal requirements for the use of these agents.

The paragraphs on principles and interpretation are frequently incomplete and oversimplified and should not be taken as complete expositions on these subjects. They are provided solely as an introduction in the hope that even a cursory knowledge will aid considerably in the performance of quality work.

In brief, this book is meant to enable the user to establish working procedures which will give satisfactory results with the equipment and facilities available within an individual laboratory.

JOHN W. KEYES, JR., EDITOR

John W. Keyes, Jr. is Professor of Internal Medicine and Radiology for the Nuclear Medicine Section of the University of Michigan Medical School.

Born October 20, 1940 in Detroit, Michigan, he graduated cum laude from the University of Michigan Medical School in 1965 and served both his residency and internship at Detroit's Henry Ford Hospital. He also served on the faculty of the University of Rochester School of Medicine and Dentistry prior to returning to his alma mater.

Dr. Keyes has more than 40 published articles, abstracts, and contributions to books to his credit in the area of nuclear medicine. In addition, he co-authored the two previous editions of the *Manual of Nuclear Medicine Procedures.*

Dr. Keyes is a member of several professional organizations, including the Society of Nuclear Medicine, the Radiological Society of America, and the American Heart Association's Council on Cardiovascular Radiology.

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HOW TO USE THIS BOOK

Each procedure in this manual is broken down under a series of headings, with the same format being followed in each protocol. In the interests of simplicity and to prevent redundancy and make the procedures applicable to a wide variety of laboratory situations, a number of assumptions and generalizations have been made. These are explained below.

By way of general comments, the term "scan" is used throughout this book as a generic term for any imaging procedure. This is not correct in the strictest sense since a camera does not produce a scan, but the term is in such general use that no misunderstandings should occur.

Principle

This section gives a brief explanation of the physiologic mechanisms which underlie each procedure.

Indications

A listing of common situations in which the test may be helpful is given. No attempt is made to be encyclopedic.

Limitations

An attempt is made to define those circumstances in which a procedure will not be helpful.

Specific contraindications, where present, are also listed in this section. Note that general contraindications are not listed. Pregnancy and nursing are relative contraindications to all in vivo procedures unless specifically excluded, as in placental scanning.

Radiopharmaceutical and Dose

This section lists the preferred radionuclide, its chemical form, the dose, and the route of administration. The usual adult dose is given. Pediatric doses may be determined by reference to the appropriate chart in the section "Pediatric Considerations".

This is followed by a listing of the significant emissions for that isotope. In most cases these were arbitrarily limited to energies above 50 keV which comprise more than 10% of total emissions, as it was felt that only these would cause any problems in window setting. The photopeak energy(-ies) to be used in imaging is(are) italicized in each case. Several nuclides now in use have multiple photopeaks which can be used with suitable equipment. In such cases, detailed instructions will be found under "Procedure," Step 2.

The dosimetry listing gives the dose to the total body, the gonads, and the "critical" organ in rads per millicurie. In the frequent case of conflicting dosimetric data, the value shown was arbitrarily placed on the high side.

A listing of acceptable alternative radiopharmaceuticals is given. These are agents which should give results comparable to the specified radionuclide with appropriate alterations in scanning technique but which are not in routine use for a variety of reasons. The relative merits and disadvantages of these alternative agents compared to the preferred agent are discussed briefly.

Patient Preparation

Any required or recommended premedication, dietary preparation, or other treatment prior to the actual administration of the radiopharmaceutical and/or scanning is given here.

Procedure

1. The route and technique of radionuclide administration and the waiting period before starting the procedure are listed. Any special techniques in radiopharmaceutical preparation are also given here.
2. Suitable equipment for performing the study is listed. Frequently, more than one type of equipment can be used. If one type is preferred over another, this is indicated. For many newer procedures, such as gated cardiac studies, specialized additional equipment is needed. Such equipment is also listed here.

The specific procedures to be followed when using a rectilinear scanner and a gamma camera have been separated for simplicity. Techniques to be followed when using a whole-body scanning gamma camera are listed under the camera procedure. The whole-body scanner manufactured by the Cleon Corp. represents a special hybrid. Although technically a close kin of the rectilinear scanner, in practice, the user will find the guidelines for whole-body camera scanning most applicable to the Cleon machine.

Window width settings for both techniques are given in keV and are symmetrical about the photopeak unless a baseline is specified. For nuclides with multiple, useable photopeaks, set-up instructions for the use of extra-wide windows or multiple windows are also given.

3. Rectilinear scan technique:
   a. Suitable collimators are listed. Collimators have been grouped for simplicity. High-energy collimators are those designed for energies over 400 keV, medium-energy for energies between 200 and 400 keV, and low-energy for below 200 keV. The terms fine, medium, and coarse focus refer to collimators with radii of resolution less than 8 mm, 8 to 15 mm, and greater than 15 mm, respectively. The recommended focal lengths are based on the assumption that a 5-in diameter crystal scanner is being used.
   b. The recommended information density in counts per square centimeter is given. For some equipment, this must be translated into counts per square inch or counts per lineal inch.

$$\text{Counts/inch}^2 = \text{counts/centimeter}^2 \times 6.5$$

$$\text{Counts/lineal inch} = \text{counts/inch}^2 \times \text{line spacing in inches}$$

Contrast enhancement (electronic alteration of the exposure curve for the photoscan) is so variable from manufacturer to manufacturer that only broad generalizations are listed. Minimal contrast enhancement would be the equivalent of a count range differential of 70 to 80% on a Picker® scanner. Moderate contrast enhancement would be at a CRD of 40 to 70% and extreme contrast enhancement at a CRD of less than 40%. The equivalent values for other manufacturers must be determined.

Background subtraction refers to a count rate cut-off threshold setting. Values less than 10% should be used unless otherwise specified.

   c. The recommended set-up points for rectilinear scanning, i.e., the points from which the maximum count rate is taken, are listed. In conjunction

with the desired information density, this determines scanning speed and other operating parameters.

d. The views to be taken with suggestions for patient positioning and detector placement are listed. The limits of the area to be scanned are described.

4. Gamma camera technique:
   a. Suitable collimators are listed. Collimators for cameras have been grouped as follows: Low-energy collimators are those designed for energies below 150 keV, medium-energy are for energies between 150 and 300 keV and high-energy are for those above 300 keV. Parallel hole collimators have been broadly classified as high resolution, medium resolution, and high sensitivity. The multiplicity of collimators available from different manufacturers makes it difficult to be more precise than this. Special-purpose collimators such as the pinhole, diverging, and converging types will be referred to in more detail where appropriate.
   b. The recommended total counts per image are given for gamma camera studies done with a standard size (10-in.) gamma camera. These figures should be doubled for studies done with a camera with a wide field of view (14 to 15 in.).
   c. The views to be taken are listed with suggestions for patient positioning and detector placement. The gamma camera collimator face should be placed as close to the patient as possible unless otherwise specified. For "whole-body" scans, the limits of the area to be imaged are described.
   d. Any special instructions relevant to whole-body scans as opposed to conventional camera images are given here.
5. The anatomic landmarks which should be placed upon the scan are described.

Rectilinear scans are generally marked with the internal marking system built into the scanner. Gamma camera images are usually marked with small external sources placed on the patient's skin or with a lead overlay that casts a negative shadow.

Notes

Special views, extra equipment, or special points which require emphasis are described in this section.

Interpretation

An attempt is made to describe the normal results and, in a very general way, to give the significance of abnormalities which may appear. No attempt at completeness or subtlety is made. Illustrated examples are specifically avoided.

IMAGING PROCEDURES

Bone and Joint Procedures

BONE SCANNING

James H. Thrall

Principle

Areas of bone injury or bone destruction are usually associated with ongoing bone repair with increased metabolic activity and increased bone blood flow. Radiopharmaceuticals which mimic the metabolic behavior of bone constituents will localize in these regions of bone repair in increased concentration relative to normal bone. Certain other tracers will also become fixed to sites of mineral deposition and still others will be attracted to areas of osteoid formation. Technetium-99m pyrophosphate and technetium-99m diphosphonate chemisorb to microcrystalites of hydroxyapatite. These technetium-99m compounds have replaced strontium-85 and fluorine-18 as the bone-imaging agents of choice. They offer improved imaging characteristics with lower radiation doses.

Indications

Bone scanning is considerably more sensitive than conventional X-rays in identifying the presence and extent of active bone pathology. The most frequent indication is for detection of bone metastatic lesions in patients with malignancy for staging, treatment planning, or lesion localization for biopsy. Follow-up scans are useful in assessing the effects of therapy. Major recent interest has centered on applications in benign disease. The bone scan is positive before conventional X-rays in osteomyelitis, Legg-Perthes' disease, and stress fracture. Bone scans also are useful in certain metabolic disorders such as Paget's disease and hyperparathyroidism.

Limitations

The technetium-99m-labeled, phosphorus-containing compounds are excreted in the urine and accumulate in the bladder, which tends to obscure the mid-portion of the pelvis. Partial retention in the kidneys may also obscure the lower ribs.

The major limitation of skeletal imaging is the nonspecific nature of tracer uptake. Any cause of active bone formation will result in increased tracer localization and incidental, benign lesions including healing fractures, areas of Paget's disease, and active arthritis will produce positive scans that may at times be indistinguishable from malignant lesions. Occasional false negative scans may result from purely lytic lesions or lesions that have been previously treated and are quiescent.

Radiopharmaceutical and Dose

Technetium-99m pyrophosphate or Tc-99m diphosphonate
10 to 15 mCi given intravenously
Emissions: *140 keV gamma*

Dosimetry:	Total body	0.01 rad/mCi
	Gonads	0.02 rad/mCi
	Bone	0.04 rad/mCi
	Bladder	0.23 rad/mCi

Patient Preparation

None.

Procedure

1. Administer the dose intravenously. Wait 3 to 4 hr before imaging. The patient should void immediately prior to pelvic scans.
2. Use a rectilinear scanner or a gamma camera. Use a 30 keV window.
3. Rectilinear scan technique:
   a. Use a 5-in., low-energy, medium-focus collimator.
   b. Scan statistics should be 600 to 800 counts/cm², and 1000 to 1200 counts/cm² can often be achieved. Moderate contrast enhancement or background subtraction of 30 to 50% should be used. Trunk areas ordinarily require more background subtraction than the lower extremities.
   c. Anterior scans are set up over the sternum avoiding pathologic "hot spots" with excessively high counts. Posterior scans are set up over the sacroiliac joints with care taken to avoid the same problem.
   d. Anterior and posterior whole-body images (head to feet and including the arms) are desirable for most applications. Additional views may be tailored to regions of interest. The usual minification setting for whole-body images on rectilinear scanners is 5 to 1.

      The collimator should be maintained at 3 to 3½ in. from the anterior body surface of patients with normal habitus and 2 to 2½ in. from the posterior body surface. Frequent adjustments are often necessary due to uneven body contour.
4. Gamma camera technique:
   a. Use a low-energy, medium- or high-resolution, parallel-hole collimator.
   b. Obtain at least 100,000 counts/image. Comparable anatomic areas, e.g., right and left hips, shoulders, etc., should be imaged for the same length of time. The initial image is obtained for a set number of counts, and the comparable area image is obtained for an equal length of time.
   c. For whole-body surveys, multiple, matched anterior and posterior images are obtained. They should be overlapped slightly to avoid excluding interval areas.
   d. Instructions for extended-field gamma camera bone scans:
      i. The manufacturer's instructions must be consulted for each specific instrument. Set-up for anterior views is ordinarily over the thorax. To achieve an appropriate information density, a minimum of 700,000 counts should be obtained for a whole-body, anterior or posterior gamma camera scan. (Often well over 1 million counts/view are achievable.) The set-up for posterior views is over the upper posterior thorax.
      ii. For most applications, whole-body (head to feet and including the arms), anterior and posterior views should be obtained.

Notes

In addition to survey imaging with either the rectilinear scanner or the gamma camera, high-count density, gamma camera views are often useful for extra detail. A minimum of 100,000 counts/image with the parallel-hole collimator and conventional-sized gamma camera should be obtained. The hips are imaged in greatest