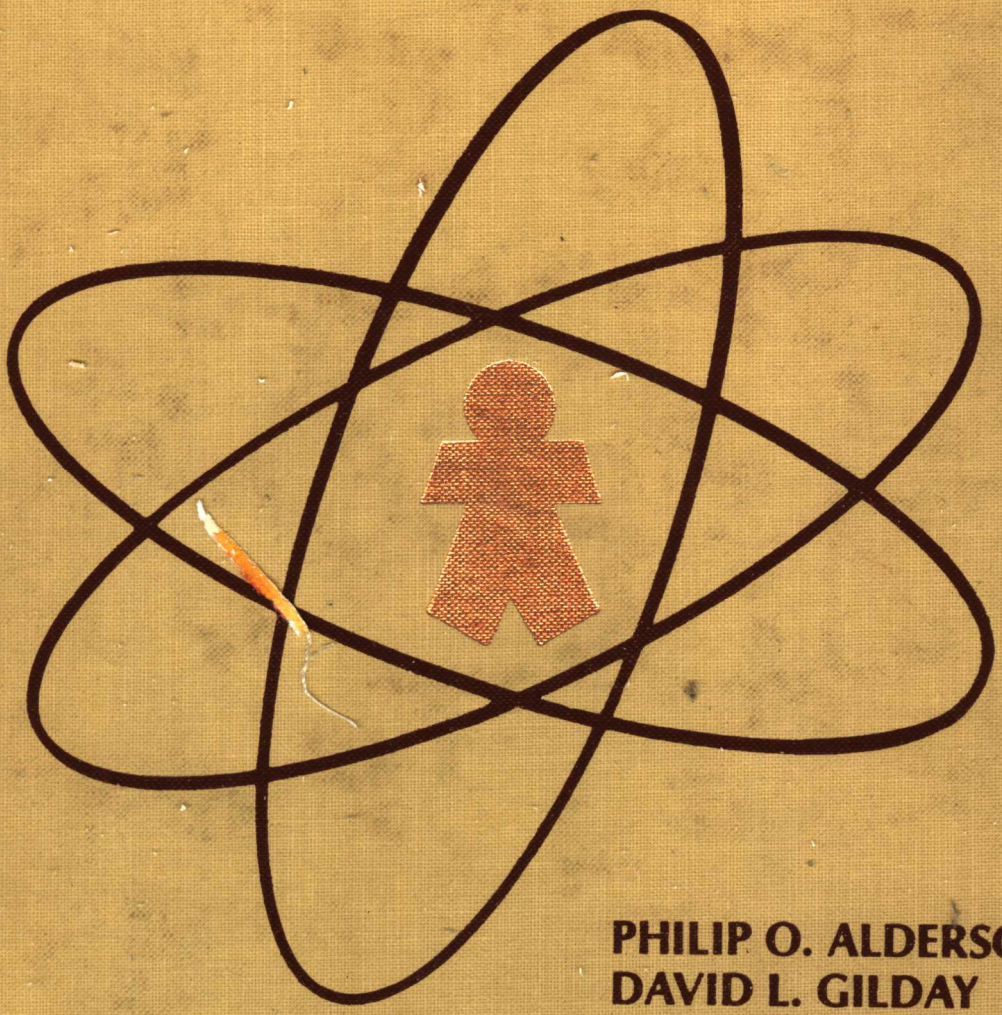
ATLAS OF
PEDIATRIC NUCLEAR MEDICINE



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ATLAS OF
Pediatric nuclear medicine

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Foreword

When I started residency training in diagnostic radiology 25 years ago, I was introduced to the American Journal of Roentgenology, Radium Therapy and Nuclear Medicine. Roentgenology and therapeutic radiology were familiar, but not nuclear medicine. From medical school and clinical practice, I knew a little about radioisotopes, but nuclear medicine seemed esoteric and oriented toward research rather than patient care. Within the University Medical Center where I was studying, the practice of nuclear medicine appeared to be not only embryonic but in danger of morcellation. Sundry individuals from internal medicine, hematology, pathology, and oncology research dabbled in the field, but it was not apparently a viable full-time occupation. The very active physics department seemed more involved than the physicians. I can remember seeing a very primitive-looking scanning device, which was made as part of a Ph.D. thesis by one of the physicists and contained at least some parts of an old bicycle. By 1956 a much more sophisticated scintiscanner had been donated by one of the ladies' societies in the province. The images produced seemed rather coarse and imprecise. At the time, however, my interest was in diagnostic pediatric radiology; nuclear medicine seemed quite remote. It was not really until 1967, when I had the opportunity to plan a new Department of Radiology at the Hospital for Sick Children in Toronto that the desirability of geographic juxtaposition of nuclear medicine and diagnostic radiology in the evolution of medical imaging became apparent. In vitro work, particularly experimental and research projects, were rather remote, but the parallel developments of all forms of in vivo imaging under the umbrella of radiologic sciences was an established trend and one to be followed. In those not-too-far-off days, nuclear medicine physicians were few and from an administrative point of view more secure under the protection of a large department like radiology.

The potential role of nuclear medicine in pediatric practice was such that the trustees of the Hospital for Sick Children and the Toronto General Hospital agreed that a joint division of nuclear medicine to serve more than 2000 active hospital beds would be adequate. It was soon obvious that an autonomous unit geared to the needs of infants and children ought to be established within the Hospital for Sick Children. So, in 1971, when the new Department of Radiology was built, there was a small area comprising little more than 600 square feet and earmarked for "research," which provided the nidus for the present division of nuclear medicine. When Dr. Gilday joined the staff of the hospital, the initial capital budget was in the region of $60,000, or about half the cost of a 1978 gamma

camera. However, a good deal of inventiveness spawned by necessity resulted in the acquisition of refurbished and donated equipment, and the new division was launched within budget. Although in the 20 years preceding 1971 it had seemed to me, as a casual observer, that progress in the development of nuclear medicine had been relatively slow, the pace set by Dr. Gilday during the past few years has been hectic.

The variety of investigative techniques covered in this book mirrors the galloping development of the science of nuclear medicine. Whereas even in the mid 1960s static liver, lung, and brain scans appeared to comprise the major part of in vivo imaging, there is now, as we approach 1980, a burgeoning list of ever more complex techniques. It is significant to me that the opening chapter deals with the skeleton and the final with the central nervous system, underscoring a changing emphasis. The whole explosive development of nuclear medicine has been part of the multidisciplinary field of medical imaging, so that now within clinical practice a physician may attempt to obtain the same diagnostic information from many different sources. Bearing in mind that it is the patient who is at the top of the health care delivery pyramid, it behooves every physician or surgeon to know and keep pace with the specific procedure or combinations of procedures that will improve the level of patient care. These, which may involve routine diagnostic radiology, neuroradiologic and arteriographic procedure and computed tomography, as well as nuclear medicine, are in a state of constantly varying specificity. In an era of continuing diagnostic sophistication and a shrinking health-care budget, it is essential, not only for the good of the patient, but for the good of the community, that each imaging method be used to provide information not available by any other means. The mere confirmation of data obtained by another method is no longer justifiable, except under exceptional circumstances.

Finally it seems clear that whereas nuclear medicine was ideally suited to develop within the nest of general radiology, the fledgling is flying strongly on its own and firmly established as an autonomous discipline with its own society and its own specialty board examinations. Whereas a diagnostic radiologist, and in fact any physician dealing with children, must scramble to keep abreast of the developments in ultrasound, computed tomography, and nuclear medicine, the complexity of each modality is such that one must know enough to realize how little one really does know. It is therefore a comfort that there are people, such as the authors of this book, who are available as expert consultants. This is why this Atlas, which has pulled together a difficult and complicated topic and explained it clearly and concisely, can help any medical practitioner, no matter how unfamiliar with the practice of nuclear medicine, to place it within the overall spectrum of pediatric practice.

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Preface

The material included in the *Atlas of Pediatric Nuclear Medicine* was compiled from the combined experience of the authors at The Johns Hopkins Hospital, Baltimore, Md., and The Hospital for Sick Children, Toronto, Ontario, Canada. This material has been supplemented by cases from Dr. Alderson's previous experience at the Mallinckrodt Institute of Radiology (MIR), St. Louis, Mo. The MIR cases were used with the permission of Dr. Barry A. Siegel, and we express our thanks for his cooperation. This book would not have been possible without the additional support of others who contributed their time and case material. Those contributors include Dr. Massoud Majd, National Children's Medical Center, Washington, D.C.; Dr. Gary Gates, Los Angeles Children's Hospital, Los Angeles; Drs. Walter Berdon and Philip Johnson, Columbia University Medical Center, New York City; and Drs. Judith Ash and Robert Brown, The Hospital for Sick Children. We thank each of these contributors for helping make the *Atlas of Pediatric Nuclear Medicine* possible.

This Atlas is intended to provide a current, easy-to-use source that explains how nuclear medicine is used to evaluate a variety of pediatric problems. Accordingly the Atlas is problem oriented. Cases are presented in the context of the patient's signs or symptoms and demonstrate how nuclear imaging aids the physician's diagnosis and management of that problem. This book provides guidelines to nuclear physicians who are uncertain about the technique or utility of an examination for a specific pediatric problem and will aid pediatric radiologists in deciding when a referral to nuclear medicine is warranted. The problem-oriented approach will make the book interesting to general pediatricians and pediatric specialists and help them better utilize nuclear medicine in their daily practice. In addition the problem-oriented approach will aid students of nuclear medicine, radiology, and pediatrics in understanding the role of nuclear imaging in the diagnosis and management of children with disease. It is our hope that this book will help improve, at least in some small way, the quality of pediatric nuclear medicine and pediatric patient care.

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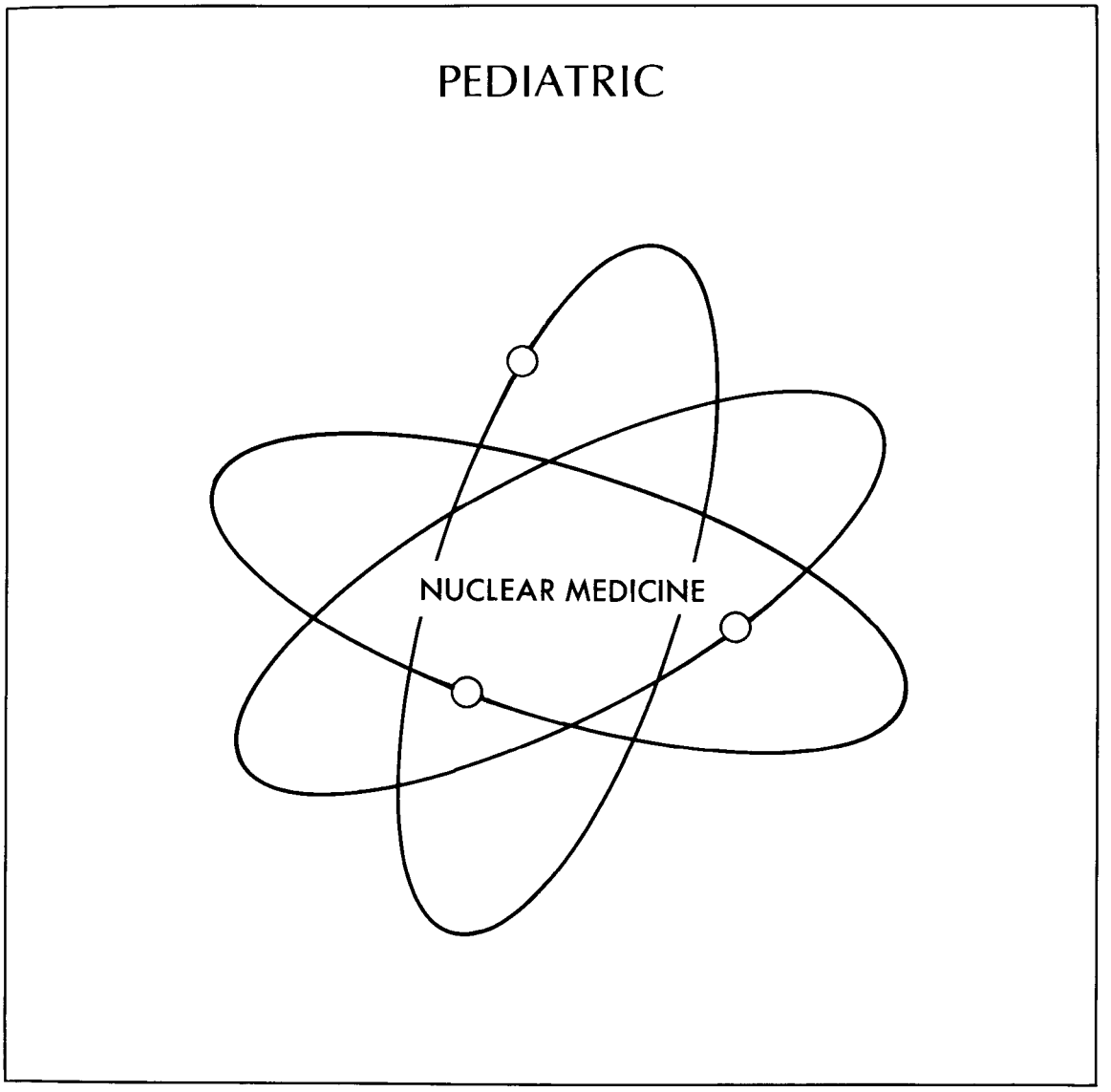
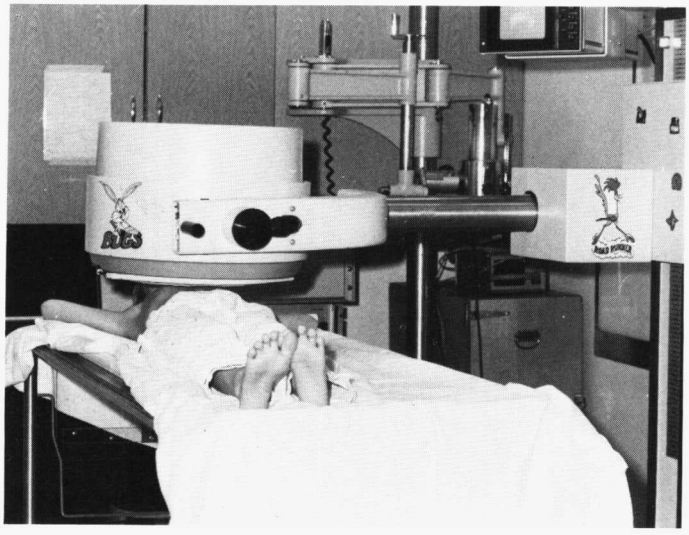


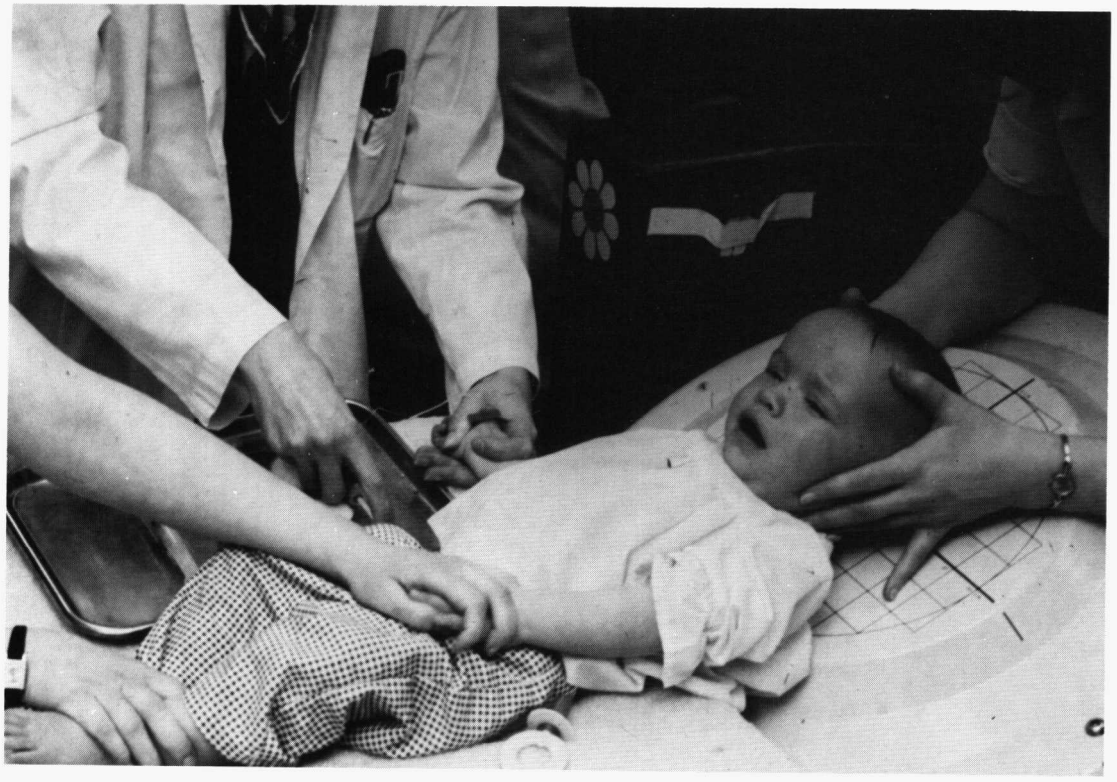
Technical considerations

INSTRUMENTATION

The gamma camera (below) is the imaging instrument of choice in pediatric nuclear medicine. Images can be rapidly acquired, and special attachments, such as pinhole or converging collimators, allow image magnification. This is especially helpful for imaging neonates and infants. Dynamic studies (for example, bone flow in suspected osteomyelitis) can be performed and easily quantitated if a nuclear medicine laboratory computer is available. Views from multiple projections, which are important in many pediatric imaging studies, are easily obtained.



Whenever possible, the examination should begin with the gamma camera behind the patient (below). This is less frightening to young children and will allow the examination to begin in a more friendly atmosphere.



RADIATION

It is important to minimize the radiation dose that children receive from diagnostic procedures. Children have a long life expectancy and their reproductive years are ahead. In addition, there is some evidence to indicate that young, rapidly growing organisms may be more sensitive to the effects of irradiation.

The radiation doses to children from nuclear medicine procedures are low, usually substantially less than comparable radiographic procedures. In order to keep these low doses to a minimum, three important factors—radiation dose, scanning time, and image quality—must be optimized. The smallest dose that will yield diagnostic quality images should be administered to the child. Each image should take no more than 5 minutes, or patient motion may become a problem.

The most common method for calculating the administered dose is based on the child's weight. The per kilogram doses for several common pediatric examinations are given in Table 1-1.

Table 1-1. Pediatric dose schedule

Examination	Radionuclide	Dose (μCi/kg)
Brain scan	$^{99m}TcO_4^-$	215
Meckel scan	$^{99m}TcO_4^-$	215
Angiocardiogram	$^{99m}TcO_4^-$	215
Thyroid	$^{99m}TcO_4^-$	215
Bone scan	^{99m}Tc-phosphate	215
Lung scan	^{99m}Tc–macroaggregated albumin (MAA)	50
	^{99m}Tc-albumin microspheres (HAM)	50
Liver scan	^{99m}Tc–sulfur colloid	70
Renal scan		
Flow, excretion	^{99m}Tc-DTPA	215
Cortical image	^{99m}Tc-DMSA	100
Tumor or abscess scan	^{67}Ga-citrate	40
Cisternogram	^{111}In-DTPA	3

The dose may also be calculated from body surface area nomograms. These charts are widely available in pediatric care facilities. If weight or body surface area charts are unavailable, the administered dose may be estimated as a fraction of the adult dose using the following formula:

$$\text{Child's dose} = \left(\frac{\text{Age [years]} + 1}{\text{Age [years]} + 7}\right) \times \text{Adult dose}$$

Thus a 2-year-old child would receive one third the adult dose.*

*Webster, E. W., and associates: Radiation doses in pediatric nuclear medicine and diagnostic x-ray procedures. In James, A. E., Wagner, H. N., Jr., and Cooke, R. E., editors: Pediatric nuclear medicine, Philadelphia, 1974, W. B. Saunders Co., pp. 36-38.

Technical considerations

When nuclear imaging studies of neonates are done, the injected dose calculated from the child's weight or body surface area charts may be too low to provide technically satisfactory images in the required time. Thus a slightly larger dose must be used. Recommended minimum doses for common nuclear imaging studies are listed in Table 1-2.

Table 1-2. Minimum pediatric doses

Examination	Radiopharmaceutical	Dose
Brain scan	$^{99m}TcO_4^-$	2.0 mCi
Meckel scan	$^{99m}TcO_4^-$	2.0 mCi
Angiocardiogram	$^{99m}TcO_4^-$	2.0 mCi
Thyroid scan	$^{99m}TcO_4^-$	1.0 mCi
Bone scan	^{99m}Tc-phosphate	2.0 mCi
Lung scan	^{99m}Tc-HAM or ^{99m}Tc-MAA	500 μCi
Liver scan	^{99m}Tc–sulfur colloid	750 μCi
Renal scan	^{99m}Tc-DTPA or ^{99m}Tc-DMSA	500 μCi
Tumor scan	^{67}Ga-citrate	500 μCi
Cisternogram	^{111}In-DTPA	25 μCi

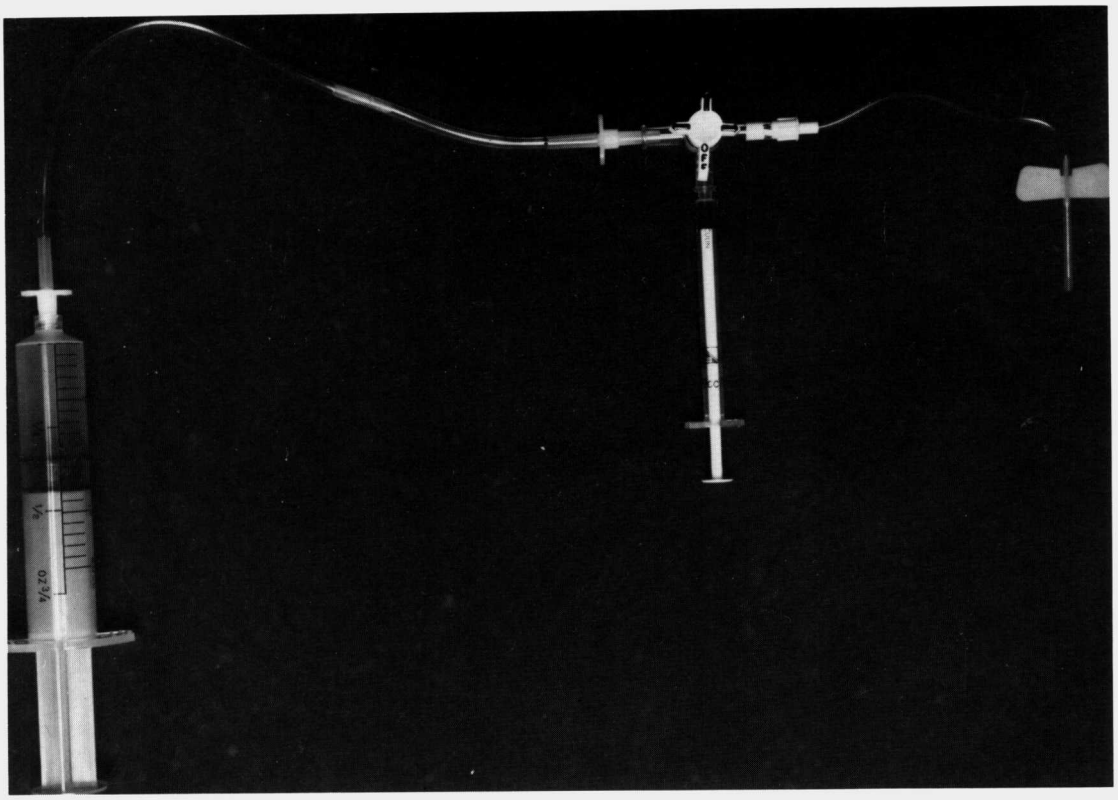
INJECTION

One of the most common problems in pediatric nuclear medicine is achieving an adequate intravenous injection of the radiopharmaceutical. This is especially true when neonates or infants are being studied. Small superficial veins are often present on the wrist or dorsum of the hands or on the feet. The external jugular vein can be used for some examinations such as radionuclide angiocardiography. Table 1-3 lists some guidelines for giving injections to infants and neonates.

Table 1-3. Guidelines for giving injections to infants and neonates

Do	Reason	Don't	Reason
Keep the needle bevel down	To avoid puncturing the back wall of small veins with the needle point	Thread the needle up the vein	The vein will almost surely be cut
Inject a test dose of saline	To ensure that the tracer will not infiltrate the skin	Draw back forcibly on the syringe to check for blood return	The vein will rupture
Flush the syringe after the initial injection	As much as 40% of a small volume dose may remain in the syringe		

To allow delivery of a compact bolus of activity and to facilitate a saline test injection, we recommend the injection set shown below.



In this set the dose syringe is connected to a three-way stopcock, which is attached to a small volume (1.5 ml) extension tube leading to a saline syringe and a scalp vein needle placed in the patient's vein. The saline is used to check the adequacy of the venous cannulation prior to the injection, after which the radiopharmaceutical is injected into the extension tube. Then the saline is used to propel the small-volume dose into the patient. Finally the remaining saline is used to flush the dose syringe of residual activity, and this dose is injected after the flow study is completed.

SEDATION

Patient motion commonly degrades the quality of pediatric nuclear imaging studies. Gentle handling and some physical restraints in nuclear medicine will often allow successful completion of the examination; however, at times sedation may be required to calm an anxious child. Several regimens have been recommended, but we prefer that sodium pentobarbital (Nembutal), 5 mg/kg, be given intramuscularly just before the child is taken to the nuclear medicine department. Rectal suppositories are ineffective, since the child often evacuates them before the desired sedation is achieved. Sedatives should be administered by (or at least in consultation with) the child's physician.

Technical considerations

PATIENT PREPARATION IN PEDIATRIC NUCLEAR MEDICINE

One of the advantages of nuclear medicine is that most procedures do not require patient preparation. Several exceptions will be discussed in the following paragraphs.

The Meckel diverticulum study. Abdominal pain and/or gastrointestinal bleeding in children may be caused by a Meckel diverticulum containing gastric mucosa. These diverticula can be detected with roughly 80% sensitivity by a ^{99m}Tc-pertechnetate abdominal scan. The Meckel scan should be obtained *prior to* barium studies of the gastrointestinal tract, since bowel irritation by barium can cause confusing "hot spots." Similarly, other irritants to the gastrointestinal tract (for example, aspirin taken by mouth) should be avoided. We recommend that the Meckel scan be obtained as the *first screening examination* in these patients. The other tests can then be obtained if the Meckel scan is negative. This examination is best performed after fasting, that is, the last feeding before the examination is eliminated.

Gallium-67 imaging. Gallium-67 is useful for detecting sites of occult abscesses and tumors in children. The examination requires no special preparation before injection. However, images are usually obtained at 24, 48, and 72 (or even 96) hours after injection. Gallium-67 is excreted in part through the colon, so colonic cleansing may be necessary. In some children with abscesses, vigorous bowel preparation may be contraindicated. Bowel cleansing in these children should be advised in consultation with the child's physician. In other children a standard barium enema preparation followed by a tap water enema just before the patient is taken to the nuclear medicine department is advised. If ^{67}Ga colon "artifacts" can be avoided, fewer repeat images will be needed (that is, the patient may require only one bowel preparation instead of one on each of 3 consecutive days). Usually no special diet or fluid restriction is required for ^{67}Ga imaging. It is a common mistake to give children nothing by mouth before ^{67}Ga imaging. We emphasize that this is not necessary.

^{131}I whole-body imaging for metastatic thyroid carcinoma. The goal of ^{131}I whole-body studies is to detect "functioning" foci of metastatic thyroid carcinoma. To accomplish this the patient's normal thyroid tissue must be ablated (this has usually been done surgically), and *maximal endogenous* TSH stimulation is required. We advise that patients be removed from all thyroid supplements 4 to 6 weeks prior to imaging. The patient will receive 3 to 5 mCi of ^{131}I and be scanned at 24 and 72 hours. Two 24-hour urine samples must be collected, one the first *and* one the second day after injection. The samples should be stored in a shielded area if possible, as they may contain significant levels of ^{131}I. The samples should be delivered to the nuclear medicine department when the collections are completed. If the procedure is performed in outpatients, the family should be advised to store the urine in an "out of the way" place. The patient's radiation burden is of minimal risk to him or his family, but excessive contact with the urine sample should be avoided.