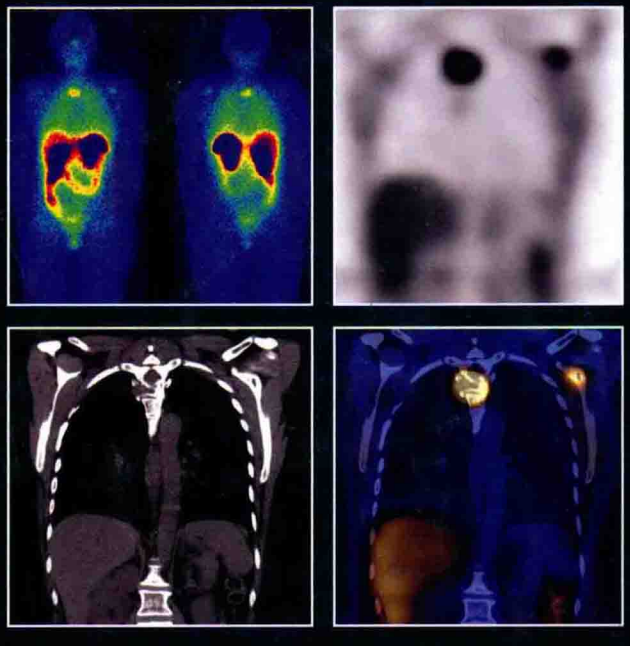
An Atlas of Clinical Nuclear Medicine

Third Editon



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CRC Press
Taylor & Francis Group

AN ATLAS OF

CLINICAL NUCLEAR MEDICINE

THIRD EDITION

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FOREWORD

The experienced interpreter of diagnostic medical images is well versed in the concept of pattern recognition. This is of particular importance in Nuclear Medicine because of the non-specificity of many of the findings we may encounter on a radionuclide image. Over the past several decades, many Nuclear Medicine atlases have appeared either devoted to a specific area of organ imaging, or more generally, attempting to encompass a broader overview of radionuclide imaging methodology. The first two editions of this current work fall into this latter category. All of these publications have served their timely purpose in the overall history of our specialty.

In the 1600 pages that follow, Drs. Fogelman, Clarke, Cook and Gnanasegaran have created a classic work that should stand for many years as the standard of what a comprehensive atlas should be. In their preface, the authors indicate that they "have made a valiant attempt to include most of what one would expect to observe routinely and to contend with issues that we personally have found interesting and challenging." They have succeeded. The net result of their "valiant attempt" is a wonderful, comprehensive, compendium of everything you want to know about interpreting radionuclide images and more.

Each of the 13 chapters has introductory sections structured as a mini-test dealing with basic anatomy, physiology and pathophysiology stressing the normal and its variants. Superb line drawings, photographs and numerous tables add to the ease of the readers' comprehension of the subject matter. I, in particular, enjoyed the beautiful, colourful anatomic casts of the bronchopulmonary segments in the lung chapter and coronary arterial tree in the cardiology chapter. The explanatory "bullets" following a great number of the figure legends provide valuable additional commentary on the particular finding being discussed. The inclusion of SPECT and PET/CT in this similar teaching format significantly adds to the uniqueness of the Atlas.

I have long known and admired Dr. Ignac Fogelman's great talents as a clinical investigator, teacher and author of innumerable articles and texts; primarily dealing with osseous disease. With the invaluable assistance of his colleagues in Great Britain, he has created this third masterful edition of an Atlas of Clinical Nuclear Medicine, which will stand as a greatly appreciated invaluable contribution to both Nuclear Medicine physicians and clinicians interested in learning how radionuclide methodology can enhance their patient care.

Our great thanks to Dr. Fogelman and his associates for their tireless efforts over several years to provide us with this ultimate reference on how to interpret radionuclide images.

Leonard M. Freeman, M.D.
Bronx, New York
June, 2013

PREFACE

It is some 18 years since the last edition of this Atlas was published. That is a long time to keep you waiting, and we are truly sorry. However, it seemed a daunting task to produce a new Atlas of Clinical Nuclear Medicine; to include all the new radiopharmaceuticals, advances with SPECT/CT; and to cover the revolution in imaging, that is PET/CT. Fortunately, help was to hand with our younger colleagues (Dr. Gnanasegaren and Dr. Cook) who injected knowledge, dynamism, and stamina into the project. Nevertheless, this remains a hugely ambitious task with an aim to provide a truly comprehensive Atlas. We have made a valiant attempt to include most of what one would expect to observe routinely and to contend with issues that we personally have found interesting and challenging. Many simple, easy-to-remember teaching points have been included throughout this text, and our hope is that the end product will be clinically useful and of practical value. Thus, our success depends on you, dear reader, as it is upon your opinion as to how close we have come to achieving our goal that we will ultimately be judged.

Ignac Fogelman
Susan E. M. Clarke
Gary Cook
Gopinath Gnanasegaran

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We would like to thank all of the contributors to the Atlas, who are identified by their contributions. We would also like to thank the staff of the Department of Nuclear Medicine at Guy's and St Thomas' Hospital who have assisted in obtaining the new material for this third edition. In particular, we acknowledge the valuable contribution made by Dr. Petra Lewis (Brain chapter), Dr. Lorenzo Biassoni (Paediatrics chapter), and Dr. Parthiban Arumugam (Nuclear Cardiology chapter). They have collated all the new material and assisted in the reconstruction of these chapters. Finally, our thanks go to the staff of CRC Press for their constructive help throughout the preparation of this new edition.

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An appendix listing of Common SPECT and PET Radionuclides and Radiopharmaceuticals used in Nuclear Medicine can be found on http://www.crcpress.com/product/isbn/9781841846538.

CHAPTER 1

BONE

CHAPTER CONTENTS

INTRODUCTION

Bone imaging encompasses a wide spectrum of pathologies from benign conditions such as trauma and infection to primary and secondary malignant lesions. Despite advances in anatomical imaging, including magnetic resonance imaging (MRI) and multidetector computed tomography (MDCT), bone scintigraphy continues to play a major role in the diagnosis of bone pathology.

Bone scintigraphy is commonly used as a screening test for suspected bone metastases because of its high sensitivity, availability, low cost, and ability to scan the entire skeleton. Historical data and clinical experience have established bone scintigraphy as the reference standard in the search for skeletal metastatic disease, and, in the same way, many indications have been established for benign skeletal disorders. For many years ^{99m}Tc-labelled diphosphonates, particularly ^{99m}Tc-methylene diphosphonate (MDP), have been the most widely used radiopharmaceuticals.

A ^{99m}Tc-MDP bone scan shows exquisite sensitivity for skeletal pathology, but this technique has the limitation that scan appearances may be non-specific. However, in many clinical situations recognisable patterns of scan abnormality are seen, which often suggest a specific diagnosis. The mechanism of tracer uptake in bone is not fully understood, but it is believed that diphosphonate is adsorbed onto the surface of the bone, with particular affinity for sites of new bone formation. It is thought that diphosphonate uptake on bone primarily reflects osteoblastic activity but is also dependent on skeletal vascularity. Thus, bone scan images provide a functional display of skeletal activity. As functional change in bone occurs earlier than structural change in most pathologies, the bone scan will often detect abnormalities before they are seen on an X-ray. Any diphosphonate, which is not taken up by bone, is excreted via the urinary tract, and in a normal study the kidneys are clearly visualised on the bone scan; indeed, there are many examples of renal pathology which have been detected for the first time on a bone scan. Improvements in gamma camera design, including the increased availability of tomographic scintigraphy [single photon emission computed tomography (SPECT)], have also helped in bone imaging by increasing sensitivity and specificity. In recent years, there has been increasing interest in the use of positron emission tomography (PET) tracers, such as ^{18}F-FDG and ^{18}F-fluoride, in the investigation of various aspects of skeletal disease especially bone metastases (Table 1.1).

Mechanism of diphosphonate uptake on bone

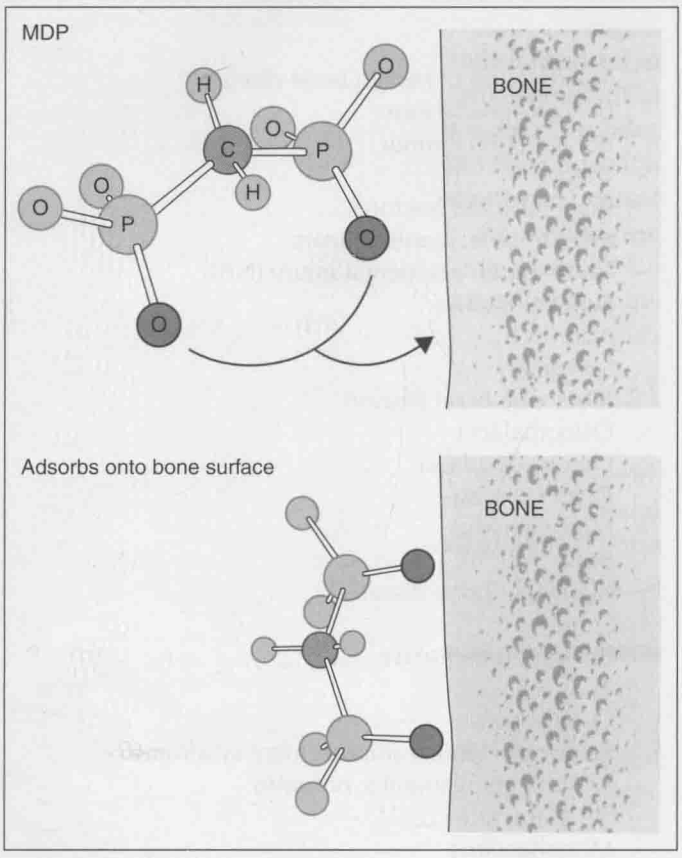
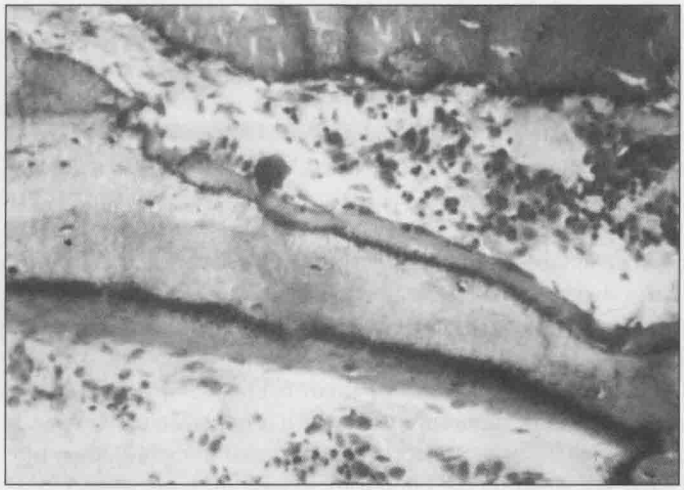


Figure 1.1 Mechanism of diphosphonate uptake on bone.



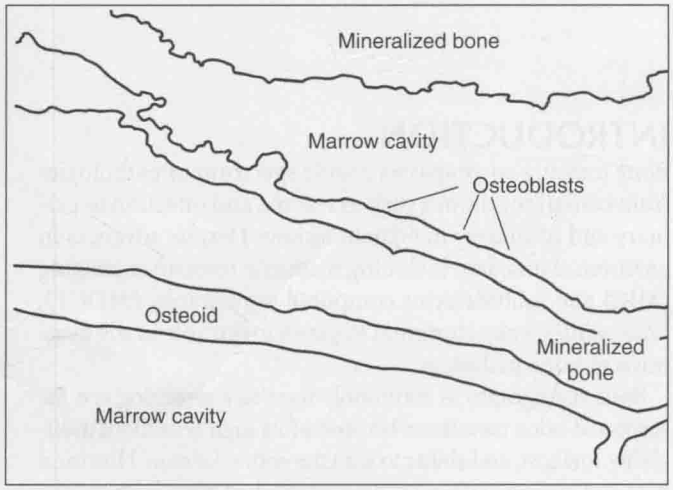


Figure 1.2 Microautoradiography of rabbit bone showing adsorption of ^{3}H-hydroxyethylidene diphosphonate on bone surfaces. The heavy concentration of silver grains is at the interface between osteoid and bone, that is, at the site where mineralisation occurs. *Source*: Courtesy of Dr. M.D. Francis, Cincinnati, USA.

Table 1.1 Specific and Non-specific SPECT and PET Radiopharmaceuticals for Bone Imaging

SPECT tracers	PET tracers
Specific	***Specific***
^{99m}Tc-methylene diphosphonate (MDP)	^{18}F-Fluoride
Non-specific	***Non-specific***
^{67}Gallium	^{18}F-fluorodeoxyglucose (FDG)
^{201}Thallium	^{11}C-Choline
^{99m}Tc-Sestamibi (MIBI)	^{11}C-Acetate
^{99m}Tc-Tetrofosmin	^{68}Ga-DOTATOC/DOTANOC
$^{123/131}$I-meta iodobenzylguanidine (MIBG)	
$^{123/131}$I-Iodine	
^{111}In-Octreotide	

Chemical structures of diphosphonates

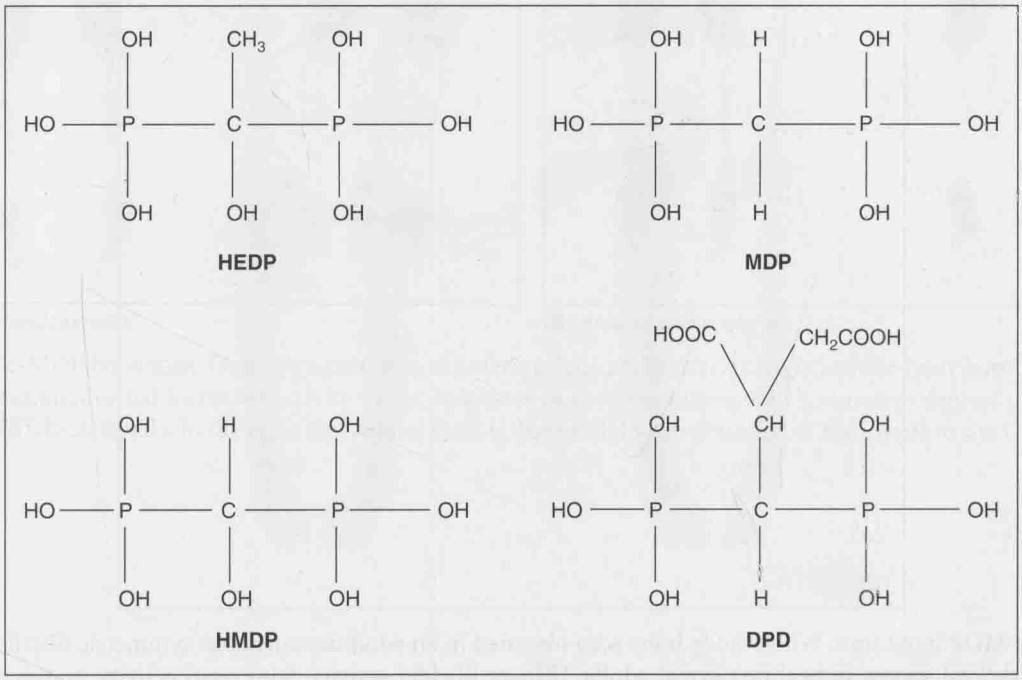


Figure 1.3 Chemical structures of bone tracers. At the present time MDP is the most widely used agent. *Abbreviations*: HEDP, hydroxyethylidene diphosphonate; MDP, methylene diphosphonate; HMDP, hydroxymethylene diphosphonate; DPD, dicarboxypropane diphosphonate.

NORMAL SCANS

Normal whole-body scan

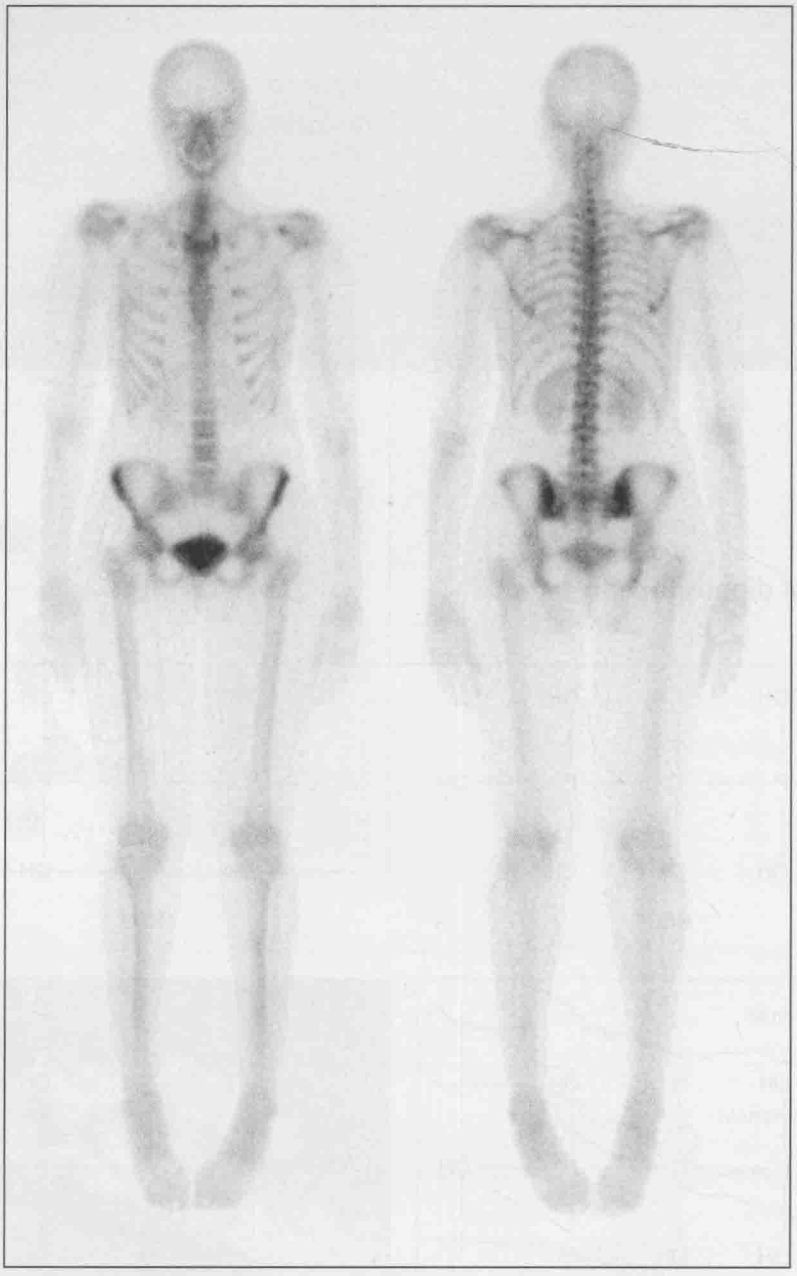
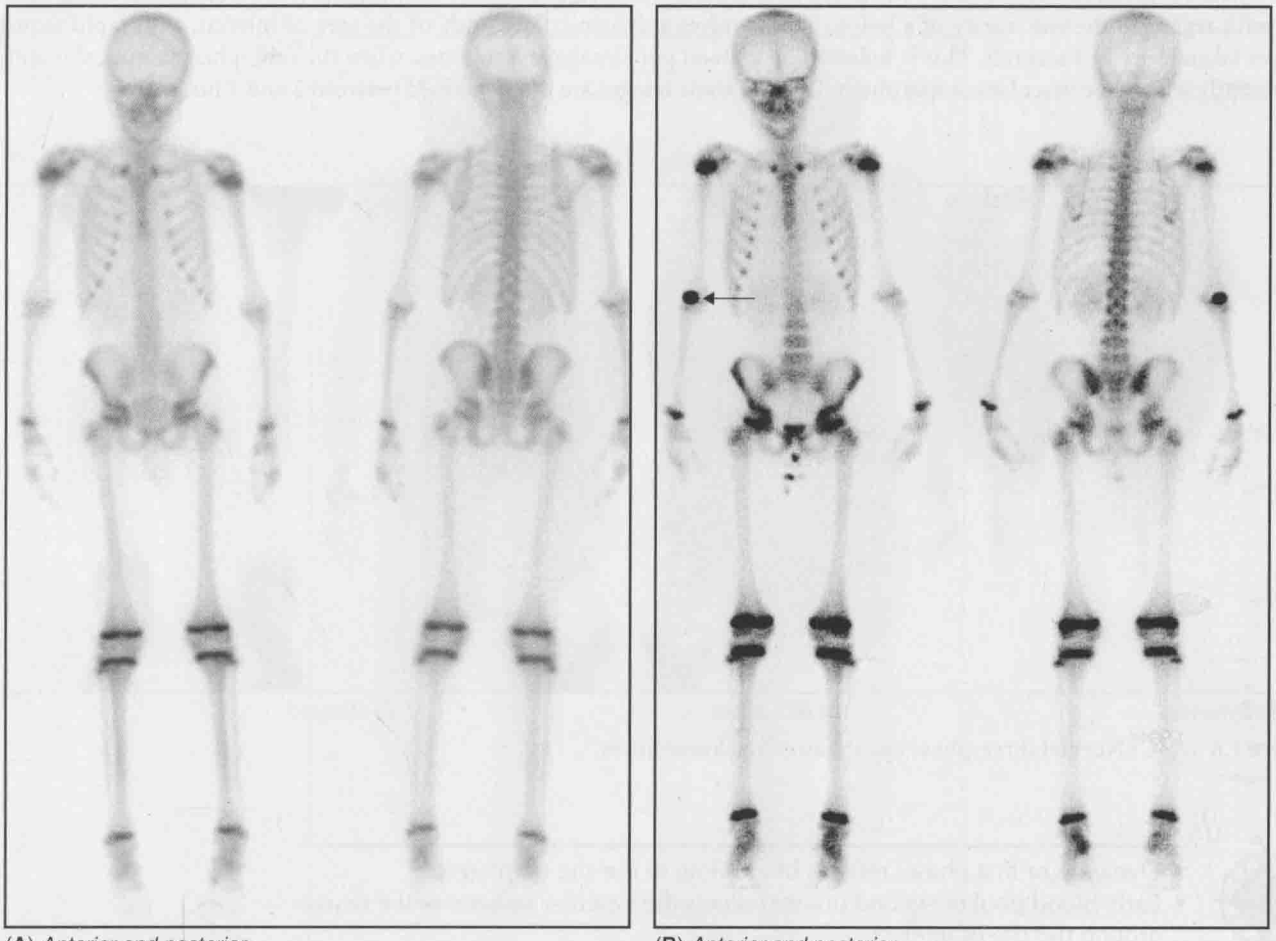


Figure 1.4 ^{99m}Tc-MDP bone scan. Whole-body bone scan obtained in an adult demonstrates symmetric distribution of activity throughout the skeletal system in healthy normal adults. Urinary bladder activity, faint renal activity, and minimal soft-tissue activity are commonly seen.

Normal paediatric whole-body scans



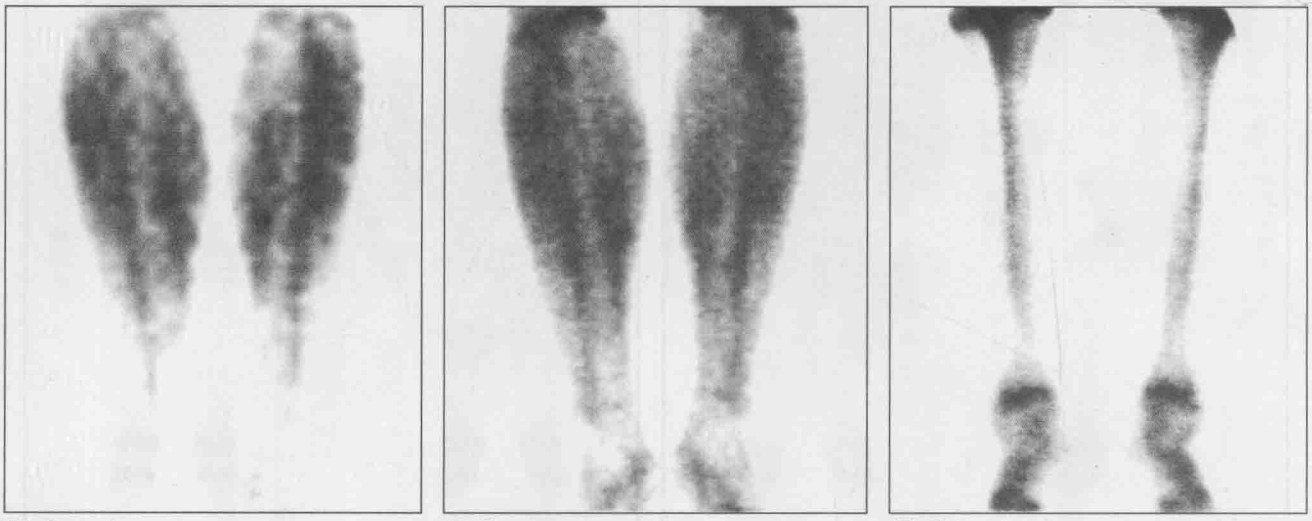
(**A**) *Anterior and posterior*

(**B**) *Anterior and posterior*

Figure 1.5 ^{99m}Tc-MDP bone scan. (**A,B**) Two examples of anterior (left) and posterior (right) whole-body bone scans obtained in children demonstrate normal increased activity in the epiphyses of the long bones, which represent centres of normal growth. Note in image (**B**), focal uptake in the right antecubital fossa is due to slight extravasation at the injection site (*arrow*).

Three-phase bone scan

The timing of bone scan images will depend upon the clinical problem under investigation. In general, it is customary to obtain static images at between 2 and 4 hours. In certain circumstances a three-phase bone scan will provide valuable additional information with regard to the vascularity of a lesion. This involves a dynamic flow study of the area of interest, with rapid sequential images taken every 2–3 seconds. This is followed by a blood pool image at 5 minutes, when the radiopharmaceutical is still predominantly within the vascular compartment. Delayed static images are then obtained between 2 and 4 hours.



(**A**) *Dynamic* (**B**) *Blood pool* (**C**) *Delayed*

Figure 1.6 (**A–C**) Normal three-phase bone scan of the lower limbs.

- Dynamic or first phase: reflects blood flow to the site of interest.
- Early blood pool or second phase: reflects the vascular volume of the tissues around the site of interest.
- Delayed, static, or third phase: reflects the skeletal metabolic activity.
- Many departments carry out two-phase bone scan as a compromise, that is, blood pool and delayed images only, arguing that adequate information regarding vascularity is contained in the blood pool images.

Blood pool scans

Normal whole-body blood pool image

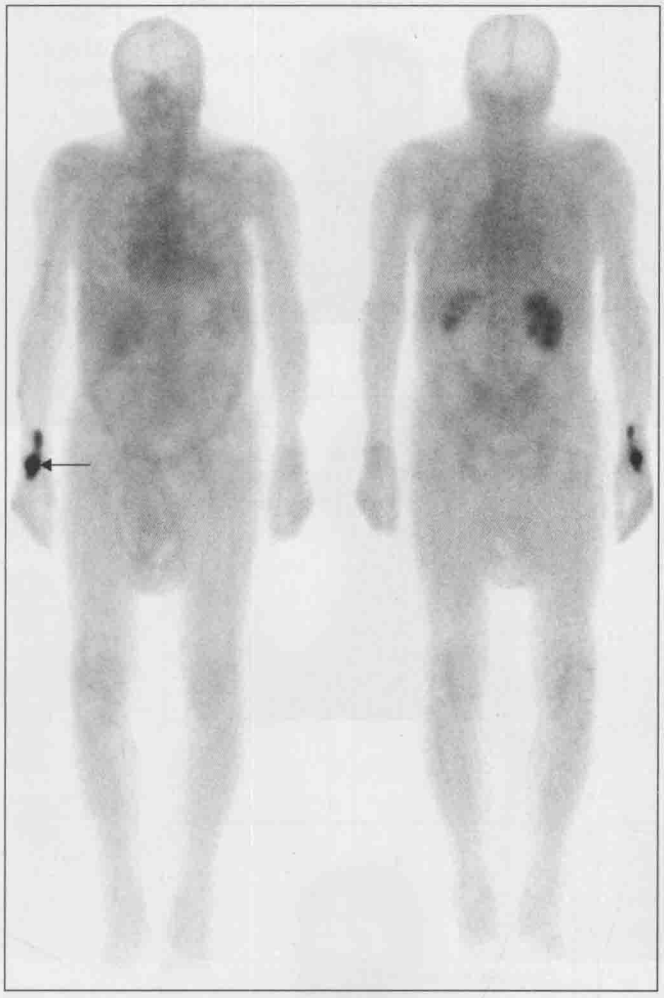
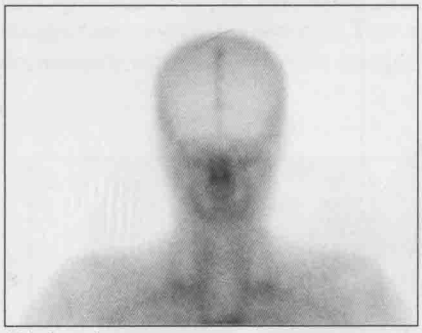


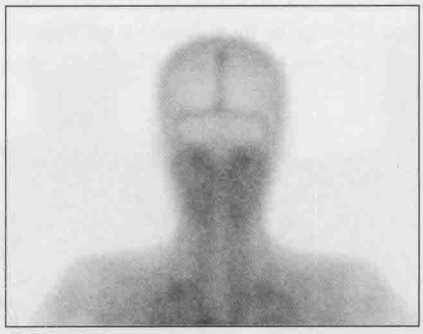
Figure 1.7 ^{99m}Tc-MDP bone scan, anterior and posterior views. Normal whole-body blood pool image. Increased activity in the distal right arm is the site of injection. Incidental asymmetric renal size is noted (*arrow*).

Skull: Normal early blood pool and delayed images

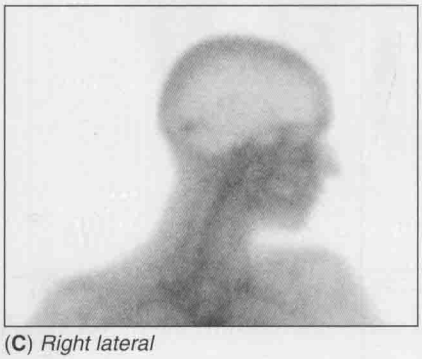
Skull: Normal early blood pool images



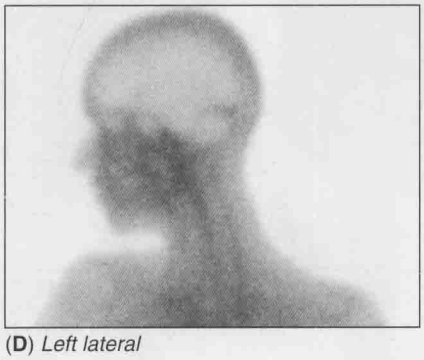
(**A**) *Anterior*



(**B**) *Posterior*

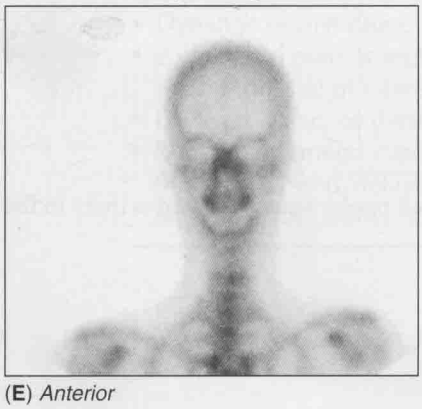


(**C**) *Right lateral*

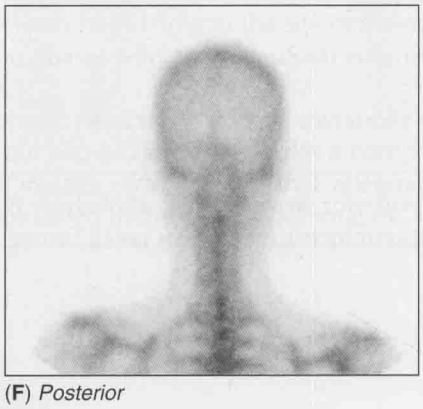


(**D**) *Left lateral*

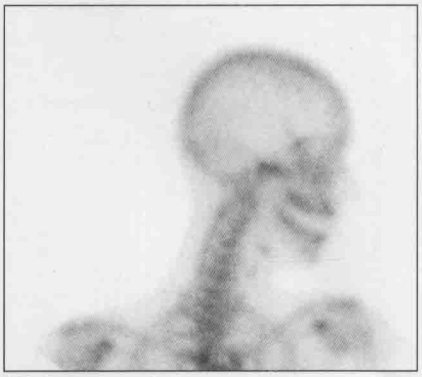
Skull: Normal delayed images



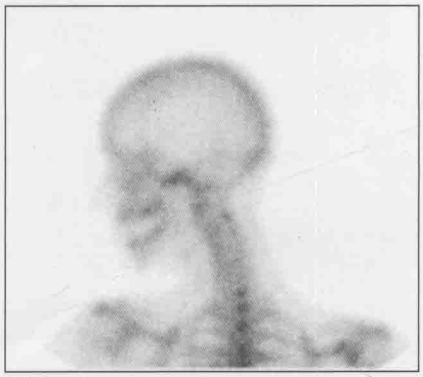
(**E**) *Anterior*



(**F**) *Posterior*



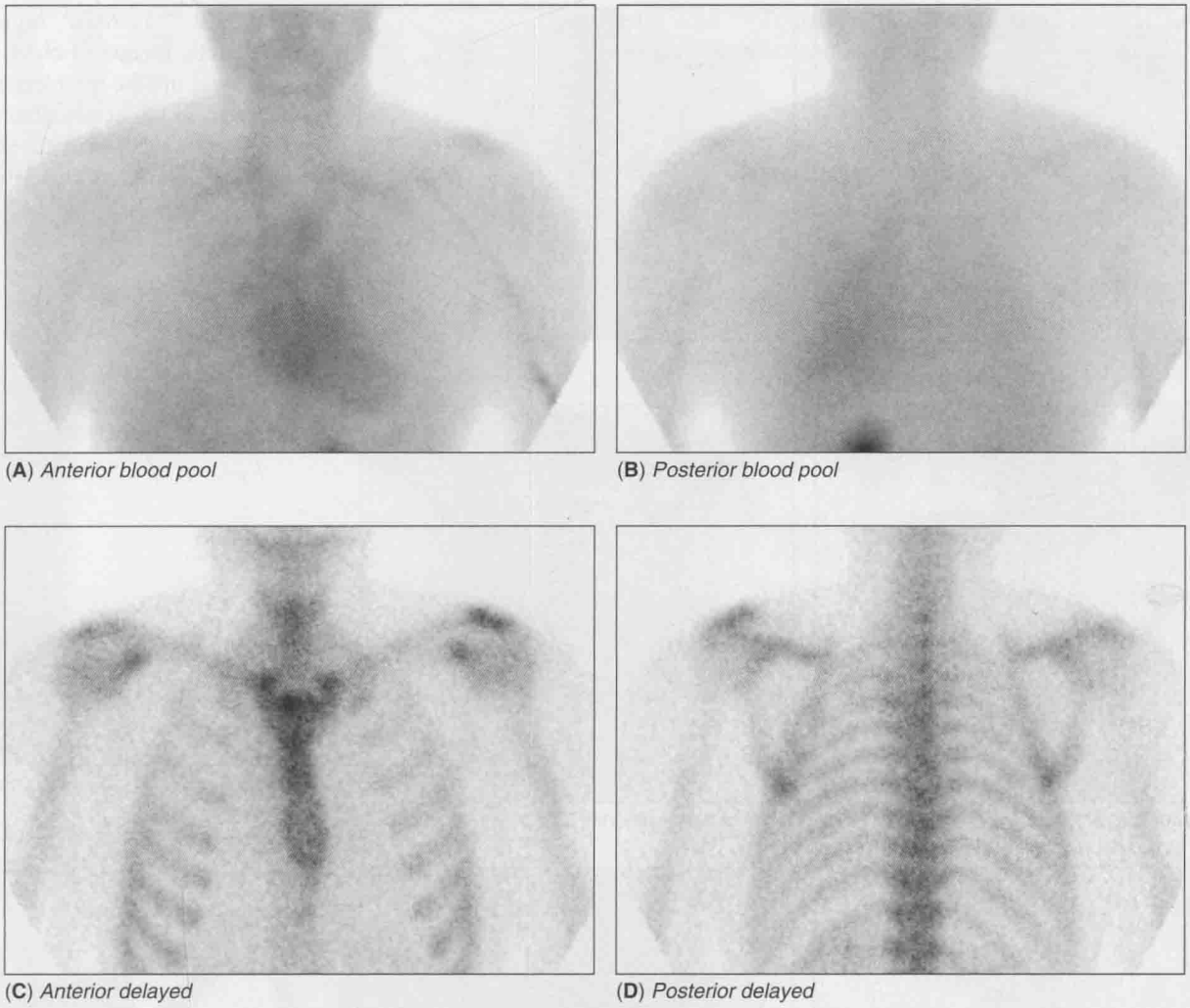
(**G**) *Right lateral*



(**H**) *Left lateral*

Figure 1.8 ^{99m}Tc-MDP bone scan of a normal skull. (**A–D**) early blood pool and (**E–H**) delayed images. The venous sinuses are prominent in the early blood pool images.

Normal blood pool and delayed images of the thorax



(**A**) *Anterior blood pool*

(**B**) *Posterior blood pool*

(**C**) *Anterior delayed*

(**D**) *Posterior delayed*

Figure 1.9 ^{99m}Tc-MDP bone scan. (**A–D**) Normal two-phase bone scan of chest/thorax.

Blood pool images (phase 2) should be acquired immediately after the dynamic phase (phase 1) of the scan. Blood pool images should be completed within 10 minutes post tracer injection.