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Procedure Guideline for Brain Perfusion SPECT Using Technetium-99m Radiopharmaceuticals

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PART I: PURPOSE

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting and reporting the results of brain perfusion SPECT studies using ^{99m}Tc radiopharmaceuticals.

PART II: BACKGROUND INFORMATION AND DEFINITIONS

SPECT of the brain is a technique for obtaining tomographic images of the three-dimensional distribution of a radiopharmaceutical that reflects regional cerebral perfusion (*1–4*).

PART III: COMMON INDICATIONS

A. Detection and evaluation of cerebrovascular disease.
B. Evaluation of patients with suspected dementia.
C. Presurgical localization of epileptic foci.

Additional indications, not listed here, are under active evaluation, many of which appear promising at this time.

PART IV: PROCEDURE

A. Patient Preparation
1. Prearrival
   No special preparation required.
2. Preinjection
   The most important aspect of patient preparation is to achieve a consistent environment at the time of injection and uptake.
   a. Evaluate patient for ability to cooperate.
   b. Place patient in quiet, dimly lit room.
   c. Keep patient's eyes and ears open.
   d. Ensure that patient is seated or reclining comfortably.
   e. Place intravenous access at least 10 min prior to injection to permit accommodation.
   f. Explain importance of no head motion.
   g. Instruct patient not to speak or read.
   h. Have no interaction with patient prior to, during or up to 5 min postinjection.

B. Information Pertinent to Performing the Procedure
Relevant patient data suggested for optimal interpretation of scans include patient history (including any past drug use or trauma), neurologic exam, psychiatric exam, mental status exam (e.g., Folstein mini-mental status examination or other neuropsychological test), recent morphologic imaging studies (e.g., CT, MRI) and current medications and when last taken.

C. Precautions
1. Demented patients must be closely monitored at all times.
2. Patients with neurologic deficits may require special care and monitoring.
3. Sedation should be given after injection of radiopharmaceutical when possible.

D. Radiopharmaceutical
1. Radiopharmaceuticals (See Tables 1 and 2.)
   a. Technetium-99m-HMPAO (exametazime [unstabilized]).
   b. Technetium-99m-HMPAO (exametazime [stabilized]).
   c. Technetium-99m-bicisate (ethyl cystine dimer [ECD]).
2. Radiopharmaceutical Preparation
   a. Use fresh generator eluate (<2 hr old) for optimal results with ^{99m}Tc-HMPAO.
   b. Do not use pertechnetate obtained from a generator that has not been eluted for 24 hr or more.

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Note: All 26 SNM-approved procedure guidelines are available on the Society's home page. We encourage you to download these documents via the Internet at www.snm.org. If you would like information on the development process of this guideline or to order a compendium of all 26 procedure guidelines for $20.00, contact Marie Davis, Society of Nuclear Medicine, at (703) 708-9000, ext. 250, or by e-mail at mdavis@snm.org.

TABLE 1
Radiation Dosimetry for Adults

Radiopharmaceutical	Administered activity MBq (mCi)	Organ receiving the largest radiation dose* mGy (rad)	Effective dose* mSv (rem)
^{99m}Tc-HMPAO†	555–1100 i.v.	0.034 Kidneys	0.0093
	(15–30)	(0.126)	(0.034)
^{99m}Tc-bicisate ECD‡	555–1100 i.v.	0.073 Bladder wall	0.011
	(15–30)	(0.27)	(0.041)

*Per MBq (per mCi).
†ICRP 62, page 13.
‡Treves ST, *Pediatric nuclear medicine*, 2nd ed. New York: Springer-Verlag;1995:576.

3. Radiopharmaceutical Injection
   a. Technetium-99m-HMPAO (unstabilized): Inject tracer no sooner than 10 min and no more than 30 min postreconstitution. For seizure disorders it is important to inject the tracer as soon as possible after reconstitution (within 1 min).
   b. Technetium-99m-HMPAO (stabilized): Inject tracer no sooner than 10 min and no more than 4 hr postreconstitution.
   c. Technetium-99m-bicisate (ECD): Inject tracer no sooner than 10 min and no more than 6 hr postreconstitution.
4. Delay Time from Injection to Imaging
   a. Technetium-99m-HMPAO (unstabilized and stabilized): Delay of ≥90 min from injection to imaging for best image quality. Images obtained after a 60-min delay will be interpretable.
   b. Technetium-99m-bicisate ECD: Greater than 45-min delay from injection to imaging for best image quality. Images obtained after a 30-min delay will be interpretable.
   c. Imaging should be completed within 4 hr postinjection.
5. Dosage
   a. Adults: 555–1100 MBq (15–30 mCi ^{99m}Tc-HMPAO or bicisate (ECD), typically 20 mCi).
   b. Children: 7.4–11.1 MBq/kg (0.2–0.3 mCi/kg). Minimum dose is 3–5 mCi.
6. Quality Control
   Radiochemical purity determinations should be performed on each vial prior to injection using the method outlined in the package insert. A shortened one-step technique may also be used for ^{99m}Tc-HMPAO (*5*).

E. Image Acquisition
   Setup and acquisition
   1. Multiple-detector or other dedicated SPECT cameras generally produce results superior to single-detector general-purpose units. However, with meticulous attention to procedure, high-quality images can be produced on single-detector units with appropriately longer scan times (5×10^6 total counts or more are desirable).
   2. The patient should void prior to the study in order to maximize patient comfort during the study.
   3. The patient should be positioned for maximum comfort. Minor obliquities of head orientation can be corrected in most systems during processing.
   4. The patient's head should be lightly restrained to facilitate patient cooperation in minimizing motion during acquisition. It is not possible to rigidly bind the head in place. Patient cooperation is necessary. Sedation may be used following the injection of radiopharmaceutical if patient is uncooperative.
   5. Use smallest radius of rotation possible with appropriate patient safeguards.
   6. Use of high-resolution or ultra-high-resolution collimation is recommended. All-purpose collimation is not suitable. As a general rule of thumb, use the highest resolution collimation available.
   7. Fanbeam or other focused collimators are generally preferable to parallel-hole collimators as they provide improved resolution and higher count rates. Parallel-hole

TABLE 2
Radiation Dosimetry for Children (5-yr-old)

Radiopharmaceutical	Administered activity MBq/kg (mCi/kg)	Organ receiving the largest radiation dose* mGy (rad)	Effective dose* mSv (rem)
^{99m}Tc-HMPAO†	7.4–11.1 i.v.	0.14 Thyroid	0.026
	(0.2–0.3)	(0.52)	(0.096)
^{99m}Tc-bicisate ECD‡	7.4–11.1 i.v.	0.083 Bladder wall	0.023
	(0.2–0.3)	(0.31)	(0.085)

*Per MBq (per mCi).
†ICRP 62, page 13.
‡Treves ST, *Pediatric nuclear medicine*, 2nd ed. New York: Springer-Verlag; 1995:576.

collimation is acceptable if adequate counts are obtained. Slant-hole collimation may be used.

8. A 128 × 128 or greater acquisition matrix is required for multidetector systems.
9. Use 3° angular sampling. Acquisition pixel size should be ⅓–½ the expected system resolution. It may be necessary to use a hardware zoom to achieve an appropriate pixel size. Different zoom factors may be used in the x and y dimensions of a fanbeam collimator.
10. Continuous acquisition may provide shorter total scan duration and reduced system mechanical wear when compared to a step-and-shoot technique.
11. Segmentation of data acquisition into multiple sequential acquisitions will permit exclusion of bad data; e.g., removing segments of projection data with patient motion.
12. It is frequently useful to use detector pan and zoom capabilities to ensure that the entire brain is included in the field of view while allowing the detector to clear the patient's shoulders.

F. Interventions

Vasodilatory challenge with acetazolamide (Diamox) or equivalent.

Indication: Evaluation of cerebrovascular reserve in transient ischemic attack, completed stroke and/or vascular anomalies (e.g., arterial-venous malformation) and to aid in distinguishing vascular from neuronal causes of dementia.

Contraindications: Known sulfa allergy (skin rash, bronchospasm, anaphylactoid reaction). May induce migraine in patients with migraine history. Generally avoid within 3 days of an acute stroke.

Dosage: Adults: 1000 mg by slow intravenous push for typical patient. Children: 14 mg/kg. Wait 15–20 min after administering acetazolamide before injecting tracer.

Adverse effects: Mild vertigo, tinnitus, paresthesias and, rarely, nausea may be experienced. These are generally self-limiting and do not require specific treatment. Patients may experience postural hypotension when arising and should be appropriately warned and assisted if necessary.

Various protocols have been used, including split-dose, 2-day repeat study and dual-isotope techniques. The 2-day repeat study technique is simplest and may therefore be preferred. Typically, the challenge portion is performed first. If this is normal, consideration may be given to omitting the baseline study. If a baseline scan is performed, allow sufficient time for residual activity to clear (typically 24 hr).

Acetazolamide is a diuretic. The patient should be instructed to void immediately before beginning of image acquisition. Acquisition and processing are identical to nonacetazolamide study.

G. Processing

Image Processing

1. Filter all studies in three dimensions (x, y and z). This can be achieved either by two-dimensionally prefiltering the projection data or by applying a three-dimensional post-filter to the reconstructed data.
2. Low-pass (e.g., Butterworth) filters should generally be used. Resolution recovery or spatially varying filters should be used with caution, as they may produce artifacts.
3. When possible, reconstruct the *entire* brain. Use care not to exclude cerebellum or vertex.
4. Reconstruct data at highest pixel resolution (i.e., 1 pixel thick). Slices should be summed only after reconstruction and oblique reorienting (if performed).
5. Attenuation correction should be performed in all cases unless a specific application or circumstance would dictate otherwise. Use shape contouring if available. Be sure that contour includes scalp and not just gray matter.
6. Reformat transaxial data into at least three orthogonal planes. Generate transverse sections relative to a repeatable anatomic orientation, and coronal and sagittal sections orthogonal to the transverse.
7. Compton subtraction may be performed using a dual-peak acquisition.

H. Interpretation/Reporting

1. The extent of normal variability must be appreciated during scan interpretation. Substantial variability may be noted between normal individuals and between scans of a single subject obtained at different times. Individual laboratories should obtain or be familiar with a normal database to best interpret patient studies (*6–10*).
2. Unprocessed projection images should be reviewed in cinematic display prior to viewing of tomographic sections. Projection data should be assessed for the presence and degree of patient motion, target-to-background ratio and other potential artifacts. Inspection of the projection data in sinogram form may also be useful.
3. Images should be viewed on a computer screen rather than from film to permit interactive adjustment of contrast, background subtraction and color table.
4. Caution must be used in selecting levels of contrast and background subtraction. Noncontinuous color scales may be confusing or misleading if abrupt color changes occur in the range of expected gray matter activity. Thresholding should be selected based on knowledge of normal database for specific radiopharmaceuticals and instrument used in acquiring the study. Artifacts can be created when inappropriate thresholding is performed.
5. Three-dimensional renderings may be useful in appreciating overall patterns of disease. Care must be exercised in choice of threshold as artifactual defects are easily generated.
6. Images must be evaluated in the context of relevant structural information (CT/MRI). Specific attention should be paid to the extent of perfusion abnormalities relative to underlying morphologic defects (e.g., ischemic penumbra versus infarct) as well as to the possible effects of atrophy and partial-volume effect.
7. Study reports should describe the extent and severity of defects, their correlation with morphologic and clinical abnormalities and, when relevant, a differential diagnosis. It must be recognized that many patients will present with nonspecific perfusion patterns that cannot be directly attributed to a specific disorder or causative agent. Care must be taken to avoid implying the existence of cause-and-effect relationships between scan and behavioral/neurologic abnormalities.
8. Epilepsy evaluation: Images must be correlated with the relevant EEG data and clinical observations in seizure patients. The exact timing of tracer injection relative to observed or electrical seizure activity must be known. The scintigraphic appearance and extent of seizure foci may change dramatically depending on the exact timing of tracer injection relative to seizure onset. Ictal and interictal studies should be compared for optimal patient evaluation.

9. Interpreters should be familiar with the document issued by the Ethical Subcommittee for Functional Brain Imaging, a subcommittee of the Society of Nuclear Medicine Brain Imaging Council (*7*).

I. Quality Control
See *Society of Nuclear Medicine Procedure Guideline for General Imaging.*

J. Sources of Error
1. Presence of sedating medications at the time of tracer injection may alter tracer distribution. If sedation is absolutely necessary, it should, whenever possible, be administered at least 5 min after tracer injection. When sedation is used, record type and dosage of sedative and time at which sedation was administered in relation to tracer injection.
2. Patient motion during data acquisition may produce blurring of image data and may result in artifacts.

PART V: DISCLAIMER

The Society of Nuclear Medicine has written and approved guidelines to promote the cost-effective use of high-quality nuclear medicine procedures. These generic recommendations cannot be applied to all patients in all practice settings. The guidelines should not be deemed inclusive of all proper procedures or exclusive of other procedures reasonably directed to obtaining the same results. The spectrum of patients seen in a specialized practice setting may be quite different than the spectrum of patients seen in a more general practice setting. The appropriateness of a procedure will depend in part on the prevalence of disease in the patient population. In addition, the resources available to care for patients may vary greatly from one medical facility to another. For these reasons, guidelines cannot be rigidly applied.

Advances in medicine occur at a rapid rate. The date of a guideline should always be considered in determining its current applicability.

PART VI: ISSUES REQUIRING FURTHER CLARIFICATION

1. Normal database issues.
2. Quantification techniques.
3. Superimposition techniques with MRI and CT.

PART VII: CONCISE BIBLIOGRAPHY

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PART VIII: LAST HOUSE OF DELEGATES APPROVAL DATE

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PART IX: NEXT ANTICIPATED APPROVAL DATE

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