

Introduction

This book has been designed as an informational tool that describes the basic steps necessary to perform the most common nuclear medicine procedures ordered by a referring physician. Although there are many possible variations in the way these protocols may be performed, the objective of this book is to provide simple instructions following best practice techniques as described by professional organizations in nuclear medicine and the current literature. It should be recognized that adherence to these guidelines will not assure an accurate diagnosis or successful patient treatment outcome.

These protocols should not be viewed as inflexible requirements or absolute standards of care. Every patient is different and presents with a unique clinical scenario and individual needs. Thus, modifications to a scanning procedure are necessary to accommodate the patient and to ensure that the results of the examination answer the clinical question as described by the referring physician. The ultimate judgment regarding the use of these protocols rests with the nuclear medicine technologist working under the direction of the authorized user and/or interpreting physician.

Successful completion of these protocols relies on the training, competency, and experience of the nuclear medicine technologist. The technologist must have a thorough understanding of all aspects of nuclear medicine technology, including quality assurance and quality control; instrumentation; radiopharmaceutical and pharmaceutical preparation, administration, and disposal; radiation safety and protection; patient care, safety, and satisfaction; and compliance with applicable government and institutional regulations. The technologist has the ultimate responsibility to ensure that the procedure is performed accurately and effectively.

Although each protocol in this book details the required steps for performing a scan, there are other fundamental practices, common to every procedure, that must be considered and followed. Oftentimes, these additional steps are just as important to achieving optimal quality and accurate results as the steps for performing the examination listed in each protocol. These fundamental practices will be briefly described in this chapter to serve as a reminder to the technologist regarding the basic aspects of patient care in nuclear medicine.

Initiation of the Procedure

Verification of the order

The first step in any procedure includes the review of the referring physician's order for the test. The request for services should include the identity of the patient, the referring physician's name, and any clinical information that describes the rationale for the procedure. When reviewing the order, the technologist should confirm that the correct procedure has been scheduled.

Orders for hospitalized patients are usually found in the medical chart or in the hospital information system. Outpatients may initially be scheduled via telephone, with the prescription or order brought to the appointment by the patient on the day of the examination. Best practice recommends that all orders be written and signed, with verbal orders accepted only in an emergency.

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Before the administration of any therapeutic dose of radioactive material, there must be a written directive. In nuclear medicine, a written directive is an authorized user's written prescription for the administration of a therapeutic dose of an unsealed radioactive material that is intended to deliver a prescribed dose of radiation for palliative or curative treatment. The written directive must be signed and dated by the authorized user and contain the radioactive drug or material, dosage, and route of administration.

Patient identification

The technologist must assure accurate patient identification before initiation of a procedure and immediately before the administration of any radiopharmaceutical or medication. Each facility should have a policy in place to ensure that patients are reliably identified.

Best practice requires that the patient is identified by 2 independent patient-specific identifiers. Examples of patient identifiers include hospital identification bracelet, medical record number, insurance card, or driver's license. Patients may also be identified by asking them to state their full name, date of birth, social security number, or address. This information should be matched to the written order. It is best to avoid asking questions in which the patient can answer "yes" or "no." As a reminder, the patient identification process should *always* be performed in a confidential manner.

The technologist must act with exceptional care in positively identifying patients when handling and administering blood products. Procedures that involve the removal of blood for radiolabeling and reinjection have serious consequences when performed on the wrong patient. Special precautions and procedures are needed to prevent the misadministration of radiolabeled blood products such as ^{111}In - and $^{99\text{m}}\text{Tc}$ -leukocytes for infection studies or $^{99\text{m}}\text{Tc}$ -labeled red blood cells for equilibrium radionuclide angiography, imaging of gastrointestinal bleeding, or hemangioma studies. When a test requires the collection and administration of blood products, 2 independent patient-specific identifiers must also be used to mark the collection containers.

Verification of pregnancy and/or breast-feeding

Before the administration of any radioactive material, pregnant or potentially pregnant and breast-feeding patients must be identified. Therefore, female patients of childbearing age must be questioned about their pregnancy and breast-feeding status and clear documentation of their status must be provided, including the signature or initials of the patient and signature or initials of the technologist verifying the information and the date.

Pregnancy testing should be performed if the patient is possibly pregnant. In explicit terms, pregnancy testing must be performed before the administration of any radiopharmaceutical that could potentially result in a dose to an embryo or fetus of 50 mSv (5 rem) or more, such as doses usually prescribed in ^{131}I therapy.

Elective diagnostic procedures should be postponed until the patient is no longer pregnant. If it is determined that the study will not be performed, the patient should be instructed on options for alternative care.

In pregnant patients, the potential risk of radiation to the fetus and the clinical benefits of the procedure must be carefully considered. The patient must be counseled by knowledgeable staff such as the authorized user, physicist, or radiation safety officer before proceeding with the study. This counseling must be clearly documented in the patient's medical record.

Similarly, if the patient is breast-feeding, the potential risk of radiation to the child should be considered and counseling provided to the mother regarding discontinuation of breast-feeding. Breast-feeding should be interrupted for an amount of time appropriate for the radiopharmaceutical used. Again, knowledgeable staff should instruct the patient regarding timing of pumping breast milk rather than breast-feeding and appropriate disposal versus storage and use of pumped breast milk.

Verification of clinical indication and appropriateness

Before initiating the procedure, the technologist should review the described clinical indication for the procedure. The clinical indication is the specific purpose or reason why the test is being performed and should include any relevant symptoms the patient may be experiencing. The clinical indication should represent a valid reason for performing the test and should correlate with the acceptable clinical indications listed in the procedure manual.

The technologist should confirm the clinical indication for appropriateness of the procedure. Nuclear medicine procedures should only be performed when necessary and likely to produce useful information for managing a patient's care. Any questions pertaining to the appropriateness of the procedure should be referred to the interpreting physician and/or referring physician.

To aid health care personnel in determining when a procedure will benefit a patient, appropriateness criteria have been developed by the professional medical societies. Appropriateness guidelines are currently available from the American College of Cardiology Foundation along with several other professional societies for cardiac radionuclide imaging, including SPECT, PET, and equilibrium radionuclide studies. The Society of Nuclear Medicine and Molecular Imaging, along with the Alzheimer's Association, has published appropriateness criteria for brain amyloid imaging, and the American College of Radiology has many published criteria for nuclear medicine procedures.

Medical history

After reviewing the referring physician's order for the procedure, the technologist should obtain a pertinent medical history to confirm that the patient is a candidate for the procedure. Particular attention is required to determine if there are any contraindications to performing the procedure. Medications and prior diagnostic tests utilizing radiopharmaceuticals or contrast agents can alter the distribution of radiopharmaceuticals in the body and therefore should be noted.

While obtaining the patient's clinical history, the technologist should also assess the patient's physical and mental capacity and ability to cooperate during the procedure. The technologist should consider this and the other information obtained as part of the medical history when planning the procedure. At times, the protocol may need to

be modified. Patients who are physically challenged may require special accommodations.

The information obtained as part of the medical history is often helpful for the interpreting physician in reconciling any alterations in the distribution of the radiopharmaceutical and in the final interpretation of the study.

Specific medical history relevant to a given procedure is discussed in each of the individual protocols described in this book. In general, the medical history should contain the following:

- Relevant history and physical findings, including signs and symptoms (including pain that may require management during the procedure)
- Medications and recent imaging with contrast material
- Prior administration of radiopharmaceuticals
- Prior therapy, including surgery, that might affect radiopharmaceutical distribution
- Results of other pertinent imaging studies
- Results of pertinent laboratory tests
- Allergies

Patient preparation

For many nuclear medicine procedures, no special preparation is necessary. However, when patient preparation such as fasting, hydration, withholding of medications, bowel cleansing, or blood glucose assessment is required, the preparation is described in the specific protocol. The technologist must determine whether the patient has complied with the required preparation or whether there are any contraindications as a result of the patient not being properly prepared.

Explanation of the test

The technologist should establish and maintain courteous communication with the patient throughout the test. An explanation of the procedure should be provided using terminology that the patient can understand and that is appropriate to the patient's age and cultural background. Where appropriate, the explanation may also need to include family members, parents, or a legal guardian. The assistance of a translator may at times be necessary. The technologist should take extra time to answer any questions the patient may ask and, when available, provide written documentation or pamphlets describing the procedure.

The following information should be included in the explanation of the procedure:

- Name and a “generic” description or purpose of the procedure
- Total length of time for the procedure
- Return visit(s) – time, day, and date
- How the radiopharmaceutical is administered and the target organ
- Possible side effects and/or discomfort the patient may experience
- Radiation risks and safety instructions
- Description of the equipment used
- Description of how the procedure is performed, including specific imaging time segments
- Description of the required physical position during the imaging procedure
- Hydration and/or eating instructions
- Aftercare/discharge instructions
- How and when the patient will learn the results of the procedure
- Other specific instructions relevant to the procedure

Informed consent

Written informed consent is not required for most diagnostic nuclear medicine procedures. However, when required by institutional policy or state or federal regulations, the technologist must assure that informed consent has been obtained before initiation of the procedure. Informed consent is usually required for procedures such as radioactive therapy, exercise or pharmacologic myocardial perfusion imaging, cysternography, or sedation.

Informed consent is the process by which an educated patient, parent, or legal guardian participates in choices about requested procedures or health care. It is the ethical duty of the physician or approved health care provider obtaining informed consent to involve the patient, parent, or legal guardian in decisions related to a procedure that requires informed consent.

Information provided for informed consent should include the following:

- Discussion of the procedure in simple terms
- Alternative to the proposed procedure
- Relevant risks, benefits, and uncertainties related to the procedure and to each alternative
- Assessment of understanding
- Acceptance of performance of the procedure by the patient, parent, or legal guardian

For the patient’s consent to be valid, the patient, parent, or legal guardian must be competent to make decisions and consent must be voluntary.

Administration of the Radiopharmaceutical

Verification of radiopharmaceutical identity, dose, and route of administration

The administration of a radiopharmaceutical to a patient must be prescribed by an authorized user, either by an individually written prescription or a standardized protocol. The radiopharmaceutical identity, amount or infusion rate, and route of administration (e.g., oral, inhalation, subcutaneous, intramuscular, intravenous, intradermal) must be specifically stated. Before administration, it is the technologist's responsibility to verify that the identity, amount of radioactivity, and route of administration are consistent with the written prescription. The goal is to ensure that the right patient receives the right test with the right radiopharmaceutical or medication at the right time with the right dose and by the right route of administration.

The quantity of radioactivity to be administered must be assayed using a dose calibrator before administration. Alternatively, for sites using unit doses, where permitted by state or federal regulation, the radioactivity may be determined using decay correction of the unit dose based on the activity determined by the radiopharmacy. The amount of radioactivity must fall within the tolerance levels of applicable state and federal regulations, such as $\pm 20\%$, and be documented in the patient's medical record. In addition, the date of expiration must be verified to assure that it is administered before its expiration.

Dose documentation

The administration of all radiopharmaceuticals and medications must be documented. The identity of the patient, identity of the radiopharmaceutical, amount of radioactivity, route of administration, site of administration, date, time, and identity of the technologist performing the administration must be recorded.

If a patient is planning to travel to a location where radiation detectors are likely to be in use, a card identifying the radionuclide, quantity, date of administration, and facility contact numbers should be provided. Radiation detectors are commonly found at US ports and borders and in many federal buildings.

Aseptic technique

Aseptic handling procedures must be followed whenever preparing, dispensing, administering, or otherwise handling radiopharmaceuticals. In addition, the compounding of radiopharmaceuticals must be sterile and in accordance with USP General Chapter <797> Pharmaceutical Compounding – Sterile Preparations.

Aseptic technique is a set of specific practices and procedures performed under carefully controlled conditions with the goal of minimizing contamination by pathogens as much as possible. Technologists must use particular care when performing venipuncture and establishing intravenous access or when using and maintaining established venous access routes.

Technologists must also use appropriate precautions in accordance with universal precautions and infection control practices to provide a safe and sanitary work environment when handling biologic material such as used syringes, needles, blood, and body fluid.

Basic radiation safety and protection

Technologists must comply with all applicable radiation safety regulations, including maintenance of records of receipt, usage, administration, and disposal of all radioactive materials. All packages containing radioactive materials must be inspected on receipt and tested for external contamination, as required by the appropriate regulatory agency. All radioactive material must be disposed of in accordance with institutional, state, and federal regulations.

Technologists must apply appropriate radiation protection procedures, including the use of syringe shields and vial shields. Any shield that has been in contact with a patient or used in a patient care area must be properly sanitized before being returned to any radiopharmaceutical dose preparation area or used for another patient dose. Technologists must use personnel monitoring devices such as dosimeters, film badges, and thermoluminescent dosimeters. Technologists must also wear gloves when handling radioactive materials.

Radiation dose reduction

Nuclear medicine professionals, including technologists, nuclear medicine physicians, radiologists, and physicists, have the responsibility to optimize the dose of radiation given to the patient. Imaging protocols should be routinely reviewed to ensure that the lowest dose of radiation necessary to acquire diagnostic-quality images is used.

Policies should be in place to vary examination protocols to address specific body habitus, including height and weight. The lowest dose of radiation possible to produce quality images should be chosen. The dose of radiation can be lowered by reducing the amount of radioactive material administered and increasing the scan time or utilizing available new hardware and software with radiation dose reduction techniques when available and appropriate.

CT acquisition protocols should be optimized to provide diagnostic information while minimizing radiation exposure on hybrid imaging equipment.

Image Acquisition

Patient preparation/image artifacts

Image artifacts compromise the overall quality of any study. Before positioning the patient, it is important to remove anything that may cause an artifact on the images. Depending on the type of examination, zippers, watches, wallets, jewelry, and other metallic or dense objects should be removed. For myocardial perfusion imaging, a female patient's bra may be removed as required by laboratory policy. The presence of pacemakers, implantable defibrillators, or other surgical implants should be noted in the medical history.

Intravenous lines, especially if used for injection and urine collection devices, should be placed outside the field of view as much as possible. The patient should also be assessed for possible contamination from the injection site or urine contamination and, if necessary, changed into a hospital gown.

For most procedures, the patient should be instructed to use the restroom before imaging. This often helps to minimize interruptions in the middle of an acquisition. It is particularly important for procedures involving images of the pelvis.

Injection to imaging time

It is critical to use the appropriate injection to imaging time for a particular procedure. Some procedures, such as renography or hepatobiliary imaging, must be started at the time of injection to assess perfusion or a physiological process. However, for other procedures, injection to imaging time is delayed to allow adequate uptake of the tracer in the target organ and clearance from background or other organs, such as clearance from the liver during myocardial perfusion imaging.

Patient positioning

Precise positioning of the patient is critical to the accuracy of any nuclear medicine examination. The patient may be positioned supine, prone, upright, reclined, and so on, depending on the procedure and organ of interest. For example, when performing a ventilation lung scan with xenon, it is preferable to have the patient in the upright position, whereas the preferred position for a whole body bone scan is supine.

The camera should be positioned as close to the patient as possible to optimize image resolution. The target organ or area of interest is usually centered in the field of view. However, there are many procedures in which the target organ is positioned off-center or on the edge of the field of view to allow a physiological process to be monitored, such as hepatobiliary imaging, in which the liver is positioned superiorly in the field of view.

There may be occasions in which the patient and camera position should be adapted to accommodate a patient's needs. For instance, a claustrophobic patient may be more comfortable being imaged in the prone position or with a single-head gamma camera positioned under the imaging table.

Camera configuration

The camera must be appropriately configured for the acquisition. This includes collimator, energy window setting, orbit and orbit type, acquisition type (static, dynamic, planar, SPECT, SPECT/CT, PET, PET/CT, step and shoot, continuous), gating, matrix size, zoom, and so on. The procedures detailed in this manual list specific acquisition parameters.

The prescribed views according to the established protocol must be obtained. If needed, additional views as recommended should be acquired to optimize the information obtained. The technologist must exercise independent judgment to best demonstrate pathology. As necessary, appropriate anatomic landmarks should be demonstrated using radioactive or radiopaque markers.

Patient comfort

The technologist should always focus on patient comfort and care during the procedure. There are many simple measures that can enhance the patient's comfort. The use of pillows placed under the patient's knees or head can immediately increase the patient's comfort. Warm blankets can enhance comfort and help the patient feel more relaxed. Supportive materials or immobilizers such as arm supports should be used as appropriate. Methods to protect a patient's modesty will also increase a patient's comfort during the procedure.

Patient monitoring

The technologist is responsible for monitoring the patient from the moment of arrival to departure and must be able to recognize and respond to medical emergency conditions.

Patient monitoring may include intravenous fluids, oxygen, Foley catheters, or other drainage apparatus. For some procedures, the technologist will observe and record physiological data such as electrocardiography, pulse, and/or respiration rate and initiate calls for assistance as necessary. The technologist must have appropriate training to administer cardiopulmonary resuscitation in the event of an emergency until dedicated medical emergency staff arrive.

Before starting the acquisition, the patient should be instructed on the importance of remaining still and not moving or, in some cases, talking. Patient movement during the scan can have devastating results and possibly mimic artifact, such as during myocardial perfusion imaging. It is important for the technologist to clearly explain to the patient what to expect during the imaging procedure and the amount of time movement is not allowed. Best practice mandates that the technologist must continuously monitor the patient during the entire scan acquisition.

Patient monitoring – sedation

Sedation may be used as a form of immobilization in a younger patient or to assist an adult patient when pain, physical limitations, or psychological problems, including claustrophobia, preclude the patient from successfully completing an imaging study. Regardless of the level of sedation, continuous monitoring of the patient during the entire imaging procedure is required to minimize complications or unexpected adverse reactions to the sedation medication.

Strict regulatory and institutional guidelines define personnel approved to participate in patient sedation. Health care providers, including nuclear medicine technologists, who have been approved to participate in patient sedation must participate in rigorous training programs provided by the institution and maintain the appropriate competency documentation.

Patient sedation requires additional planning and coordination of appropriate personnel. Depending on the level of sedation, the patient may also need time to recover after the procedure. It is important that the nuclear medicine technologist understand and follow institutional and state regulatory guidelines associated with patient sedation.

Postacquisition

On completion of acquisition, the technologist must review the image data to confirm that all required information has been acquired and processed properly, that the data are of the highest quality, and that the correct information has been provided. The study is forwarded to the interpreting physician with any pertinent information, including variances to the protocol or dose, specific patient history, or other information essential to the final interpretation of the study. Documentation of the completed scan should be recorded in the patient's medical record.

The patient's privacy and confidentiality should be respected at all times, and patient information should always be protected as required by the Health Insurance Portability and Accountability Act (HIPAA).

Once the final image data have been reviewed, the technologist should provide the patient with instructions for return or aftercare such as increased hydration, frequent voiding, and the ability to resume eating. The technologist should also consider providing the patient with a reminder regarding availability of the study report as well as contact information should the patient experience any adverse events after departure.

Processing – a word about filters

The selection of the proper filter and the determination of appropriate filter parameters is a frequent problem for technologists. Unfortunately, published literature and guidelines often lack useful information in regard to filtering. Routinely, the choice of filter is left to the manufacturer's recommendation with little variation or manipulation by technologists in an attempt to standardize images in a facility. The most common filters applied in nuclear medicine preprocessing and postprocessing include the ramp, Hann, and Butterworth filters. No filter is perfect, and there is no specific filter that can be used for all organs or applications. Technologists working together with interpreting physicians must judiciously select filters and parameters that smooth images, remove noise, and maximize resolution and contrast. The following basic principles review the components of image quality and filtration.

The quality of nuclear medicine imaging, particularly SPECT imaging, is dependent on spatial resolution, contrast, and noise.

- **Spatial resolution** is the measure of how close 2 point sources of activity can be placed and still be distinguished as separate.
- **Contrast** is the measure of counts or intensity in the target object or organ compared with the intensity in a background region. The higher the contrast, the more visible the target organ.
- **Noise** is the measure of the irrelevant information in an image that results from the random nature of counting statistics. As count statistics increase, noise becomes less evident.

The goal of filtering is to enhance an image by balancing the suppression of noise and the preservation of spatial resolution and contrast.

Filtering is a mathematical process that, in addition to suppression of noise, includes smoothing, edge enhancement, and resolution recovery. Filters are applied during image reconstruction to data in the frequency domain. Low frequencies from an image are associated with large uniform objects, and high frequencies are associated with small objects or sudden variations in count levels such as those seen at the edge of an object. High frequencies are also related to noise.

High-pass filters allow higher-frequency data to pass through while eliminating lower frequencies. High-pass filters preserve spatial resolution for smaller objects and preserve edge detection but also allow noise to remain in the image. An example of a high-pass filter is the ramp filter used to remove the star artifact during filtered back projection.

Low-pass filters allow lower-frequency data to pass through while blocking higher frequencies. These filters remove noise and smooth the image, which results in a loss of spatial resolution. They can also make it difficult to discern small lesions. Low-pass filters are characterized by 2 parameters: the “cutoff” frequency and the “order.” The cutoff frequency defines the frequency above which noise is eliminated. A high cutoff frequency will improve the spatial resolution with more detail, but the image will be noisy. A low cutoff frequency will increase smoothing but decrease image contrast. The order defines the slope of the filter and describes the steepness of the roll-off. The higher the order, the sharper the fall of the curve. Order is also referred to as “power.” The power is twice the order.

Common low-pass filters used in nuclear medicine to reduce noise include the Butterworth, Hanning, Hamming, Parzen, and Shepp-Logan filters. Each of these filters varies in their degree of smoothing and resolution. There are also enhancement or restoration filters such as the Metz or Wiener filter, which enhance the signal while simultaneously reducing noise with a loss of resolution.

Iterative reconstruction is a different technique that is based on the algebraic reconstruction technique. This technique starts with the filtered back projection image as an initial estimate of the source distribution and reconstructs the image using the projections and a mathematical model of the imaging process. Each time the mathematical model is applied is an iteration. Usually 10 to 15 iterations are required to achieve a clinical image. As the speed and power of the processing computers have increased, iterative reconstruction has become more widely used. This reconstruction method is commonly used for attenuation correction, dose reduction, and resolution recovery software.

Pediatric Patients

Pediatric nuclear medicine presents new challenges that require different strategies and communication techniques when compared with adult nuclear medicine procedures. Children are not small adults. For nuclear medicine departments that primarily serve an adult population, a pediatric patient may quickly disrupt the flow of the work day. Additional time must be scheduled to accommodate anticipated challenges, including starting an intravenous line, sedation, urinary catheterization, and so on. The ability to successfully work with pediatric patients requires an active imagination, the ability to be flexible, and the willingness to quickly adapt to the ever-changing environment of a child who can rapidly become bored, nervous, or anxious. Honesty is essential when communicating with the patient and/or the patient’s parent or legal guardian. The technologist’s ability to communicate in a calm and clear manner is the cornerstone to developing a successful working relationship with the patient, parent, or legal guardian and is essential in producing an optimal procedure outcome.

Instrumentation

In most cases, the same technology used for imaging in adults is also used in children; however, several modifications must be made to the instrumentation. First, procedures should be performed using equipment with the highest resolution possible. Small field of view cameras are often more appropriate if available. Second, it is important to remember when imaging a child to only include the specific area of interest in the field of view and exclude unnecessary counts from outside the area of interest. Finally, the equipment should have the ability to magnify the images to enhance the resolution. Computer zooming is not equal or comparable to magnification and does not increase resolution. The use of pinhole collimators or converging collimators produces optimal images for small areas of interest.

Immobilization

Optimal image data require motion-free acquisition. In the pediatric population, immobilization may be required when the patient is unable or unwilling to attain this goal. Immobilization restricts the patient's movement and should not be confused with restraint, which allows movement while keeping the patient safe. Immobilization techniques include the use of wrapping or swaddling, cloth tape, vacuum pillows or sandbags, papoose boards, or other similar equipment.

Immobilization using various techniques to restrict movement may cause the child to become anxious or fearful. Whenever possible, this fear may be relieved by releasing the areas that have been scanned at the earliest possible time.

Another method to alleviate fear and anxiety is through distraction. Distraction can play an important supporting role in immobilization. The ability to distract the pediatric patient through conversation; close access to a favorite toy or stuffed animal; movies displayed on DVD players, iPads, or telephones; and having the parents or legal guardians in close proximity can assist in helping the pediatric patient relax and remain quiet for the required time.

It is important to note that wrapping or swaddling can result in overheating during an extended imaging procedure. It is essential that the technologist closely monitor the pediatric patient throughout the imaging procedure for signs of overheating, including sweating, skin that is hot to the touch, or increased respirations or pulse rate.

When the pediatric patient cannot tolerate the imaging procedure, continues to be uncooperative, or has a history of disruptive behavior, sedation or anesthesia may be the only choice to produce an optimal scan. Sedation or anesthesia requires the consent of the patient's parent or legal guardian and must follow the institution's policies and guidelines. It requires the participation of other health care professionals to administer the sedation or anesthesia, monitor the patient during the imaging procedure, and recover the patient, as necessary, after the procedure. Refer to institutional guidelines for further information regarding patient sedation.

Patient/parent cooperation

Communication plays a key role when working with the pediatric population. The nuclear medicine technologist must develop the ability to explain the procedure to the child as well as the parent or legal guardian. This explanation needs to be at a level of understanding that is appropriate for the patient's age group as well as for an adult.

There are several key points for improving communication. Keep the explanation simple; be clear about what to expect and how the patient and the parent or legal guardian can help in that process. Be honest. Never tell a child that it won't hurt if an injection is required. Avoid distractions during the conversation. If 2 parents are present, allow one parent to tend to the child while the second parent listens to the information presented. Allow plenty of time for questions. Whenever possible, provide written information to support the discussion with the parents.

Injection

Intravenous access is essential to most nuclear medicine procedures; however, it can be a difficult challenge for technologists with little or no experience. In most institutions, pediatric personnel can provide the necessary support for establishing intravenous access with minimal trauma before the child is transported to the nuclear medicine department.

When a peripheral line is not in place and an experienced pediatric staff member is unavailable, the technologist must work closely with the patient, parent, or legal guardian and a coworker, as necessary, to successfully establish a peripheral line. Appropriate selection of an available site for injection may be limited and age dependent. In a very young child, the dorsum of the hand or foot may offer the best option; however, in an older child, additional sites such as the antecubital vein may be an option.

Regardless of the site selected, clear and concise communication with the patient, parent, or legal guardian and coworker is critical to successfully establish the peripheral line. Explain to the child what will happen and be honest in explaining that there will be a tiny stick that will hurt just a little. Tell the child that it is okay to cry or say "Ouch!" Confirmation of the patency of the line is essential before the administration of the radionuclide. Establishing an intravenous line that includes a heparinized injection port minimizes the number of injections required for patients who are scheduled for multiple procedures on the same day that require intravenous injections.

Radiation dose reduction/individual dose determination

In the past, pediatric dose calculations have been calculated using a formula that simply reduced the adult administered activity: pediatric administered activity = (dose formula) \times (adult reference activity). Formulas included the patient's weight, body surface area, Webster's formula, or the European Association of Nuclear Medicine Paediatric Dose Card. Unfortunately, use of body surface area or Webster's formula results in administered activity that is much higher per kilogram in infants and small children than in the adolescent population.

In an effort to reduce the dose of radiation to the pediatric population, multiple consensus workshops were held to review available data and derive a standardized method to calculate administered radiopharmaceutical doses. Based on the findings from these workshops, the Pediatric Nuclear Medicine Dose Reduction Workgroup, consisting of pediatric nuclear medicine physicians, technologists, and physicists representing multiple professional organizations, achieved consensus on pediatric administered radiopharmaceutical doses for 9 commonly use radiopharmaceuticals. The calculated dose is based on activity per kilogram and minimum administered radiopharmaceutical dose for the smallest patient. The recommended pediatric doses are listed in the protocols in this book. The recommended administered activity is also available in published guidelines titled “North American Consensus Guidelines for Administered Radiopharmaceutical Activities in Children and Adolescents” and is based on body weight except for the gastric emptying study and radionuclide cystography. Administered activity may also be affected by instrumentation, software, clinical protocols, and the physician’s judgment.

The use of weight-based administered activity is reported to result in a lower effective dose than the currently established threshold for radiation-induced carcinogenesis.

Summary/Conclusion

The fundamental practices discussed in this chapter provide an overview of the basic tasks associated with every imaging and therapeutic procedure performed in nuclear medicine. As noted, the quality and accuracy of the procedure rely in part on the precision of patient care and preparation.

This overview of the basic aspects of patient care should be considered generic recommendations that do not supersede institutional policies or state regulatory requirements.

References

- ACR-SNM technical standard for diagnostic procedures using radiopharmaceuticals. Revised 2011, resolution 5. http://interactive.snm.org/docs/ACR-SNM_Technical_standards_for_diagnostic_procedures_using_radiopharmaceuticals.pdf. Accessed May 10, 2013.
- Alessi A. Basic myocardial processing techniques. *Nuclear Cardiology Technology Study Guide*. Reston, VA: Society of Nuclear Medicine; 2010:75–77.
- Callahan RJ, Chilton HM, Ponto JA, Swanson DP, Royal HD, Bruce AD. Procedure guideline for the use of radiopharmaceuticals 4.0. *J Nucl Med Technol*. 2007;35(4):272–275.
- Clinical performance standards for the nuclear medicine technologist. May 11, 2011. http://interactive.snm.org/docs/Performance_Responsibility_Guidelines_NMT_June_2011.pdf. Accessed May 12, 2013.
- Gelfand MJ, Parisi MT, Treves ST; Pediatric Nuclear Medicine Dose Reduction Workgroup. Pediatric radiopharmaceutical administered doses: 2010 North American consensus guidelines. *J Nucl Med*. 2011;52(2):318–322.
- Lyra M, Ploussi A. Filtering in SPECT image reconstruction. *Int J Biomed Imaging*. 2011;2011:693795.
- McQuatti S. Pediatric PET/CT imaging: tips and techniques. *J Nucl Med Technol*. 2008;36(4):171–180.

- Roberts EG, Shulkin BL. Technical issues in performing PET studies in pediatric patients. *J Nucl Med Technol.* 2004;32(1):5–9.
- Steves A, Jones-Thomas D, Brady AB. Patient care. In: Bolus NE, Brady AB. *Steves' Review of Nuclear Medicine Technology: Preparation for Certification Examinations.* 4th ed. Reston, VA: Society of Nuclear Medicine Inc; 2011:14–24.
- The Intersocietal Accreditation Commission standards and guidelines for nuclear/PET accreditation. 2012. http://intersocietal.org/nuclear/main/nuclear_standards.htm.
- The SNM procedure guidelines for general imaging 6.0. Revised 2010. http://interactive.snm.org/docs/General_Imaging_Version_6.0.pdf. Accessed May 12, 2013.
- The United States Pharmacopeial Convention (USP). *USP <797> Guidebook to Pharmaceutical Compounding – Sterile Preparations.* <http://www.usp.org/products/797Guidebook/>. Accessed May 10, 2013.
- Thompson-Hunt K, Mars D, Mehlberg L. Patient care and quality improvement. In: Christian PE, Waterstram-Rich KM, eds. *Nuclear Medicine and PET/CT Technology and Techniques.* 6th ed. St Louis, MO: Elsevier Mosby; 2007:226–246.
- Veitch TA. Pediatric nuclear medicine, part I: developmental cues. *J Nucl Med Technol.* 2000;28(1):3–7.
- Veitch TA. Pediatric nuclear medicine, part II: common procedures and considerations. *J Nucl Med Technol.* 2000;28(2):69–75.
- Weiss SC, Conway JJ, Hahn K, Fischer S. Pediatric imaging. In: Christian PE, Waterstram-Rich KM, eds. *Nuclear Medicine and PET/CT Technology and Techniques.* 6th ed. St Louis, MO: Elsevier Mosby; 2007:623–630.