Management of the Pediatric Nuclear Medicine Patient (or Children Are Not Small Adults)

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This is the first of a four-part continuing education series on pediatric nuclear medicine. After reading and studying this article, the nuclear medicine technologist will be able to: (1) identify clinical indications for performing nuclear medicine studies in children; (2) compare and contrast nuclear medicine procedures for adult and pediatric patients; (3) compare and contrast radiopharmaceuticals to select the most appropriate for performing pediatric studies; (4) discuss radiation protection techniques used in pediatric nuclear medicine; (5) identify the principles of pediatric radiopharmaceutical dose calculation and determine dosages using common calculation methods; (6) identify possible injection sites and administration methods useful in pediatric nuclear medicine; (7) compare radiopharmaceutical clearance times and imaging times in adults and children; (8) identify the collimators of choice for most procedures performed in children; (9) recognize certain behaviors exhibited by children according to their stage of emotional development and anticipate children's response to the hospital setting; and (10) describe patient immobilization techniques and discuss the advantages of physical restraint over sedation. Information about CEU (VOICE) credit appears immediately following this article.

Working with children can be fun and rewarding but it can also be difficult and trying. Children, especially sick children, need special technical and psychological attention to ensure a quality study with maximum patient cooperation. We discuss the techniques that allow a pediatric patient's visit to the nuclear medicine department to be productive and pleasant.

Technical Considerations

Types of Studies: The types of nuclear medicine studies and the indications for performing them differ accordingly for adult and pediatric patients. This is due to basic differences in disease modalities and congenital anomalies. Pediatric nuclear medicine studies tend to be more invasive owing to the nature of the examinations. They can also be perceived as threatening to a child because of cognitive immaturity and his developmental stage.

Gastroesophageal reflux can occur in both adults and children but its determination is especially important in infants who have a history of recurrent and excessive vomiting. It may be accompanied by wheezing, respiratory distress, and aspiration pneumonia, and has been associated with apnea and sudden infant death syndrome (*1*). To image gastroesophageal reflux in adults, the patient drinks a radiopharmaceutical. In infants, however, a nasogastric tube may have to be inserted prior to the examination, which may be unpleasant.

Renal abnormalities are common in children and consequently renal imaging and radiocystourethrograms are done frequently. Common indications include recurrent urinary tract infections, enuresis, hydronephrosis, tumor, congenital defects, and ureteral reflux, which is usually only found in children. The renal image requires an intravenous injection, while the radiocystourethrogram requires catheterization.

Thyroid imaging is common to both adult and pediatric nuclear medicine but the indications differ. Adults are imaged primarily for neoplasm or nodule evaluation. On routine blood studies many neonates indicate a hypothyroid condition, necessitating a scan to determine if there is functioning thyroid tissue. The clinically hypothyroid infant may have a lingual, sublingual, or absent thyroid gland.

The child who exhibits rectal bleeding with or without abdominal pain may be imaged for presence of Meckel's diver-

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ticulum, a condition usually manifesting itself in childhood.

Bone imaging is probably the most commonly performed procedure in both adult and pediatric hospitals. Children again differ in their pathology. Some indications for imaging include osteomyelitis, juvenile rheumatoid arthritis, Legg-Calve-Perthes disease, sickle-cell anemia crisis, and child abuse.

Cholecystitis is the most common indication for hepatobiliary imaging in the adult but in the infant it is used to differentiate between biliary atresia and neonatal hepatitis.

Choice of Radiopharmaceutical: When choosing a radiopharmaceutical one must keep in mind a child's special needs and limitations.

Iodine-123 capsules were a great improvement over I-131 for thyroid imaging because of lower radiation dose, short half-life, and optimal energy for gamma camera imaging. Unfortunately, most small children and infants cannot swallow capsules. Iodine-123 oral solution, however, allows the benefits of capsules without the administration problem. If no uptake is required, [^{99m}Tc] pertechnetate can be administered. To further reduce the radiation dose to the thyroid gland, potassium perchlorate (4 mg/kg) may be used when indicated.

Bone scans should be performed with compounds that have the most rapid clearance time.

Technetium-99m PIPIDA is more advantageous than I-131 Rose Bengal in terms of delivered radiation dose, activity, energy for the gamma camera, and overall image quality in differentiating between biliary atresia and neonatal hepatitis.

Dosage and Administration: There are several methods available to calculate pediatric radiopharmaceutical dosage. All are concerned with minimizing radiation exposure while also optimizing imaging time and quality. Differences are based on age, weight, body mass, or combinations thereof. Some common calculation methods are (*2*):

(a) Clark's rule:

$$\frac{\text{weight in lb} \times \text{adult dose}}{150 \text{ lb}}$$

(b) Young's rule:

$$\frac{\text{age in years}}{\text{age} + 12} \times \text{adult dose}$$

(c) Webster's rule:

$$\frac{\text{age} + 1}{\text{age} + 7} \times \text{adult dose}$$

(d) Area rule:

$$\frac{(M_1)^{2/3}}{(M_2)^{2/3}} \times \text{adult dose}$$

where M_1 = mass of pediatric patient and M_2 = mass of the adult.

It is important to use the lowest practical dose that will allow the study to be performed effectively. Dosages may be increased slightly for dynamic studies to insure good counting statistics.

Table 1 contains examples of some pediatric dosages.

Injection Technique: Most nuclear medicine studies require an intravenous radiopharmaceutical injection. One system (*3*) that insures a good injection is a three-way stopcock connected to a 25-gauge butterfly needle with 12-in. tubing, a syringe containing a 3–5-cc saline flush, and a syringe containing the radiopharmaceutical. The injection site can then be tested with saline to assure proper needle placement. The stopcock is switched first to the radiopharmaceutical and then to the saline to flush the residual radiopharmaceutical through the tubing.

The antecubital space can be used to inject children but with infants and neonates the dorsum of the hand or foot is more accessible.

If the pediatric patient has an IV or heparin trap in place, it may be used for injecting if the patient's physician approves.

Imaging and Clearance Times: Although clearance time is faster in pediatric patients than in adults (because of children's increased metabolic rates), imaging time is longer. Radiopharmaceutical dosages of lower activity may cause imaging times to be two or three times longer. Examples of imaging and clearance times are presented in Table 1.

Collimation Considerations: Another important consideration when imaging the pediatric patient is collimation. The parallel-hole collimator, commonly used for imaging adults, does not always provide high resolution pediatric images. Converging collimators may be better. In particular, the 140-keV super converging (spotcon) collimator rivals the pinhole collimator in terms of resolution—with a maximized count rate. This is extremely useful with pediatric patients, allowing excellent images with a minimum of patient motion.

Psychological Considerations

One of the best methods for eliciting cooperation in the pediatric patient is to consider his individual emotional needs. To do this, one must first understand how a child at any stage of development responds to the hospital setting.

For a child, a hospital is an unknown place where terrible things happen. He may be invaded at any of his orifices, receive numerous injections, and be subjected to strange sights, sounds, and odors. He may have a history of traumatic hospitalization or may know someone who died in a hospital.

Certain fears are associated with each stage of a child's development. From infancy to approximately age three, a child fears separation from his parents. Children ages three through eight have highly developed imaginations. To them, a hospital may raise a fear of dismemberment; they may also feel that hospitalization is punishment. The eight- to 13-year-old child often fears death. Adolescents may understand hospitalization but resent its lack of privacy at an age when they are extremely aware of their own bodies and need to be treated with respect (*4–6*).

A pediatric patient entering the nuclear medicine department may have any of these fears; thus tantrums, physical abuse of the technologist, or attempts to escape may result. Nuclear medicine technologists have a responsibility to alle-

TABLE 1. Sample of Radiopharmaceuticals, Doses, and Time Delays

Study	Radiopharmaceutical	Dose	Time delay	Time for procedure
Bone scan	Tc-99m-pyrophosphate	300 μCi/kg	1 hr	1–2hr
Gastroesophageal reflux study	Tc-99m-sulfur colloid	3–5 μCi/ml of solution	immediate	1.5–2 hr
Meckel's scan	[^{99m}Tc] pertechnetate	100μCi/kg	5 min	1.5 hr
Radiocysto-urethrogram	[^{99m}Tc] pertechnetate	500 μCi–1mCi	immediate	40 min–1.5 hr
Renal scan	Tc-99m-dimercapto-succinic acid	50 μCi/kg	1 hr	30 min
Thyroid scan	[^{99m}Tc] pertechnetate	10–20 μCi/kg	30 min–1 hr	15–20 min
Brain scan	[^{99m}Tc] pertechnetate	300 μCi/kg	1 hr	1 hr
Cisternogram	In-111-DTPA	100–200 μCi	1,4,24, and 48 hr	30 min
Gallium scan	Ga-67 citrate	500 μCi–3 mCi	24–48 hr	1–2 hr

viate as much psychological trauma as possible. To do this, it is most important to establish trust and open the lines of communication among patient, parent, and technologist. The technologist should be perceived as an honest, intelligent, and competent health professional genuinely interested in the child's well being. With a friendly, honest, and consistently calm manner, the technologist demonstrates to parents and patients that he cares and can handle any emergency that may arise.

Parents are very concerned about what is happening to their child. The first contact with the parent, whether by phone or in person, is the time to explain the procedure. All questions should be answered honestly and adequately. The parents should be informed that there will be an injection of a radiopharmaceutical. If parents and teenage patients express concerns about long-term effects of radiation, they should be reassured of the relative safety of the procedure when compared with other types of procedures. The radiopharmaceutical's rapid clearance from the body should be noted. It should also be stated that their physician believes that the benefits of the nuclear medicine procedure outweigh the risks.

If a woman whose child is having a nuclear medicine procedure is pregnant, she should be cautioned. In order to protect the unborn baby, the mother may be advised not to hold the child on or close to the abdominal area for approximately 24 hr if possible, especially in the first trimester of the pregnancy.

There is controversy about whether parents should be with their child during the study. The 18-month to 3-year age group suffers from separation anxiety and will usually feel more secure if a parent is present. However, parents should not remain in the room if they cannot cope with the procedure.

The procedure should be explained at least twice to each child. First, talk with him in the waiting area. Place yourself at his eye level and explain everything in very simple terms. Next, orient him to the department, pointing out toys to play with and mobiles to view (Fig. 1). Then introduce him to the equipment. If another patient is being imaged, encourage them to talk. They may realize that they are not alone and that the procedure is not threatening. All questions must be answered honestly and at the level of the child's understanding.

Ask the child to select a toy to hold while being injected or imaged. Children may also be encouraged to bring their own toys or blankets with them (*4*).

Cooperation is best solicited by encouraging the child as much as possible. For instance, when potassium perchlorate must be administered, the patient can be told that he must drink it to "make the test better." If the patient does not appear cooperative, make a game of it. Place the medication in a syringe and pretend the syringe is a squirt gun that the child can drink from. If the syringe bothers him use a cup and point out the very small amount he must drink. Follow this by a glass of water or a lollipop to help relieve the aftertaste.

Often it helps to make the child feel that he is a coconspirator. For example, an iodine-131 hippuran renogram (sometimes Lasix-augmented), followed by a Tc-99m DMSA renal scan, necessitates 2–3 injections; the child can be told there is a "2 for 1 sale" or a "3 for 1 sale." Normally he would get 2 or 3 shots but if he so chooses, through the use of a heparin trap, he will receive only one. Patients are usually relieved to have choices and this increases cooperation. Telling a child what he can do to help make the injection easier often eases feelings of helplessness. If the child needs to cry, encourage it. This may be his only outlet. Bear in mind that very young children cannot control their tears, so threats only add guilt to their trauma (*4*).

After injection, inform the patient that he will go back to his parents for a while and when he returns there will be pictures—but no more shots. Children need constant reassurance. When they return after the appropriate clearance time, again emphasize that there will be no more injections.

Children also need to know what is expected of them. Use positive verbal reinforcement when a patient shows appropriate behavior in difficult situations. A child may sometimes be given choices as to how his study will be performed. For example, the technologist may say "I have to take pictures of both sides of your lungs, which side would you like to lie on first?"

In many cases it is necessary to use physical restraints, simply because young children cannot remain still (Fig. 2). The technologist might prefer to use restraining devices rather than sedation for a number of reasons. Sedation can have severe side effects, including aspiration and subsequent respiratory arrest if the patient has just eaten (*3*). The chance for morbidity is simply not warranted. Neither is the risk of aspiration, especially when physical restraints can restrict most patient motion. Sedation also requires injections and other

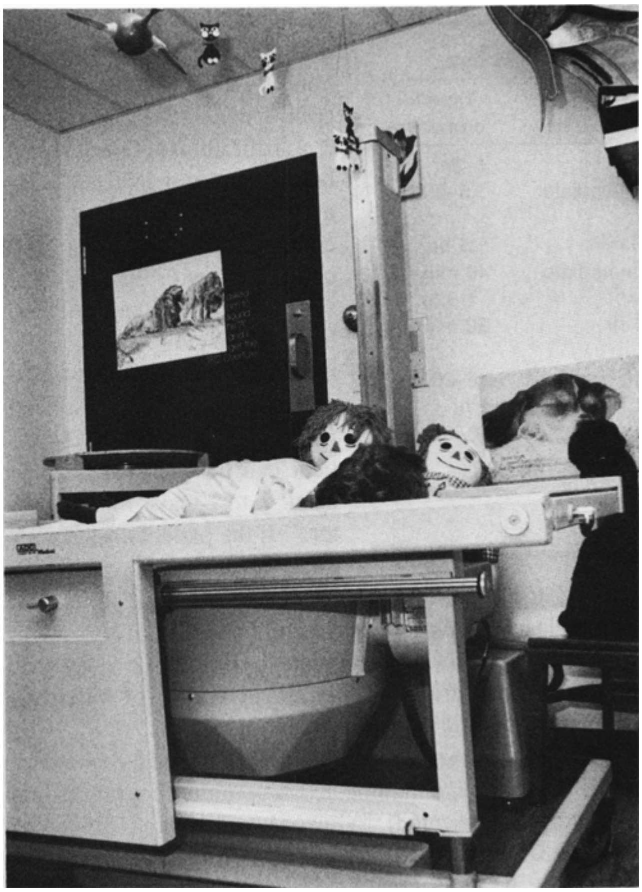

FIG. 1. Camera is placed under child. Pleasurable stimuli surround child and help to ease fears.

FIG. 2. Typical method of restraint. The three-way stopcock system is shown.

discomforts and it is often inneffective, particularly in active children.

Older children rarely need restraints, except when a procedure requires a difficult-to-maintain position. Children aged 6–12 yr can usually remain motionless but may require a piece of tape across the area of interest, as a reminder to hold still. Children below the age of six need help to counteract motion in most instances. A useful device is the papoose board, a plastic board with velcro straps that can be positioned across the chest, abdomen, or extremities. Explain to the child that this does not hurt and is just a "seat-belt" to help him hold still. In order to keep the head from moving, make use of contoured positioning pillows and place a piece of 2-in., nonallergic tape across the forehead with a piece of gauze underneath, to avoid sticking to hair or skin.

On particularly active children, usually six months to three years, the technologist must use more rigid types of restraints. These children can be placed on an open blanket. Wrap one end of the blanket completely around and under the child, securing one of the arms in the process. Bring the other side of the blanket across the chest and underneath, thereby securing the other arm. With this technique the arms are held in place at all times. Since patients can still wiggle out of this, they are then placed on the papoose board and are secured with 2-in. tape, taking care to place the tape directly over the joints to restrict freedom of movement. This does not hurt. In fact, babies seem to enjoy being bundled up in this way and often fall asleep. It is important for the child to understand why you are restraining him. Explain that he is not being punished but that it will give the doctor better pictures. For babies who cry excessively, consider a pacifier.

The use of adequate restraints also helps to minimize a technologist's potential exposure since it permits greater distance from the patient. Again, bearing exposure in mind, hold the patient as little as necessary after injection. If a proper rapport has been established with the child at the outset, this is possible. Most of the minimal exposure is then to the technologist's hands.

The pediatric patient frequently fears that an instrument will fall on him. Even newborns have repeatedly been seen trying to push the camera away. The technologist can remove this worry by saying, for example, "I know you don't like the camera but it will not fall." Also, position the detector head beneath the patient whenever possible. The patient is then often unaware of the camera's presence and is able to watch mobiles or his parents during imaging. Try to keep the patient occupied by the use of toys, stories, songs, and conversation. If views must be taken from above, for example, in a brain scan, take all other views first. Many times the child will fall asleep by the time the camera is brought overhead. If the patient is awake, explain to him that the camera will come very close but will not hurt him. Relieve the anxiety by allowing the child to touch the camera, showing how it moves, and putting your hands underneath it. If a child seems receptive, joke with him by saying, "Don't hurt my camera!" or "You look like a sandwich, what kind are you?" Covering the eyes of very young infants with gauze may help alleviate the trauma of seeing the camera coming close.

Never leave children unattended. They are very quick and may fall off a table, choke on a small toy, or pull out their IV or NG tubes. Watching and restraining the patient during imaging can eliminate motion on films and avoid repeated images. In addition, a curious child can contaminate himself if he touches diapers or saliva and this can cause artifacts on images. The technologist should be aware of these potential sources of contamination.

The procedure itself may also present problems specific to pediatric patients. One of these is the inability to void on demand. When performing a bone scan of the hips, for example, it important for the bladder to be empty. It is also necessary during a radiocystourethrogram to have the patient void while taking images. In the older child this can evoke embarassment and constitute an invasion of privacy. Infants are incapable of control. Another difficult group is the 18-month to three-year-old undergoing toilet training. Parents have instructed them to void only in the toilet and they are very reluctant to deviate from the parents' wishes. In this case, the parent should reassure the child that it is all right "just this time."

Also be aware that children can hear everything that is being said. Never discuss the pediatric patient's case in front of him; a child can easily misinterpret what has been said.

At the end of the study, reassure the patient that he has helped to make the exam easier.

Conclusion

Pediatric patients require constant attention. Procedures must be explained several times on a level that the child can understand to calm fears and provide reassurance that no harm will come to him. Because of lower activity dosages, imaging time is long and it is very important to ensure patient cooperation. Motion is an ongoing problem when imaging children, as is potential technologist exposure; thus, adequate immobilization, depending on age, is required. When all is done, however, your reward is seeing the huge smile of a child.

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