PEDIATRIC NUCLEAR MEDICINE

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DEDICATION

Dr. Freeman wishes to dedicate this volume to the memory of Jack Storm, M.D. (1927–1975), a dedicated pediatrician with extraordinary insight into the problems of the young.

Preface

THE ISSUES of "Seminars" encompassed in this hard cover edition were originally published in October, 1972 and January, 1973. The various articles represent a broad overview of the specific area of Pediatric Nuclear Medicine. As we indicated in the editorial comments made at the time of original publication, the use of radionuclide studies in children is justified in most cases by an extremely favorable benefit-to-risk ratio. Most pediatricians are rightfully very protective of their young patients and must be thoroughly convinced of the value and safety of a procedure before they will allow its use. The dosimetric data presented by Kereiakes and his co-workers strongly supports the safety of these procedures. Similarly the balanced clinical material presented in the remainder of these articles testifies to their great usefulness; often in situations where other diagnostic studies may be lacking.

In the past 2–3 yr, we have witnessed the continued acceptance of most of these studies as routine modalities in the work-up of the pediatric patient. Most of the described procedures and results remain reasonably up to date. The one major exception to this is bone imaging where the introduction of the ^{99m}Tc-labeled phosphate agents have greatly facilitated studies in benign osseous disorders in addition to neoplastic disease. We therefore have invited Dr. Hirsch Handmaker of the Children's Hospital of San Francisco to write an additional chapter for this book describing many of these newer applications associated with the "phosphate era."

This volume is not intended to present a comprehensive review of all of the radionuclide studies available in the pediatric age group. Other larger and more detailed texts are available to accomplish that purpose. It is instead hoped that this "mini text" containing two well received issues of the "Seminars" will serve as a useful introduction to Pediatric Nuclear Medicine.

Leonard M. Freeman, M.D.
M. Donald Blaufox, M.D., Ph.D.

Letter From the Editors. I*

THE APPLICATION of nuclear medicine techniques to pediatric practice has occurred at a considerably slower pace than in the other medical specialties. Physicians who deal with children rightfully are quite cautious about the introduction of any new diagnostic procedure, particularly where an additional radiation burden is involved. It seems more sensible to wait and see the value and safety of a proposed new procedure proven in adults before allowing its application to patients where the margin for error is considerably less. Most new diagnostic tests tend to have a very short half-life. Careful dosimetric data, such as those presented in this seminar by Kereiakes and his co-workers have helped convince the pediatrician that properly administered diagnostic radionuclide studies result in a very small radiation dose which in most instances is considerably less than that of the usual roentgenologic examinations used to study the same problem, e.g., radionuclide cystography for the study of vesicoureteral reflux results in a gonadal dose of approximately four to 5 mrad, while its roentgenologic counterpart is estimated at approximately 300 mrads to the gonads of boys and 1000 mrads to the gonads of girls.

Once these radiation data are carefully reviewed and accepted, the diagnostic worth of these procedures must also be proven. This requires considerably more time than initial experiments necessary for dosimetry estimations and clinical feasibility trials. Children are not merely small adults; they have normal developmental patterns and present many disease processes that are unique to them alone. Although studies in adults are necessary initially and may be used to establish safety and potential clinical value, the data accumulated through these studies cannot be directly extrapolated to children. With the ever increasing acceptance and use of pediatric radionuclide studies, the literature has finally accumulated the several years of clinical experience that are necessary to attempt an evaluation of any new diagnostic method. Several of the reports in this issue and the next are from physicians whose practice is confined solely to childrens' hospitals. The establishment of Nuclear Medicine services in such institutions itself represents significant progress and proof of its increasing acceptance.

The initial plans for this seminar projected the subject matter to be covered in one issue. After reviewing the manuscripts submitted by our contributors, most of which exceeded their page allotment, we decided to expand the seminar to two issues (Part II will appear in January, 1973). This permitted us to add several topics as well. We have asked Dr. James Conway of the Chicago Children's Hospital to attempt to place the general topic in perspective and to discuss some of the unique considerations involved in the use of radionuclide studies in children. The subsequent manuscripts systematically review the organ systems with special reference to pediatric problems. We trust that these discussions place the procedures in perspective and answer many of the questions posed by individuals interested in this area of investigation and practice.

A word of caution also is necessary. There are included here several subjects

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**This letter refers to the first seven chapters of this book, pages 1–84, originally published in October 1972.*

which still to be considered in the category of clinical investigations. They are included for the purpose of informing the reader of the "state of the art." They are not meant to be the basis of broader clinical application. In this category in this issue are the articles concerning detection of Meckel's diverticulum and measurement of body compartments. Only further experience in these areas will help determine their exact role in the pediatrician's armamentarium.

Leonard M. Freeman, M.D.
M. Donald Blaufox, M.D., Ph.D.

Letter from the Editors. II*

MANY OF THE VIEWS expressed in this, the second, portion of the Pediatric Nuclear Medicine seminar have already been discussed to a large extent in our previous editorial comment (see Vol. II, No. 4, October 1972). Throughout these articles the same basic theme recurs: The application of radionuclides to the study of diseases in children is justified by the great potential for gathering diagnostic information. All the authors continue to note their caution because of the ongoing fear of possible somatic or genetic effects of radiation in youngsters. Although the field of nuclear medicine in no way should be construed as a competitor to diagnostic radiology, certain remarks here deserve reemphasis. Repeated radiographic examination can often be avoided by the consideration of an alternate radionuclide technique. In specific clinical situations this approach may provide all the necessary information for the physician to chart his therapeutic program without risking as large a radiation burden to the patient.

At a recent meeting of the Executive Section of the Scientific Committee for the June 1973 meeting of the Society of Nuclear Medicine, the question was raised whether or not pediatric nuclear medicine is, in fact, a distinct discipline that is different from adult nuclear medicine. Just as pediatric practice differs from the practice of internal medicine, so does pediatric nuclear medicine differ from adult nuclear medicine. Both areas have a considerable degree of overlap. The young adult and the adolescent child are in many ways very similar, although certainly some distinct physiologic differences exist. The tools of the trades are essentially the same: in one case a stethoscope and the examining hands; in another case the supplementary capabilities provided by radiation detection equipment. However, there are differences in the disease entities encountered. Dandy Walker cysts, tumors of the posterior fossa, congenital cretinism, functional asplenia, crossed renal ectopia, and a wide variety of other diseases are more commonly encountered in the pediatric age group. Indeed, some are never encountered by the internist. These and other considerations necessitate a special discussion of pediatric applications of radionuclides. Just as neurologic, pulmonary, and other studies warrant individual issues of *Seminars* and special types of training for practitioners, so does pediatrics.

Leonard M. Freeman, M.D.
M. Donald Blaufox, M.D., Ph.D.

*This letter refers to chapters eight through thirteen, pages 85–190, originally published in January 1973.

Contents

Considerations for the Performance of Radionuclide Procedures in Children

By James J. Conway

A valid informed consent must be obtained by the admitting physician for routine hospital services, diagnostic procedures, and medical treatment. The matter of consent for children for radionuclide studies is considered comparable to that for routine roentgenographic procedures and thus is covered by the general consent form signed by the parent upon admission to the hospital. A second consent must be obtained for the therapeutic use of radionuclides and for the use of radionuclides for research in children. Therapeutic research, implying the probability of immediate or delayed benefit to the child studied, requires a separate consent. Parental consent may not be valid for nontherapeutic research, i.e., research where there is little probability of benefit to the child studied. Recommendations for preparation of children for nuclear imaging are given in this review. Dosage tables for radiopharmaceuticals used in routine imaging studies, and potassium perchlorate and Lugol's solution dosage schedules are offered. Pediatric dosimetry is discussed elsewhere in this seminar. A sedation technique for younger children, including dosage schedule, is described. Children cannot be treated as small adults. They present special problems that relate to their age and stage of development. This review attempts to place these unique requirements in perspective and to help the reader become aware of them.

THE USE OF RADIONUCLIDES in children for diagnostic purposes has increased considerably in recent years. Previous reluctance to use the innovative techniques of nuclear medicine, particularly by the pediatrician, because only long half-life radionuclides and less than ideal imaging equipment were available, was probably justified. But this reluctance is receding with the increasing availability of shorter half-life radionuclides, particularly ^{99m}Tc pertechnetate, and with the use of rapid imaging devices such as the gamma camera.

The increased use of radionuclides in pediatrics has prompted the establishment of nuclear medicine facilities in a number of children's hospitals this past year. Interest has been further reflected and stimulated by the addition of scientific sessions devoted to pediatric nuclear medicine at the annual meetings of The Society of Nuclear Medicine, in the presentation of a recent symposium on Pediatric Nuclear Medicine[1] and of course, by these two Seminars, which are devoted entirely to pediatric nuclear medicine. As the indications for and the value of both new and established techniques become better known to the

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practicing pediatrician, an ever increasing work load of pediatric patients will present to the nuclear medicine laboratory. With them will also come the unique problems of handling children, for the child is not a miniature adult. His problems, diseases, and responses are radically different from the adult's. I would emphasize that nuclear medicine is a distinct unique medical discipline which requires special facilities, equipment, and personnel. Nuclear medicine technologists are required to have extended training beyond that of the laboratory or X-ray technologist. The nuclear medicine specialist performs his services on a consultative basis, for there is no routine study when handling children.

The editors have requested that I address myself to the problems of radionuclide imaging in children, in particular to the recurrent questions most often asked about the medico-legal aspects of using radionuclides in children, including the area of research, and the problems of handling children for imaging studies.

Medico-Legal Aspects of Radionuclide Use in Children

Relatively little has been written on the medico-legal aspects of the use of radionuclides for diagnostic purposes in children. A search of the literature has produced a considerable volume of somewhat related material concerning (1) consent for medical or surgical treatment of minors;[2,3] (2) the effect of diagnostic and therapeutic doses of radiation on the fetus;[4] (3) the effect of therapeutic doses of radiation on the child;[5] and (4) the complexity of benefit–risk relationships and their role in the above.[6] (References 4–6 are suggested for extensive bibliographies on these topics.)

Certain conclusions have been reached from this information and extrapolated to the use of diagnostic radionuclide examinations in children. I cannot qualify as an expert in legal matters, thus these conclusions are of necessity personal opinions that satisfy my immediate needs to function as a medical practitioner in the developing field of pediatric nuclear medicine. I offer them for consideration as possible suggestions for other practitioners of pediatric nuclear medicine faced with the same questions.

The Necessity for Consent

The law provides that anyone who intentionally takes an action which affects the body or mind of another person, without the legally valid consent of that person, is liable for damages unless there is a specific legal justification for that action. To be an effective defense against such liability, consent must be informed and voluntary. The procedure or therapy must be described in nontechnical terms and must explain any unusual hazard or risk of complications inherent in the procedure or therapy.[2]

Obviously, all the risks, from trivial to substantial, cannot be individually discussed or explained, except possibly in a comprehensive manual which would be inadequate as soon as a new technique or heretofore unknown hazard arose; therefore, most standard procedures are covered in a general written consent form which is signed upon admission to the hospital. This

form provides a record of consent to routine hospital services, diagnostic procedures, and medical treatment.[3] A special, signed consent form should be procured prior to every medical or surgical treatment, with the exception of the routine treatment mentioned above. An oral consent, if proved, is just as binding as a written one, but oral consent may be difficult to substantiate in court.[3] A written consent is obtained to ensure proof of valid consent.

The informed consent does not absolve the physician from liability for inappropriate treatment. The ultimate responsibility for the patient's care remains with the physician, and so it behooves him to receive formal written consent for any procedure that carries an unusual risk or increased hazard that is out of the ordinary.

The Capacity for Consent[2]

Children who have not reached the age of discretion are not usually recognized as legally capable of giving consent on any matter. To whatever extent a person is incapable of giving consent, the law grants to some other person the authority to act for him, at least for limited purposes. Generally, it is the parent or legal guardian who is responsible for the consent. A parent who himself is a minor may legally give consent for his child. It is also generally agreed that consent is not needed in the case of an emergency or when unnecessary delay may prove detrimental to the health of the child. The laws of each state vary on the problem of consent; one should determine those that are applicable in his own area of practice.

The Necessity for Consent for Radionuclide Use in Children

Most of the foregoing statements have application for medical or surgical procedures which carry an implied or known hazard or risk with them. When they are applied to the use of radionuclides for diagnostic purposes, it may be difficult to determine if they are still binding. For example, it is most difficult to determine the risks involved in the small doses of radiation which are received from diagnostic tests. While animal experimentation provides some insight into the problem, it does not give definitive answers to the questions posed for humans.[7] In addition, much of the information on the risk of diagnostic doses of radiation is extrapolated from data derived from moderate or high doses of radiation; any effect from low doses of radiation to the child has not been demonstrated or proved. Furthermore, the extrapolation of data from the limited studies in humans is susceptible to the faults of retrospective studies in general.[8] Indeed, recent studies have arrived at conflicting viewpoints.[9]

As discussed by Saenger, the demonstration of radiation-linked genetic changes in the human has been extremely difficult, but it is generally conceded that there is no reason to doubt these genetic effects.[5,6] Again, most of the reports are either about the effect of therapeutic radiation doses in children or the effect of diagnostic or therapeutic radiation doses upon the fetus.

Somatic effects are even less well documented. The induction of neoplasia has been implicated with therapeutic doses of radiation; but, as pointed out

by Gibson,[10] factors other than radiation, such as viruses, may play as vital a role, if not a more important one.

Saenger[5] concludes that in older children and adults there is no evidence of an increase in somatic effects following diagnostic irradiation of any kind and that with current practices, using good techniques, there need be no further decrease in permissable radiation limits.

Even in the presence of risks, potentially substantial benefits may be seen to outweigh those risks and therefore warrant them. The problem exists in defining what is a benefit. Not only is the definition of a benefit difficult; but how does one measure it? For example, does a procedure alter the course of a disease process or prolong the life of a patient? Is that alteration or prolongation of life worthwhile or even humane? Is the procedure less costly, less painful, simpler, more accurate than a comparable study? These questions and many more are difficult to answer, and it is almost impossible to find valid controls to compare one against the other.[11,12]

Furthermore, it is difficult to compare radiation doses from radionuclides to that from roentgenography or X-ray therapy, upon which many of the cited risk examples in the literature are based. In addition to differences in dose rate, total body irradiation must be considered with radionuclides, whereas a properly collimated X-ray beam irradiates only localized areas. Moreover radionuclides may localize in one or more organs, producing a much higher dose to that organ than would be suspected from total body measurements. The critical organ limiting the amount of radionuclide administered may not even be the organ of interest, e.g., the dose which the gastrointestinal tract receives from ^{99m}Tc pertechnetate during brain imaging.

With the selection of proper radionuclides, proper doses, and proper detection equipment, there has been a considerable reduction in radiation from that of earlier methods, and this dose usually is less than that from comparable roentgenographic techniques. One example is the radiation dose to the gonads during radionuclide cystography, seeking vesicoureteral reflux, which is approximately 100 times less than that from comparable roentgenographic methods.[13] In general, one can say that the radiation dose to the child from present day radionuclide examinations falls within the range of that received during routine roentgenographic procedures.

The matter of consent for radionuclide studies in children is considered comparable to that for routine roentgenographic studies. The general consent form signed by the parent upon admission allows the routine hospital services, diagnostic procedures and medical treatment to be given, and thus covers diagnostic radionuclide examinations. An individual consent for each routine diagnostic study is not needed, nor is it feasible. Any examination or therapy which is out of the ordinary, however, requires a separate written consent. This would include therapy or research with radionuclides.

Research with Radionuclides in Children

The question of whether or not one may use radionuclides in children for research is an even more ticklish problem. Again, little has been written about

the effect of diagnostic levels of radiation in children, particularly that used for research. The same problems inherent in determining risks and benefits in procedures are even more pronounced in research, for the benefits here are theoretically even less well known.

Two categories of research should be considered: therapeutic and nontherapeutic. Therapeutic research implies that the results of a given experiment, test, or treatment have a probability of providing immediate or delayed benefit to the patient. Schreiner[14] has further categorized the types of human research into five grades. Grade One implies that there may be immediate benefit for the patient's clinical condition. An example of this would be the use of a proven radiopharmaceutical for another purpose, such as ^{99m}Tc pertechnetate for radionuclide cystography. A written informed consent is still required, such as was used in a recent prospective study at The Children's Memorial Hospital (Fig. 1).

A Grade Two type of research implies that the results may provide a delayed benefit to the patient for his known or suspected clinical condition. An example might be the use of a new radiopharmaceutical or diagnostic test to document the excretion of certain products such as in mucopolysaccharidosis. A Grade Three type of research would involve conditions that the child may acquire with a high degree of probability, such as certain infectious viral diseases.

Grades One, Two and Three could be considered as therapeutic research, for the benefit of the results would affect the child involved in the study. A formal informed written consent from the parent or guardian should suffice in these instances of therapeutic research.

Nontherapeutic research would imply that there is no expectation of either immediate or delayed benefit to the child. Schreiner's[14] Grades Four and Five would fall into this category.

Where there is no expectation of immediate or even delayed benefit to the

Your child has been referred to the Radiology Department for an examination of the bladder and kidneys in an attempt to evaluate or seek a cause for his symptoms. To perform the study of cystography, a catheter will be inserted into the bladder. Through this catheter we instill a solution of an iodine containing compound which shows the outline of the bladder when X-rays are taken. We are particularly interested in demonstrating abnormal passage of the urine from the bladder back into the kidneys. This phenomenon is known to be correlated with urinary tract infection.

We would like to study this problem with a similar method except we will be using a radioisotope instead of the iodine compound. X-rays will not be used to visualize the bladder during the isotope study. The radioisotope has been used in countless number of examinations of the brain after intravenous injection. To our knowledge there has not been recorded an adverse reaction to this material. The radiation from this examination has been calculated to be 100 to 300 times less than that of the X-ray studies and we therefore believe that this examination may be a better procedure for evaluating children with kidney problems. To prove this we must correlate the findings of the radionuclide study against those of the X-ray study. Therefore we are requesting that you allow us to perform this study on your child in addition to the X-ray study with the understanding that it is a research technique which to our knowledge contains no perceptible additional hazard to your child and potentially may be extremely useful in the evaluation of children with these problems.

_____
Signature of Parent or Guardian
Consenting

_____
Witness

Fig. 1. Permission for radionuclide cystography.

child, the problem of consent becomes most difficult because the courts have made it clear that a child is not the property of his parents and may not be dealt with by them without regard for his best interests. In a number of cases, e.g., the courts have intervened to order medically indicated blood transfusions over the objections of the child's parents. Indeed, the parent may be culpable if the child is exposed to unnecessary danger. Consequently, the validity of the parent's consent to the use of a child for clinical investigation that is not medically indicated for the child's benefit may be doubtful as a defense against a liability claim.[2] An example of this would be the use of a radionuclide in a normal child to establish normal values. Perhaps a third party arbitrator to decide the merits and risks of such a study can be established. In fact, the requirement of the National Institutes of Health for peer review and approval of all human investigation sets this precedent.

Policy for the Use of Radionuclides at The Children's Memorial Hospital

(1) The general consent form signed by the parent or guardian suffices for all diagnostic radionuclide studies. In addition, the study is usually discussed with the parents. (2) An additional written informed consent must be obtained if radionuclides are to be used for therapeutic purposes. (3) Therapeutic research requires a written informed consent from the parent or guardian after approval of the project by the Human Use and Research Committees of The Children's Memorial Hospital and the Human Use and Radioisotope Committees of Northwestern University, under which the individual radioisotope licenses are issued. (4) Nontherapeutic research with radionuclides in children has not been approved at The Children's Memorial Hospital.

Recommendations for dose limits in research have been made for the child.[12] The suggested limits for acceptable dose in 1 yr is 0.5 rem for the fetus and 5 rem for the newborn infant and child. The acceptable total dose is the same.

General Imaging Procedure

The choice of radiopharmaceutical, the amount used and the technique of imaging is dependent upon many factors. These include the age, size, and condition of the child; the radionuclide and type of detection equipment available and the information desired. Of course, one must choose the combination of factors that will give the necessary information with the least risk to the child. The risks one should be most concerned about are the possible genetic effects which the child may transmit during his reproductive years and, to a lesser extent, the somatic effects. Suffice it to say, one should use the most appropriate technique or radiopharmaceutical. For example, one should not use ^{198}Au colloid for liver scanning when ^{99m}Tc sulfide colloid is readily available.

It has also been established that the radiation to an infant is greater for a given amount of radiopharmaceutical than to an older child or adult.[15–17] This is particularly important when considering the use of ^{131}I in the newborn period. The thyroid has a great affinity for iodine in the first few weeks of life and

thus it is recommended[17] that such studies be postponed for at least 2–3 wk following birth unless the diagnosis is of paramount importance.

Calculations of radiation dose have been made for pediatric studies[13,15,17–19] and need not be reiterated here. These values may also be obtained from Kereiakes and co-workers.[19a] The administered dosage for the more common studies performed at The Children's Memorial Hospital is listed in Table 1. Also listed are the administered dosages for potassium perchlorate and Lugol's solution. The choroid plexus is sometimes noted in the lateral projection on the early brain scan views with these dosages but usually rapidly disappears. Excessive Lugol's solution, i.e., adult doses, in the newborn or infant seems to induce vomiting after several days.

Sedation Technique

When performing imaging studies in children, one attempts to achieve a balance between the amount of radionuclide needed and a practical imaging time. The imaging time is of prime concern in attaining a satisfactory study, because motion can obscure results even with the most sophisticated equipment designed to improve resolution. One must arbitrarily choose a time which allows for adequate data acquisition while still maintaining an acceptable radiation dose to the child. In most studies with a gamma camera, this ranges from 3 to 7 min and averages approximately 5 min. With infants and children, especially those between 6 mo and 3 yr of age and retarded or hyperactive children, cooperation for this length of time is virtually impossible.

Immobilization has been attempted by swaddling in towels or bed sheets,

Table 1. Pediatric Nuclear Medicine Dosage Schedule: The Children's Memorial Hospital

Procedure	Radiopharmaceutical	Dosage
Brain scan	^{99m}Tc pertechnetate	100 μCi/lb
Ventricular scan	^{131}I high specific activity Human serum albumin	50–75 μCi
Subarachnoid scan	^{131}I high specific activity Human serum albumin	50–100 μci
Thyroid scan	^{99m}Tc pertechnetate	1–2 mCi
Thyroid uptake	^{131}I sodium iodide	2–5 μCi
Lung scan	^{99m}Tc human albumin Microspheres	25 μCi/lb minimum 500 μCi
Liver	^{99m}Tc sulfide colloid	25 μCi/lb minimum 500 μCi
Liver function and scan	^{131}I rose bengal	25–50 μCi
Renogram–renal scan	^{131}I orthoiodohippurate	50–100 μci
Radionuclide cystogram	^{99m}Tc pertechnetate	1 mCi
Radionuclide angiogram	^{99m}Tc pertechnetate	125 μCi/lb

All patients given ^{131}I also receive Lugol's solution prior to and for 5 days following the examination with these exceptions: (1) thyroid uptake, (2) allergy to iodine, and (3) Omit post study doses of Lugol's solution if renal function is normal when using ^{131}I orthoiodohippurate.

Dosage schedule. Lugol's solution: 0–1 yr, 1 drop t.i.d. 1–4 yr, 2 drops t.i.d. 4+ yr, 3 dros t.i.d. Potassium perchlorate: 0–1 yr, 150 mg; 1–4 yr, 300 mg; 4+ yr, 450 mg.

taping, sand bagging, head clamping, fixation to brat boards, and even the simple mechanism of forcibly holding the child. Each of these methods has its disadvantages. Visual appraisal of the patient's color and respiratory rate is inhibited by those techniques that hide the child. Clamps or sandbags can absorb radiation, producing unwanted imaging artifacts. Tape adheres to hair, producing discomfort during removal and inhibiting slight positioning changes; some patients are even allergic to tape. Overheating may occur in infants who are swaddled or immobilized with sheets or sandbags.

The best restraint is adequate sedation. With judicious use, the previously mentioned items (tape, straps and sandbags) inhibit subtle motion, but none should be used as the principal device for immobilization. At the same time, various sedatives or sedation mixtures that have been advocated are often found to be ineffective. A variety of sedation agents have been tried, including phenobarbital, secobarbital, chloral hydrate, and ketamine. The last agent requires the ready availability of an anesthesiologist, which limits its usefulness.

The basic requirements for satisfactory sedation include ease in administering, relief of pain and anxiety, adequate immobilization during the period of examination, and minimal morbidity. A broad margin of safety in the dosage to compensate for variable individual responses is helpful. None of the previously mentioned agents meets all of these criteria.

At The Children's Memorial Hospital, a sedation mixture of meperidine hydrochloride–promethazine hydrochloride–chlorpromazine (Demerol–Phenergan–Thorazine) administered on the basis of weight has been our most successful agent in achieving satisfactory sedation for nuclear imaging[20,21] (Table 2). This formula has been adapted from that used for cardiac catheterization and roentgenographic angiography at The Children's Memorial Hospital. This formula or variations have also been used by other children's institutions.

The necessity for prolonged, deep sedation should be discussed with the referring physician. His assessment of the child's general health, activity, and clinical presentation warrants priority in ordering the sedation. A decrease from the indicated dose is suggested in debilitated children, brain damaged children, or in children with respiratory depression.

Rarely, mentally retarded or hyperactive and disturbed children will require additional sedation above the recommended dose. When necessary, an anesthesiologist is requested to give the additional sedation during the study.

Table 2. Sedation Mixture

Meperidine hydrochloride (Demerol)		50 mg/cc
Promethazine hydrochloride (Phenergan)		25 mg/cc
Chlorpromazine (Thorazine)		25 mg/cc
Weight in pounds	cc of each	
10–20	0.2	
20–40	0.5	
40–60	0.6	
60–80	0.7	
80–100	0.8	
100+	1.0	