ACR–ACNM–SNMMI–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF SINGLE-PHOTON EMISSION BRAIN PERFUSION IMAGING (INCLUDING SPECT AND SPECT/CT)

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

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1 *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.*

I. INTRODUCTION

This practice parameter has been revised collaboratively by the American College of Radiology (ACR), the American College of Nuclear Medicine (ACNM), the Society of Nuclear Medicine and Molecular Imaging (SNMMI), and the Society for Pediatric Radiology (SPR).

Nuclear medicine imaging, including single-photon emission computed tomography (SPECT) brain perfusion

imaging, using lipophilic radiopharmaceuticals that cross the blood-brain barrier and localize in brain tissue is a proven and useful procedure to define the regional distribution of brain perfusion, evaluate a variety of brain abnormalities, and corroborate the clinical diagnosis of brain death in appropriate situations [1-3]. The radiotracers technetium-99m (Tc-99m) exametazime (hexamethyl propylene amine oxime [HMPAO]) and Tc-99m bicisate (ethyl cysteinate dimer [ECD]), have high first-pass extraction across the blood-brain barrier and are significantly trapped in the brain by conversion to polar metabolites that do not readily cross intact cell membranes.

Application of this practice parameter should be in accordance with the ACR-ACNM-SNMMI-SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4].

The goal of brain perfusion imaging is to detect abnormalities in cerebral perfusion.

II. INDICATIONS

A. Clinical indications for brain perfusion imaging examinations include, but are not limited to:

1. Evaluating patients with suspected dementia [3,5]
2. Localizing seizure foci [6,7]
3. Mapping of brain perfusion during interventions [2,3,8]
4. Detecting and evaluating cerebrovascular disease [1-3,9]
5. Corroborating the clinical diagnosis of brain death (note that these examinations can be performed with SPECT or planar imaging; see section IV.H) [10-18]

B. For information on radiation risks to the fetus, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [19].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR-ACNM-SNMMI-SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4].

IV. SPECIFICATIONS OF THE EXAMINATION

A. Nuclear Medicine Examination Request

The written or electronic request for a brain perfusion examination should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation. Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

In addition to data needed to document medical necessity, optimal interpretation often requires additional relevant patient data. These data should include additional patient history, such as past and current drugs and medication use (including when last taken); traumatic, neurologic, and psychiatric findings (eg, clinical evaluations or neuropsychological test, etc); neurodiagnostics (eg, electroencephalography); and results of recent anatomic brain imaging examinations (eg, CT, magnetic resonance imaging (MRI) [10]).

IV. SPECIFICATIONS OF THE EXAMINATION

B. Radiopharmaceuticals

Either Tc-99m ECD or Tc-99m HMPAO (stabilized or unstabilized) is used.

1. Radiopharmaceutical preparation
   a. Use fresh generator eluate (< 2 hours old) for optimal results with Tc-99m HMPAO [20].
   b. Use only eluate from a Tc-99m generator that was previously eluted within 24 hours.
   c. Radiochemical purity determinations should be performed on each vial prior to patient

administration by using the method outlined in the package insert.

2. Radiopharmaceutical administration
    a. Tc-99m ECD: radiopharmaceutical should be injected intravenously no more than 6 hours after reconstitution.
    b. Tc-99m HMPAO: stabilized radiopharmaceutical should be injected intravenously no more than 4 hours after reconstitution; unstabilized radiopharmaceutical should be injected no more than 30 minutes after reconstitution.
    c. When examinations are performed to localize a seizure focus during a seizure, ideally the radiopharmaceutical should be injected within 30 seconds from the seizure onset.

3. Interval between injection and imaging
    a. Tc-99m ECD: for best image quality, a minimum interval of 45 minutes is recommended.
    b. Tc-99m HMPAO: Images should be obtained > 90 minutes after injection.
    c. If possible, patients should be instructed to void within 2 hours postinjection to minimize radiation exposure.

4. Administered Activity
    a. Adult: 555 to 1110 MBq (15 to 30 mCi)
    b. Pediatric: 11.1 MBq/kg (0.3 mCi/kg); minimum 185 MBq (5.0 mCi), maximum 740 MBq (20 mCi) [21]

IV. SPECIFICATIONS OF THE EXAMINATION

C. Patient Preparation

1. Prearrival
   Patients should be instructed to avoid caffeine, alcohol, and other drugs known to affect intracranial perfusion for at least 24 hours and to avoid smoking cigarettes for at least the day of the examination.

2. Preinjection
    a. Evaluate the patient for ability to cooperate.
    b. Explain the procedure to the patient or to the responsible family member or health care proxy.
    c. Achieve a consistent environment at the time of injection and during uptake:
        i. Place the patient in a quiet, dimly lit room with no direct light source facing the patient's eyes. Whether the eyes are covered or the patient is instructed to open or close their eyes should be according to department policy and should be followed consistently.
        ii. Ensure that the patient is sitting or reclining comfortably.
        iii. Place intravenous access at least 10 minutes prior to injection.
        iv. Instruct the patient not to speak, read, or move prior to, during, and up to 5 minutes after injection.

3. Precautions
    a. Cognitively impaired patients must be closely observed at all times.
    b. Patients undergoing epilepsy evaluation should have electroencephalogram (EEG) monitoring during injection as seizure activity can alter scan appearance.

IV. SPECIFICATIONS OF THE EXAMINATION

D. Intervention: Acetazolaminde Administration for Identification of Cerebrovascular Reverse

Cerebral perfusion imaging examinations may be performed both before and after the administration of acetazolamide in patients with cerebrovascular disease to evaluate cerebrovascular reserve [1,3]. The indications include evaluation of cerebrovascular reserve in transient ischemic attack (TIA), completed stroke, and/or vascular anomalies (eg, arteriovenous malformation) and to aid in distinguishing vascular from neuronal causes of perfusion defects.

1. Contraindications and adverse reactions

    a. Known sulfa allergy (skin rash, bronchospasm, and anaphylactic reaction) and advanced liver disease. In case of sulfa allergy contraindication, an alternative method is to use 5% carbon dioxide by inhalation to evaluate cerebrovascular reserve. Usually the Tc-99m ECD or Tc-99m HMPAO is administered intravenously (IV) during the first 1 to 2 minutes of a 5-minute inhalation. Carbon dioxide inhalation can cause side effects of headache and nausea.
    b. May induce migraine in patients with migraine history.
    c. Generally avoid within 3 days of acute stroke or recent TIA.
    d. Mild vertigo, tinnitus, paresthesias, and, rarely, nausea may be experienced. These are generally self-limited and do not require specific treatment. Patients may experience postural hypotension when rising from a supine or sitting position and should be appropriately warned and assisted, if necessary.

2. Protocols

    Various protocols have been used. The 2-day technique is simple and preferable. Typically, the acetazolamide challenge examination is performed first. If this examination is normal, consideration may be given to omitting the baseline examination. If a baseline examination is performed, allow sufficient time for residual activity to clear (at least 24 hours).

3. Administered Dose (injected IV slowly)

    a. Adult: Acetazolamide 1,000 mg
    b. Pediatric: Acetazolamide 14 mg/kg

    Wait 15 to 20 minutes after administering acetazolamide before injecting radiopharmaceutical.

4. Acetazolamide is a diuretic. The patient should be instructed to void immediately before image acquisition begins. Acquisition and processing are identical to those of a non–acetazolamide-enhanced examination.

IV. SPECIFICATIONS OF THE EXAMINATION

E. Refractory Epilepsy Ictal/Interictal Evaluations

Cerebral perfusion imaging performed at onset of a focal epileptic seizure may be used to localize the refractory seizure focus for consideration of surgical resection. Imaging performed at onset (ictal imaging) is compared with repeated imaging without seizure activity or effect (interictal imaging) to specifically identify functional changes attributable to the seizure and distinguish from static changes that may be attributable to underlying brain developmental or structural features.

1. Patient Preparation and Management – Ictal Imaging

    For ictal imaging, the patient should be monitored clinically and with continuous EEG. Anticonvulsants may be reduced or discontinued to increase likelihood of seizure episode (tracer at beside). After tracer injection and initial uptake, the patient should be medically stabilized and appropriate medication administered to terminate prolonged or repetitive seizure activity.

2. Interictal Examination

    Interictal perfusion imaging should be performed with the patient at neurological baseline and without recent seizure activity. Although evidence-basis is not available, a 24-hour interval after last seizure is recommended, if possible.

3. Procedural Considerations

    a. Administered radiopharmaceutical and dosage should be the same for both ictal and interictal studies.

b. Time from tracer administration to imaging should be the same for both ictal and interictal studies.
c. To the extent possible, the ambient environment and patient state (other than seizure activity) should be comparable for ictal and interictal studies (eg, eyes open or closed for both injections, etc).

IV. SPECIFICATIONS OF THE EXAMINATION

F. Image Acquisition

1. The patient should void prior to imaging for maximum comfort during the examination.

2. The patient should be positioned for maximum comfort. Minor obliquity of head orientation can be corrected in most systems during processing or image review.

3. The patient's head should be positioned in the middle of the field of view with the intercanthal line at a 90° angle to the axis of rotation and parallel to the horizontal plane. If the patient cannot be positioned with the intercanthal line at a 90° angle to the axis of rotation and parallel to the horizontal plane, images can be realigned during postprocessing. The entire brain (cerebrum and cerebellum) should be included in the field of view. The head should be lightly restrained to facilitate patient cooperation in minimizing motion during acquisition.

4. Sedation should be avoided if possible. If sedation is required, it should be given at least 5 minutes after injection of radiopharmaceutical and preferably just prior to image acquisition. In rare circumstances, sedation may need to be administered prior to radiopharmaceutical administration to obtain an interpretable examination, particularly in young children.

5. Ensure that there is no patient movement during image acquisition.

See equipment specifications below in section VI.

IV. SPECIFICATIONS OF THE EXAMINATION

G. Data Processing

1. Iterative reconstruction is preferred to filtered back projection.

2. Attenuation correction should be performed in all cases unless a specific application or circumstance dictates otherwise [22]. If calculated attenuation correction is used, the contours should include the scalp and should be defined individually for each transaxial slice. If slice-specific attenuation correction software is not available, it is acceptable to review non–attenuation-corrected images. If SPECT/CT imaging is performed, the low-dose, noncontrast CT images may be used for attenuation correction and image fusion.

3. Transaxial data should be reformatted into at least 3 orthogonal planes. Transaxial sections should be generated relative to a repeatable anatomic orientation (eg, the anterior commissure–posterior commissure (AC-PC) line) and coronal and sagittal sections orthogonal to the transaxial [22]. Additional sections along a plane parallel to the long axis of the temporal lobes may be useful, particularly in assessment of temporal lobe epilepsy [22].

4. Image fusion with anatomical imaging (MRI or CT) is highly desirable, and it may be considered essential for the localization of functional abnormalities detected on perfusion SPECT.

IV. SPECIFICATIONS OF THE EXAMINATION

H. Image Interpretation

1. All examinations should be interpreted with the knowledge of all clinical data, including EEG and results of other imaging studies, especially MRI and CT.

2. The extent of normal variability must be appreciated during the scan interpretation. Substantial variability may be noted between normal individuals and between examinations of a single subject obtained at different times.

3. Images should be viewed on a computer display so as to permit interactive adjustment of contrast, background subtraction, and color table.

4. Unprocessed projection images should be assessed in cinematic display prior to viewing of tomographic sections 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 be useful [28]. It is important that the brain SPECT is corrected for motion and 3-D image be aligned along the orthogonal planes.

5. Three-dimensional volume or surface renderings may be useful in appreciating overall patterns of disease.

6. 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, if used, must be based upon knowledge of a normal database for specific radiopharmaceuticals and instruments used in acquiring the examination. Artifacts can be created when inappropriate thresholding is performed.

7. Quantitative analysis and comparison with normal database values can be used to detect asymmetry in cerebral perfusion or other focal or diffuse abnormalities and is recommended for adults [23].

    a. Images obtained as part of a seizure evaluation should be correlated with the relevant EEG data and clinical observations. The timing of radiopharmaceutical injection relative to observed seizure activity should be noted [3,6]. Image characteristics and the extent of seizure foci may change dramatically, depending on the exact timing of radiopharmaceutical injection relative to seizure onset. Ictal and interictal examinations should be compared for optimal patient evaluation. The ictal and interictal scans should be reviewed, with visual assessment initially, to evaluate for areas of increased uptake on the ictal scan that reverse on the interictal scan.
    b. Ictal-interictal subtraction images should ideally be computed employing dedicated commercial software by registering and normalizing the ictal to the interictal SPECT images. The seizure focus will "stand out" on the subtraction images.
    c. The ictal, interictal, and subtraction images must be registered and overlaid to the patient's CT or MRI for anatomic localization of the seizure focus.

IV. SPECIFICATIONS OF THE EXAMINATION

I. Brain Death Imaging

1. Goal

    To corroborate the clinical diagnosis of brain death by determining the presence or absence of intracranial perfusion [10]

2. Indications

    a. As part of a standardized institutional protocol for establishing brain death
    b. In situations in which hypothermia or coma caused by barbiturates or other medications impedes evaluation by other modalities
    c. In situations in which the referring and interpreting physicians agree that evidence for the presence or absence of intracranial perfusion would be helpful
    d. In compliance with local hospital and government regulatory requirements.

3. Administered Activity

a. Tc-99m ECD and Tc-99m HMPAO
   i. Adhere to package insert and quality control instructions to ensure optimal image quality
   ii. Adult: 555 to 1,110 MBq (15-30 mCi)
   iii. Pediatric: 11.1 MBq/kg (0.3mCi/kg); minimum 185 MBq (5.0 mCi), maximum 740 MBq (20 mCi) [21]

b. Tc-99m diethylenetriaminepentaacetic acid (DTPA) and Tc-99m pertechnetate
   i. Agents that cross the blood-brain barrier (eg, Tc-99m ECD or HMPAO) are preferred. If they are not available, Tc-99m DTPA or pertechnetate may be used for cerebral vascular imaging.
   ii. Adult (DTPA/pertechnetate): 555 to 1,110 MBq (15-30 mCi)
   iii. Pediatric (DTPA): 7.4 MBq/kg (0.2 mCi/kg); minimum 37 MBq (1.0 mCi), maximum 740 MBq (20 mCi)

4. Patient

Injection of the radiopharmaceutical must be made directly into a vein or through an IV line that is not being used for infusion of vasoactive medications or transfusion of blood. If available, a central venous line is preferable for injection.

5. Examination

Dynamic blood flow imaging is required for use of Tc-99m DTPA, and it is recommended, but optional, for Tc-99m ECD and Tc-99m HMPAO. Acquisition should be in the anterior projection with the skull vertex (permitting potential visualization of the sagittal sinus) and the common carotid arteries in the field of view (FOV).
For Tc-99m HMPAO and Tc-99m ECD, planar static image acquisition for 500,000 to 1,000,000 counts in the anterior view is recommended. Additional lateral or posterior images depicting the cerebellum are required. SPECT or SPECT/CT imaging may be performed.

6. Other considerations

The President's Council on Brain Death (1982) [24] determined that of the 4 examinations available to establish the presence or absence of brain death, 2 (clinical examination and properly performed 4-vessel cerebral angiography) are diagnostic and 2 (electroencephalography and cerebral scintigraphy) are confirmatory of the clinical examination. Thus, one may corroborate the clinical diagnosis by determining the absence of intracranial perfusion with cerebral scintigraphy. According to an evidence-based review, radiopharmaceutical examinations remain an acceptable confirmatory test [18,25].
For Tc-99m HMPAO and Tc-99m ECD, the absence of demonstrable radiopharmaceutical activity within the brain is consistent with the absence of intracranial perfusion (cerebral and cerebellar), but is not sufficient by itself to make the diagnosis of brain death and should be corroborated with other clinical, neurodiagnostic, and imaging findings.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [26].

The report should include the radiopharmaceutical, administered activity, and route of radiopharmaceutical administration, as well as any other pharmaceuticals administered, also with dosage and route of administration.

Direct communication of the results of the examination to a physician from the referring clinical service is mandatory for brain death examinations.

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Nuclear Medical Physics Performance Monitoring of Gamma Cameras [27].

For planar imaging, any gamma camera equipped with a low-energy all-purpose/general all-purpose (LEAP/GAP) or high-resolution collimator may be used.

For SPECT imaging, a multiple-detector instrument or a dedicated brain imaging system is preferred to a single-

head gamma camera system. A SPECT/CT system may be used, if available.
The following is recommended for SPECT imaging:

A. The smallest radius of rotation possible with appropriate patient safeguards should be used [22].

B. Low-energy high-resolution or ultrahigh-resolution collimators may be used. Fan-beam or other focused collimators are preferable to parallel-hole collimators because they provide improved resolution and higher count rates. However, care must be taken to ensure that the entire brain is visualized in all projections to avoid the problem of "incomplete" views. When parallel-hole collimation is used, care should be taken to ensure that adequate counts are obtained.

C. A 128 × 128 or greater acquisition matrix is preferred. Camera zoom should be set to produce a pixel size of 3.5 mm or less.

D. Continuous acquisition may provide shorter total scan duration when compared with a step-and-shoot technique. When continuous acquisition is used, angular sampling should be 3° or less.

E. If SPECT/CT imaging is performed, all additional relevant quality control procedures should be used. See the ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of SPECT-CT Equipment [28].

F. Segmentation of data acquisition into multiple sequential acquisitions will permit exclusion of bad data, eg, removing segments of projection data with patient motion. The scan may be repeated if there is excessive patient motion.

VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, non-physician radiology providers**,** radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

Facilities and their responsible staff should consult with the radiation safety officer to ensure that there are policies and procedures for the safe handling and administration of radiopharmaceuticals in accordance with ALARA principles. These policies and procedures must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) and by applicable state, local, or other relevant regulatory agencies and accrediting bodies, as appropriate. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol, using body habitus or other customized method when such guidance is available.

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unnecessary radiation exposure.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *ACR Position Statement on Quality Control &*

Improvement, Safety, Infection Control, and Patient Education on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

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2007 (Resolution 21)
Revised 2012 (Resolution 25)
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