## Medical Policy

**Title:** Positron Emission Tomography (PET) Scanning: Miscellaneous (Non-cardiac, Non-Oncologic) Applications of Fluorine 18 Fluorodeoxyglucose

*See also:*  
- PET Scanning: Cardiac Applications  
- PET Scanning: In Oncology to Detect Early Response during Treatment  
- PET Scanning: Oncologic Applications

### Professional

- **Original Effective Date:** October 1, 1997  
- **Revision Date(s):** October 30, 2013; December 31, 2013; October 22, 2015; November 26, 2018  
- **Current Effective Date:** November 26, 2018

### Institutional

- **Original Effective Date:** September 11, 2004  
- **Revision Date(s):** October 30, 2013; December 31, 2013; October 22, 2015; November 26, 2018; June 12, 2020  
- **Current Effective Date:** November 26, 2018

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<table>
<thead>
<tr>
<th>Populations</th>
<th>Interventions</th>
<th>Comparators</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| Individuals:  
- With epileptic seizures who are candidates for surgery |
| Interventions of interest are:  
- Fluorine 18 fluorodeoxyglucose positron emission tomography |
| Comparators of interest are:  
- Ictal scalp electroencephalography  
- Magnetic resonance imaging |
| Relevant outcomes include:  
- Symptoms  
- Change in disease status  
- Functional outcomes  
- Health status measures  
- Quality of life  
- Hospitalizations  
- Medication use  
- Resource utilization |
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<td>Individuals:</td>
<td>Interventions of interest are:</td>
<td>Comparators of interest are:</td>
<td>Relevant outcomes include:</td>
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<tr>
<td>• With suspected chronic osteomyelitis</td>
<td>• Fluorine 18 fluorodeoxyglucose positron emission tomography</td>
<td>• Computed tomography</td>
<td>• Test accuracy</td>
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<td>• Plain radiograph</td>
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<td>• Magnetic resonance imaging</td>
<td>• Other test performance measures</td>
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<td>• Change in disease status</td>
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<td>• Functional outcomes</td>
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<td>• Quality of life</td>
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<td>• Hospitalizations</td>
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<td>Individuals:</td>
<td>Interventions of interest are:</td>
<td>Comparators of interest are:</td>
<td>Relevant outcomes include:</td>
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<tr>
<td>• With suspected Alzheimer disease</td>
<td>• Fluorine 18 fluorodeoxyglucose positron emission tomography</td>
<td>• Clinical diagnosis without fluorine 18 fluorodeoxyglucose positron emission tomography</td>
<td>• Test accuracy</td>
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<td>• Test validity</td>
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<td>• Other test performance measures</td>
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<td>• Quality of life</td>
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<td>• Hospitalizations</td>
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<tr>
<td>Individuals:</td>
<td>Interventions of interest are:</td>
<td>Comparators of interest are:</td>
<td>Relevant outcomes include:</td>
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<tr>
<td>• With suspected large vessel vasculitis</td>
<td>• Fluorine 18 fluorodeoxyglucose positron emission tomography</td>
<td>• Clinical diagnosis without fluorine 18 fluorodeoxyglucose positron emission tomography</td>
<td>• Test accuracy</td>
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<td>• Test validity</td>
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<td>• Other test performance measures</td>
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<td>• Change in disease status</td>
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<td>• Treatment-related morbidity</td>
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<td>Individuals:</td>
<td>Interventions of interest are:</td>
<td>Comparators of interest are:</td>
<td>Relevant outcomes include:</td>
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<tr>
<td>• With diverse noncardiac or nononcologic conditions (eg, central nervous system, pulmonary, and musculoskeletal diseases)</td>
<td>• Fluorine 18 fluorodeoxyglucose positron emission tomography</td>
<td>• Computed tomography</td>
<td>• Overall survival</td>
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<td></td>
<td></td>
<td>• Plain radiograph</td>
<td>• Symptoms</td>
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<td>• Magnetic resonance imaging</td>
<td>• Change in disease status</td>
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<td>• Functional outcomes</td>
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<td>• Health status measures</td>
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<td>• Resource utilization</td>
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**DESCRIPTION**

Positron emission tomography (PET) images biochemical and physiological functions by measuring concentrations of radioactive chemicals that have been partially metabolized in a particular region of the body. Radiopharmaceuticals used for PET are generated in a cyclotron (nuclear generator) and then introduced into the body by intravenous injection or by respiration.

**Objective**

The objective of this evidence review is to determine whether use of fluorine 18 fluorodeoxyglucose positron emission tomography improves the net health outcome in individuals with epilepsy, suspected chronic osteomyelitis, suspected Alzheimer disease, suspected large vessel vasculitis, and other noncardiac and nononcologic conditions (eg, central nervous system, pulmonary, and musculoskeletal diseases).
Background

Positron Emission Tomography

Positron emission tomography (PET) scans coupled positron-emitting radionuclide tracers to other molecules, such as glucose, ammonia, or water. The radionuclide tracers simultaneously emit two high-energy photons in opposite directions that can be simultaneously detected (referred to as coincidence detection) by a PET scanner, which comprises multiple stationary detectors that encircle the region of interest.

A variety of tracers are used for PET scanning, including oxygen 15, nitrogen 13, carbon 11, and fluorine 18. The radiotracer most commonly used in oncology imaging has been fluorine 18, coupled with fluorodeoxyglucose (FDG), which has a metabolism related to glucose metabolism. While FDG has traditionally been used in cancer imaging, it potentially has many other applications.

Regulatory Status

Following the U.S. Food and Drug Administration’s (FDA) approval of the Penn-PET in 1989, a number of PET scan platforms have been cleared by FDA through the 510(k) process. These systems are intended to aid in detecting, localizing, diagnosing, staging and restaging of lesions, tumors, disease and organ function for the evaluation of diseases, and disorders such as, but not limited to, cardiovascular disease, neurologic disorders, and cancer. The images produced by the system can aid in radiotherapy treatment planning and interventional radiology procedures.

PET radiopharmaceuticals have been evaluated and approved as drugs by FDA for use as diagnostic imaging agents. These radiopharmaceuticals are approved for specific conditions.

In December 2009, FDA issued guidance for Current Good Manufacturing Practice for PET drug manufacturers\(^\text{15}\) and, in August 2011, issued similar Current Good Manufacturing Practice guidance for small businesses compounding radiopharmaceuticals.\(^\text{16}\) An additional final guidance document, issued in December 2012, required all PET drug manufacturers and compounders to operate under an approved new drug application (NDA) or abbreviated NDA, or investigational new drug application, by December 12, 2015.\(^\text{17}\)

In 1994, the FDG radiotracer was originally approved by FDA through the NDA (20-306) process. The original indication was for “the identification of regions of abnormal glucose metabolism associated with foci of epileptic seizures”. Added indications in 2000 were for “Assessment of glucose metabolism to assist in the evaluation of malignancy...” and “Assessment of patients with coronary artery disease and left ventricular dysfunction....”

Multiple manufacturers have approved NDAs for FDG.
POLICY

A. Positron emission tomography (PET) using 2-[fluorine-18]-fluoro-2-deoxy-D-glucose (FDG) may be considered medically necessary in:
   1. the assessment of selected patients with epileptic seizures who are candidates for surgery (see Policy Guidelines)
   2. the diagnosis of chronic osteomyelitis

B. The use of FDG-PET for all other miscellaneous indications is experimental / investigational including but not limited to:

Central Nervous System Diseases
1. Autoimmune disorders with central nervous system (CNS) manifestations, including:
   a. Behçet syndrome
   b. lupus erythematosus

2. Cerebrovascular diseases, including:
   a. arterial occlusive disease (arteriosclerosis, atherosclerosis)
   b. carotid artery disease
   c. cerebral aneurysm
   d. cerebrovascular malformations (arteriovenous malformation and Moya-Moya disease)
   e. hemorrhage
   f. infarct
   g. ischemia

3. Degenerative motor neuron diseases, including:
   a. amyotrophic lateral sclerosis
   b. Friedreich ataxia
   c. olivopontocerebellar atrophy
   d. Parkinson disease
   e. progressive supranuclear palsy
   f. Shy-Drager syndrome
   g. spinocerebellar degeneration
   h. Steele-Richardson-Olszewski syndrome
   i. Tourette syndrome

4. Dementias, including:
   a. Alzheimer's disease
   b. multi-infarct dementia
   c. Pick disease
   d. frontotemporal dementia
   e. dementia with Lewy bodies
   f. presenile dementia
5. Demyelinating diseases, such as multiple sclerosis

6. Developmental, congenital, or inherited disorders, including:
   a. adrenoleukodystrophy
   b. Down syndrome
   c. Huntington chorea
   d. kinky-hair disease (Menkes disease)
   e. Sturge-Weber syndrome (encephalofacial angiomatosis) and the phakomatoses

7. Miscellaneous
   a. chronic fatigue syndrome
   b. sick building syndrome
   c. posttraumatic stress disorder

8. Nutritional or metabolic diseases and disorders, including:
   a. acanthocytosis
   b. hepatic encephalopathy
   c. hepatolenticular degeneration
   d. metachromatic leukodystrophy
   e. mitochondrial disease
   f. subacute necrotizing encephalomyelopathy

9. Psychiatric diseases and disorders, including:
   a. affective disorders
   b. depression
   c. obsessive-compulsive disorder
   d. psychomotor disorders
   e. schizophrenia

10. Pyogenic infections, including:
    a. aspergillosis
    b. encephalitis

11. Substance abuse, including the central nervous system effects of alcohol, cocaine, and heroin

12. Trauma, including brain injury and carbon monoxide poisoning
13. Viral infections, including:
   a. HIV / AIDS
   b. AIDS dementia complex
   c. Creutzfeldt-Jakob syndrome
   d. progressive multifocal leukoencephalopathy
   e. progressive rubella encephalopathy
   f. subacute sclerosing panencephalitis

14. Mycobacterium infection
15. Migraine
16. Anorexia nervosa
17. Assessment of cerebral blood flow in newborns
   a. Vegetative vs locked-in syndrome

**Pulmonary Diseases**
18. Adult respiratory distress syndrome
19. Diffuse panbronchiolitis
20. Emphysema
21. Obstructive lung disease
22. Pneumonia

**Musculoskeletal Diseases**
23. Spondylodiscitis
24. Joint replacement follow-up

**Other**
25. Giant cell arteritis
26. Vasculitis
27. Vascular prosthetic graft infection
28. Inflammatory bowel disease
29. Sarcoidosis
30. Fever of unknown origin
31. Inflammation of unknown origin

**Policy Guidelines**
In patients with epileptic seizures, appropriate candidates are patients with complex partial seizures that have failed to respond to medical therapy and have been advised to have a resection of a suspected epileptogenic focus located in a region of the brain accessible to surgery. Further, for the purposes of this policy, conventional noninvasive techniques for seizure localization must have been tried with results suggesting a seizure focus but not sufficiently conclusive to permit surgery. The purpose of the PET examination should be to avoid subjecting the patient to extended preoperative electroencephalographic recording with implanted electrodes, or to help localize and
minimize the number of sites for implanted electrodes to reduce the morbidity of that procedure.

**RATIONALE**
This evidence review been updated with searches of the MEDLINE database. The most recent literature update was performed through July 8, 2019.

Evidence reviews assess whether a medical test is clinically useful. A useful test provides information to make a clinical management decision that improves the net health outcome. That is, the balance of benefits and harms is better when the test is used to manage the condition than when another test or no test is used to manage the condition.

The first step in assessing a medical test is to formulate the clinical context and purpose of the test. The test must be technically reliable, clinically valid, and clinically useful for that purpose. Evidence reviews assess the evidence on whether a test is clinically valid and clinically useful. Technical reliability is outside the scope of these reviews, and credible information on technical reliability is available from other sources.

**Fluorine 18 Fluorodeoxyglucose Positron Emission Tomography**

**Suspected Epilepsy**

**Intractable Epilepsy**

**Clinical Context and Test Purpose**
The purpose of FDG-PET in patients with epilepsy is to inform the decision on selecting treatment regimens.

The question addressed in this evidence review is: Does the use of FDG-PET improve the net health outcome in individuals with medically refractory or intractable epilepsy who are candidates for neurosurgery?

The following PICOs were used to select literature to inform this review.

**Patients**
The population of interest are patients with intractable epilepsy.

Approximately one-third of patients with epilepsy do not achieve adequate seizure control with antiepileptic drugs. Individuals with drug-resistant epilepsy are candidates for other treatments such as surgery. Many effective surgical procedures are available and the treatment selected depends on characteristics of the seizures (eg, the epileptogenic zone) and the extent to which it can be resected safely. Neuroimaging techniques, such as magnetic resonance imaging (MRI), electroencephalography, PET, single-photon emission computed tomography, electric and magnetic source imaging, and magnetic resonance spectroscopy, have been used to locate the epileptic focus, thereby helping to guide the operative strategy. Some patients with epilepsy will have no identifiable MRI abnormality to help identify the focal region. PET, particularly using FDG, is a neuroimaging technique frequently used in patients being considered for surgery. FDG-PET produces an image of the distribution of glucose uptake in the brain, presumably detecting focal areas of decreased metabolism. PET may be able to correctly identify the focus in patients...
with unclear or unremarkable MRI results or discordant MRI and electroencephalographic results that could reduce the need for invasive electroencephalography. PET scanning may also help to predict which patients will have a favorable outcome following surgery. The Engel classification system often used to describe the surgical outcome, is as follows: class I: seizure-free (or free of disabling seizures); class II: nearly seizure-free; class III: worthwhile improvement; and class IV: no worthwhile improvement.\textsuperscript{10}

**Interventions**

The intervention of interest is FDG-PET. For patients with epilepsy, FDG-PET would be conducted prior to surgery to identify the epileptogenic focus.

**Comparators**

Ictal scalp electroencephalography and MRI are currently being used to make preoperative decisions in patients with epilepsy for whom surgery is being considered.

**Outcomes**

For patients with epilepsy, the outcome of interest is to predict which patients will have a favorable outcome following surgery. Other outcomes of interest include symptoms, change in disease status, functional outcomes, health status measures, quality of life (QOL), hospitalizations, medication use, and resource utilization. For patients with epilepsy, FDG-PET would be conducted prior to surgery.

**Study Selection Criteria**

For the evaluation of the clinical validity of the tests, studies that meet the following eligibility criteria were considered:

- Reported on the accuracy of the marketed version of the technology (including any algorithms used to calculate scores)
- Included a suitable reference standard
- Patient/sample clinical characteristics were described
- Patient/sample selection criteria were described
- Included a validation cohort separate from development cohort.

**Technically Reliable**

Assessment of technical reliability focuses on specific tests and operators and requires a review of unpublished and often proprietary information. Review of specific tests, operators, and unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

**Clinically Valid**

A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

**Systematic Reviews**

A TEC Assessment (1996) reviewed the evidence on the use of PET in individuals with seizure disorders from 12 studies in which the results of PET scans were correlated with results of an appropriate reference standard test.\textsuperscript{5} The highest quality blinded study (n=143) reported that PET correctly localized the seizure focus in 60% of patients, incorrectly localized it in 6%, and was inconclusive in 34%. Reviewers concluded that because localization can be improved with
PET, selection of surgical candidates is improved and, therefore, PET for assessing patients who have medically refractory complex partial seizures and are potential candidates for surgery met TEC criteria. All other uses of PET for the management of seizure disorders did not meet the TEC criteria. Tables 1 and 2 summarize the characteristics and results of several meta-analyses of FDG-PET published since that TEC Assessment that have assessed either presurgical planning of patients who are candidates for epilepsy surgery or prediction of surgical outcomes. A brief discussion of each trial follows.

**Table 1. Characteristics of Systematic Reviews Assessing Use of FGD-PET for Epilepsy**

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Trials</th>
<th>N (Range)</th>
<th>Design</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wang et al (2016)</td>
<td>2000-2015</td>
<td>18</td>
<td>391 (5-86)</td>
<td>NR</td>
<td>1-6.5 years</td>
</tr>
<tr>
<td>Englot et al (2012)</td>
<td>1990-2010</td>
<td>21*</td>
<td>1199 (13-253)*</td>
<td>OBS</td>
<td>&gt; 4 years</td>
</tr>
</tbody>
</table>

FDG-PET: fluorine 18 fluorodeoxyglucose positron emission tomography; OBS: observational; NR: not reported.

* Total number of studies and participants included; unclear if all studies included PET as a predictor.

Jones et al (2016) published a systematic review of neuroimaging for surgical treatment of temporal lobe epilepsy. Inclusion criteria were systematic reviews, randomized controlled trials (RCTs), or observational studies (with >20 patients and at least 1-year follow-up) of neuroimaging in the surgical evaluation for temporal lobe epilepsy. Reviewers searched EMBASE, MEDLINE, and Cochrane databases. Twenty-seven studies with 3163 patients were included in the review, of which 11 observational studies with 1358 patients evaluated FDG-PET. Good surgical outcome was defined as Engel classes I and II. Meta-analysis was not performed. Results are summarized in Table 2.

Wang et al (2016) conducted a systematic review of prognostic factors for seizure outcomes in patients with MRI-negative temporal lobe epilepsy included a search of MEDLINE. Eighteen studies (total n=391 patients) were included with a mean or median follow-up of more than 1 year. Seizure freedom was defined as freedom from any type of seizure or an Engel class I seizure outcome. Odds ratios and corresponding 95% confidence intervals (CIs) were calculated to compare the pooled proportions of seizure freedom between the groups who had localization of hypometabolism in the resected lobe vs those who did not. Table 2 shows the summary results.

Burneo et al (2015) published a recommendation report for the Program in Evidence-based Care and the PET steering committee of Cancer Care Ontario, which was based on a systematic review of studies of diagnostic accuracy and clinical utility of FDG-PET in the presurgical evaluation of adult and pediatric patients with medically intractable epilepsy. The literature review included searches of the MEDLINE, EMBASE, OVID, and Cochrane databases. Systematic reviews, RCTs, and observational studies that evaluated the use of FDG-PET in medically intractable epilepsy were eligible for inclusion. Reviewers included 39 observational studies (total n=2650 participants) in the qualitative review. Good surgical outcome was defined as Engel class I, II, or III, seizure-free, or significant improvement (<10 seizures per year and at least a 90% reduction in seizures from the preoperative year). Due to heterogeneity in patient populations, study designs, outcome measurements, and methods of PET interpretation, pooled estimates were not provided; ranges are provided in Table 2.
Englot et al (2012) performed a systematic review of predictors of long-term seizure freedom after surgery for frontal lobe epilepsy; they included articles found through a MEDLINE search that had at least 10 participants and 48 months of follow-up.¹⁴ Long-term seizure freedom was defined as Engel class I outcome. Twenty-one studies (total n=1199 patients) were included; the number of studies that specifically addressed PET was not specified. Results are summarized in Table 2. Reviewers found that PET scans did not predict seizure freedom.

Willmann et al (2007) conducted a meta-analysis on the use of FDG-PET for preoperative evaluation of adults with temporal lobe epilepsy included 46 studies published identified through a MEDLINE search.¹⁵ Follow-up ranged from 3 to 144 months. Engel class I and II were defined as a good surgical outcome. The prognostic positive predictive value (PPV) for ipsilateral PET hypometabolism was calculated but the reviewers noted a significant variation in study designs and lack of precise data. Reviewers found that ipsilateral PET hypometabolism had a predictive value for a good outcome of 86% (see Table 2). The incremental benefit of PET was unclear.

### Table 2. Results of Systematic Reviews on Use of FDG-PET for Epilepsy

<table>
<thead>
<tr>
<th>Study</th>
<th>Studies</th>
<th>N</th>
<th>Outcomes</th>
<th>Estimate or Range</th>
<th>95% CI</th>
<th>I²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones et al (2016)¹¹, ¹²</td>
<td>11</td>
<td>1358</td>
<td>Surgical outcome</td>
<td>• No overall summary given</td>
<td>No pooling</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>• Reported conflicting findings on prognostic importance of PET-identified focal hypometabolism</td>
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<tr>
<td>Wang et al (2016)¹², ¹³</td>
<td>5</td>
<td>NR</td>
<td>Surgical outcome (freedom from seizures)</td>
<td>OR for PET hypometabolism positive vs negative, 2.11</td>
<td>0.95 to 4.65</td>
<td>0</td>
<td>0.06</td>
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<tr>
<td>Burneo et al (2015)¹³</td>
<td>8</td>
<td>310</td>
<td>Percent agreement, localization with PET vs EEG</td>
<td>• 56%-90% overall (adults)</td>
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<td>• 63%-90% in temporal lobe epilepsy (adults)</td>
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<tr>
<td></td>
<td>13</td>
<td>1064</td>
<td>Prognostic accuracy (good surgical outcome)</td>
<td>36%-89% (adults)</td>
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<td></td>
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<tr>
<td></td>
<td>6</td>
<td>690</td>
<td>Clinical decisions (influence decision making)</td>
<td>• 53%-71% (adults)</td>
<td></td>
<td></td>
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<td></td>
<td>• 51%-95% (children)</td>
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</tr>
<tr>
<td>Englot et al (2012)¹⁴</td>
<td>21²</td>
<td>1199²</td>
<td>Prognostic accuracy (good surgical outcome)</td>
<td>% for PET focal vs PET nonfocal, 52% vs 48%</td>
<td>NR</td>
<td>NR</td>
<td>0.61</td>
</tr>
<tr>
<td>Willmann et al (2007)¹⁵</td>
<td>46</td>
<td>1112</td>
<td>Prognostic accuracy (good surgical outcome)</td>
<td>PPV=86%</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

CI: confidence interval; EEG: electroencephalography; FDG: fluorine 18 fluorodeoxyglucose; NR: not reported; OR: odds ratio; PET: positron emission tomography; PPV: positive predictive value.  
² Total number of studies and participants included; unclear if all studies included PET as a predictor.

**Observational Studies**

In a study published after the most recent systematic reviews, Traub-Weidinger et al (2016) reviewed a database of pediatric patients with epilepsy who underwent hemispherotomy and were evaluated with both FDG-PET and MRI before surgery (n=35).¹⁶ Identifying the hemisphere harboring the epileptogenic zone before surgery has been shown to improve surgical outcomes. Seizure outcomes were measured using International League Against Epilepsy classifications. At
12 months postsurgery, 100% of patients with unilateral FDG-PET hypometabolism were seizure-free, while 95% of patients with unilateral lesions identified by MRI were seizure-free. For patients with bilateral FDG-PET hypometabolism, 75% were seizure-free at 12 months, while 71% of patients with bilateral lesions identified by MRI were seizure-free.

**Clinically Useful**
A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

**Direct Evidence**
Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from RCTs.

The recommendation report by Burneo et al (2015) discussed 3 retrospective studies demonstrating the impact of FDG-PET on clinical management of adults with epilepsy and 3 retrospective studies on change in clinical management based on FDG-PET results in children with epilepsy. After receiving FDG-PET results on adults, some clinicians changed surgical decisions, used the results to guide intracranial electroencephalography, and ruled out additional evaluation of the patient. Among pediatric patients who underwent FDG-PET, clinicians reported using the results to alter surgical decisions, classify symptomatic infantile spasms, and avoid invasive monitoring due to localizing information. The study results were not pooled due to heterogeneity among the study designs and patient populations.

**Section Summary: Epilepsy**
The TEC Assessment and the Program in Evidence-based Care recommendations summarized evidence on the use of PET to localize seizure foci for presurgical evaluation. Although data were exclusively from observational studies and the results were heterogeneous, the findings generally supported the use of PET for presurgical evaluation of adult and pediatric patients with intractable epilepsy to localize foci. For predicting which patients would have a favorable surgery outcome, the data on PET were mixed but supported a possible moderate relation between PET findings and prognosis. There are several retrospective studies that surveyed clinicians on the utility of FDG-PET in managing patients with epilepsy. In general, the clinicians reported that the information from FDG-PET was helpful in surgical management decisions. Only observational studies are available, most having small samples sizes with varying patient characteristics and definitions of good surgical outcomes.

**Suspected Chronic Osteomyelitis**

**Clinical Context and Test Purpose**
The purpose of FDG-PET in patients with chronic osteomyelitis is to confirm a diagnosis or to inform the decision on selecting treatment regimens.

The question addressed in this evidence review is: Does the use of FDG-PET improve the net health outcome in individuals with chronic osteomyelitis?

The following PICOs were used to select literature to inform this review.
Patients
The population of interest are patients with chronic osteomyelitis.

Diabetic foot infections cause substantial morbidity and are a frequent cause of lower-extremity amputations. Foot infections can spread to contiguous deep tissues including the bone. Diagnosis of osteomyelitis is challenging. The reference standard for diagnosis is an examination of bacteria from a bone biopsy along with histologic findings of inflammation and osteonecrosis. In an open wound, another potential test for osteomyelitis is a probe-to-bone test, which involves exploring the wound for palpable bone using a sterile blunt metal probe. Plain radiographs are often used as screening tests before biopsy but they tend to have low specificity especially in early infection. When radiographs are inconclusive, a more sophisticated imaging technique can be used. Neither MRI nor computed tomography (CT), both of which have high sensitivity in diagnosing osteomyelitis, can be used in patients with metal hardware. FDG-PET has high resolution that should be an advantage for accurate localization of leukocyte accumulation and can be used when MRI is not possible or inconclusive; in addition, PET semiquantitative analysis could facilitate the differentiation of osteomyelitis from noninfectious conditions such as neuropathic arthropathy.

Interventions
The intervention of interest is FDG-PET. For patients with suspected chronic osteomyelitis, FDG-PET would be performed following inconclusive clinical examinations and standard radiographs.

Comparators
CT, radiography, and MRI are currently being used to make decisions about managing suspected chronic osteomyelitis.

Outcomes
For patients with suspected chronic osteomyelitis, the main outcomes interest are disease-related morbidity and mortality. Other outcomes of interest include test accuracy, test validity, symptoms, change in disease status, functional outcomes, health status measures, QOL, hospitalizations, medication use, and resource utilization.

Study Selection Criteria
Methodologically credible studies were selected using the principles described in the first indication.

Technically Reliable
Assessment of technical reliability focuses on specific tests and operators and requires a review of unpublished and often proprietary information. Review of specific tests, operators, and unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

Clinically Valid
A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).
**Systematic Reviews**

Lauri et al (2017) published a systematic review of 27 trials of diabetic patients with suspicion of osteomyelitis of the foot that compared the diagnostic performance of several imaging techniques. MRI, technetium 99m hexamethylpropyleneamineoxime white blood cell (WBC) scan, indium In 111 oxyquinoline WBC scan, or FDG-PET plus CT were assessed. In this population, the sensitivity and specificity of FDG-PET/CT (6 studies; 254 patients) were 89% (95% CI, 68% to 97%) and 92% (95% CI, 85% to 96%), respectively. The diagnostic odds ratio for FDG-PET was 95, and the positive and negative likelihood ratios were 11 and 0.11, respectively. Of the 4 modalities included, FDG-PET/CT and technetium 99m hexamethylpropyleneamineoxime WBC scans had greater specificity (both 92%) than MRI or In-oxine WBC scans (both 75%). Sensitivity did not differ significantly between modalities: 93% for MRI, 92% for indium In 111 oxyquinoline WBC, 91% for technetium 99m hexamethylpropyleneamineoxime WBC, and 89% for FDG-PET. The review was limited by the small size of studies included, which precluded subgroup or meta-regression analyses.

A systematic review by Treglis et al (2013) assessed 9 studies (total n=299 patients), FDG-PET and PET with CT were found to be useful for assessing suspected osteomyelitis in the foot of patients with diabetes. A meta-analysis of 4 studies found a sensitivity of 74% (95% CI, 60% to 85%), a specificity of 91% (95% CI, 85% to 96%), a positive likelihood ratio of 5.56 (95% CI, 2.02 to 15.27), a negative likelihood ratio of 0.37 (95% CI, 0.10 to 1.35), and a diagnostic odds ratio of 16.96 (95% CI, 2.06 to 139.66). The summary area under the receiver operating characteristic curve was 0.874.

Termaat et al (2005) conducted a systematic review of diagnostic imaging to assess chronic osteomyelitis. Reviewers assessed 6 imaging approaches to chronic osteomyelitis, including FDG-PET, and concluded that PET was the most accurate mode (pooled sensitivity, 96%; 95% CI, 88% to 99%; pooled specificity, 91%; 95% CI, 81% to 95%) for diagnosing chronic osteomyelitis, including leukocyte scintigraphy was adequate in the peripheral skeleton (sensitivity, 84%; 95% CI, 72% to 91%; specificity, 80%; 95% CI, 61% to 91%) but was inferior in the axial skeleton (sensitivity, 21%; 95% CI, 11% to 38%; specificity, 60%; 95% CI, 39% to 78%). The assessment of PET was based on 4 prospective, European studies published between 1998 and 2003 (total n=1660 patients). However, the study populations varied and included the following: (1) 57 patients with suspected spinal infection referred for FDG-PET and who had previous spinal surgery but not "recently"; (2) 22 trauma patients scheduled for surgery who had suspected metallic implant-associated infection; (3) 51 patients with recurrent osteomyelitis or osteomyelitis symptoms for more than 6 weeks, 36 in the peripheral skeleton and 15 in the central skeleton; and (4) 30 consecutive nondiabetic patients referred for possible chronic osteomyelitis. The results appeared to be robust across fairly diverse clinical populations, which strengthen the conclusions.

**Prospective Studies**

Rastogi et al (2016) published a study comparing the efficacy of FDG-PET plus CT with contrast-enhanced MRI in the detection of diabetic foot osteomyelitis in patients with Charcot neuroarthropathy. Patients with suspected diabetic foot osteomyelitis (n=23) underwent radiographs, FDG-PET/CT, and contrast-enhanced MRI. Bone culture, which is considered the criterion standard, identified 12 of the 23 patients with osteomyelitis. The sensitivity, specificity, PPV, and negative predictive value (NPV) of FDG-PET/CT in diagnosing osteomyelitis were 83%,
100%, 100%, and 85%, respectively. The same measures for contrast-enhanced MRI were 83%, 64%, 71%, and 78%, respectively.

**Clinically Useful**
A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

**Direct Evidence**
Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from RCTs.

No RCTs identified assessed the evidence on the clinical utility of FDG-PET for diagnosing osteomyelitis.

**Chain of Evidence**
Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

Diagnosing osteomyelitis is challenging and FDG-PET may provide additional information along the diagnostic pathway. Currently, a bone biopsy is considered the reference standard, and radiographs are often used as screening tests prior to bone biopsy. When radiographs are inconclusive, other imaging techniques have been used, such as MRI and CT. While MRI has been shown to have a high sensitivity in diagnosing osteomyelitis, FDG-PET has also been shown to have high sensitivity and can be used when MRI is inconclusive or not possible (eg, patients with metal hardware).

**Section Summary: Suspected Chronic Osteomyelitis**
Evidence for the use of FDG-PET to diagnose chronic osteomyelitis includes three systematic reviews and a prospective study published after the systematic reviews. FDG-PET and FDG-PET/CT were found to have high specificity and PPVs in diagnosing osteomyelitis. Compared with other modalities, FDG-PET and FDG-PET/CT were found to have better diagnostic capabilities than contrast-enhanced MRI.

**Diagnosing Suspected Alzheimer Disease**

**Clinical Context and Test Purpose**
The purpose of FDG-PET in patients with suspected AD is to confirm a diagnosis of AD.

The question addressed in this evidence review is: Does the use of FDG-PET improve the net health outcome in individuals with suspected AD?

The following PICOs were used to select literature to inform this review.

**Patients**
The population of interest are patients with suspected AD.
A definitive diagnosis of AD requires histopathologic examination of brain tissue obtained by biopsy or autopsy. In practice, clinical criteria based on clinical examination, neurologic and neuropsychological examinations, and interviews with informants (eg, family members or caregivers) are used to diagnose AD by excluding other diseases that can cause similar symptoms and distinguish AD from other forms of dementia.

**Interventions**
The intervention of interest is FDG-PET.

For patients with suspected AD, FDG-PET would be performed following inconclusive clinical examinations and standard radiographs.

**Comparators**
Clinical diagnosis without FDG-PET is currently being used for suspected AD.

**Outcomes**
For patients with suspected AD, the main outcomes interest are disease-related morbidity and mortality. Other outcomes of interest include test accuracy, test validity, symptoms, change in disease status, functional outcomes, health status measures, QOL, hospitalizations, medication use, and resource utilization.

**Study Selection Criteria**
Methodologically credible studies were selected using the principles described in the first indication.

**Technically Reliable**
Assessment of technical reliability focuses on specific tests and operators and requires a review of unpublished and often proprietary information. Review of specific tests, operators, and unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

**Clinically Valid**
A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

**Systematic Reviews**
Summaries of the characteristics and results of several meta-analyses of the early diagnosis of AD in people with cognitive impairment or for differentiating between potential causes of dementia are shown in Tables 3 and 4 and are briefly described below.

**Table 3. Characteristics of Systematic Reviews on Use Assessing FDG-PET for AD and Dementia**

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Studies</th>
<th>N (Range)</th>
<th>Design</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davison et al (2014)28</td>
<td>Up to 2013</td>
<td>8</td>
<td>197 (7-199)</td>
<td>OBS</td>
<td>Diagnostic accuracy for diagnosis of AD, differential diagnosis in dementia, predicting conversion from MCI to AD</td>
</tr>
</tbody>
</table>
### PET Scanning: Miscellaneous

(Non-cardiac, Non-Oncologic) Applications of FDG

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Studies</th>
<th>N (Range)</th>
<th>Design</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yuan et al (2009)</td>
<td>2001-2005</td>
<td>6</td>
<td>280 (17-128)</td>
<td>OBS</td>
<td>Diagnostic accuracy for predicting conversion from MCI to AD</td>
</tr>
</tbody>
</table>

AD: Alzheimer disease; FDG-PET: fluorine 18 fluorodeoxyglucose positron emission tomography; MCI: mild cognitive impairment; NR: not reported; OBS: observational.

Smailagic et al (2015) conducted a Cochrane review to assess the diagnostic accuracy of FDG-PET for detecting people who clinically convert to AD or other forms of dementia at follow-up. Included studies evaluated the diagnostic accuracy of FDG-PET to determine the conversion from mild cognitive impairment (MCI) to AD or to other forms of dementia. Sixteen studies (total n=697 participants) were included in the qualitative review and 14 studies (n=421 participants) were included in the analysis. Because there are no accepted thresholds to define positive findings based on PET scans and studies used mixed thresholds for diagnosis, reviewers used a hierarchical summary receiver operating characteristic curve to derive pooled estimates of performance characteristics at fixed values. Results are shown in Table 4. Five studies evaluated the accuracy of FDG-PET for all types of dementia. The sensitivities ranged between 46% and 95% while the specificities between 29% and 100%; however, a meta-analysis could not be conducted because of the small number of studies sample sizes. Reviewers indicated that most studies were poorly reported and had an unclear risk of bias, mainly for the reference standard and participant selection domains.

In a systematic review (quality assessment of included studies was not reported), Davison et al (2014) reported on studies on the diagnostic performance of FDG-PET and single-photon emission CT identified through MEDLINE. Three studies (197 patients) used histopathology as the reference standard. In patients with or without a clinical diagnosis of AD, sensitivity was 84% and specificity was 74%; in patients with memory loss or dementia, sensitivity was 94% and specificity was approximately 70%; in patients undergoing evaluation for dementia, sensitivity was 94% and specificity was 73%. Precision estimates were not given. In 3 different studies (271 participants), the sensitivities and specificities of FDG-PET for distinguishing AD from Lewy body dementia ranged from 83% to 99% and from 71% to 93%, respectively. And in 2 studies (183 participants), for predicting conversion from MCI to AD, sensitivity, and specificity of PET ranged from 57% to 82% and from 67% to 78%, respectively.

Bloudek et al (2011) assessed diagnostic strategies for AD in a meta-analysis. Reviewers included 119 studies of diagnostic performance characteristics published from 1990 to 2010. Studies were identified through a search of MEDLINE and included imaging, biomarkers, and clinical diagnostic strategies. Twenty studies included performance characteristics of FDG-PET for diagnosing AD compared with normal, nondemented controls. Thirteen studies described characteristics of FDG-PET for diagnosing AD compared with demented controls. FDG-PET demonstrated the highest area under the receiver operating characteristic curve, sensitivity, and specificity among all of the diagnostic methods for distinguishing AD from normal controls but one of the lowest receiver operating characteristic comparing AD with non-AD demented controls (excluding MCI), due primarily to the low specificity in this group. Results are shown in Table 4.
In a meta-analysis, Yuan et al (2009) compared the prognostic capacity of FDG-PET, single-photon emission CT, and structural MRI to predict patients' conversion from MCI to AD. Using 24 articles (total n = 1112 patients) published between 1990 to 2008 (6 studies with 280 patients on FDG-PET, published 2001-2005), reviewers found no statistically significant difference among the 3 modalities in pooled sensitivity, pooled specificity, or negative likelihood ratio. Results are shown in Table 4. There was strong evidence of between-study heterogeneity and marked asymmetry in the funnel plot (with studies missing from the bottom left quadrant), indicating possible publication bias of studies with null results. Efforts to identify sources of heterogeneity (eg, publication year, age, male-female ratio, follow-up interval, years of education, mean Mini-Mental State Examination score at baseline) yielded no significant results.

Using decision-analysis modeling, Matchar et al (2001) performed a technology assessment for the Agency for Healthcare Research and Quality to examine whether the use of FDG-PET would improve health outcomes for diagnosis of AD in 3 clinical populations: patients with dementia, patients with MCI, and subjects with no symptoms but with a first-degree relative with AD. For the review, a search was performed using MEDLINE, CINAHL, and the HealthSTAR databases. Eighteen articles (total n = 1018 participants) were included. The reference standard used in the studies was either histopathology or clinical diagnosis. Studies reported on various cutoffs for PET positivity, and, therefore, an unweighted summary receiver operating characteristic method was used to calculate the pooled area under the curve. Results are summarized in Table 4. Reviewers concluded that outcomes for all three groups were better if all patients were treated with agents such as cholinesterase inhibitors rather than limiting treatment to patients based on FDG-PET results. The rationale was that the complications of treatment were relatively mild, and that treatment was considered to have some degree of efficacy in delaying the progression of AD.

### Table 4. Results of Systematic Review on Use Assessing FDG-PET for AD and Dementia

<table>
<thead>
<tr>
<th>Study</th>
<th>Studies</th>
<th>N</th>
<th>Outcomes</th>
<th>Estimate (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smailagic et al (2015)</td>
<td>14</td>
<td>421</td>
<td>Diagnostic accuracy</td>
<td>• Sensitivity range: 25%-100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specificity range: 15%-100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• PLR: 4.03 (2.97 to 5.47)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• NLR: 0.34 (0.15 to 0.75)</td>
</tr>
<tr>
<td>Davison et al (2014)</td>
<td>3</td>
<td>197</td>
<td>Diagnostic accuracy</td>
<td>• Sensitivity: 84%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specificity: 74%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>183</td>
<td>Diagnostic accuracy, predicting conversion from MCI to AD</td>
<td>• Sensitivity range: 57%-82%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specificity range: 67%-78%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>292</td>
<td>Diagnostic accuracy, differentiating AD and LBD</td>
<td>• Sensitivity range: 83%-92%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specificity range: 67%-93%</td>
</tr>
<tr>
<td>Bloudek et al (2011)</td>
<td>20</td>
<td>NR</td>
<td>Diagnostic accuracy</td>
<td>• Sensitivity: 90% (84% to 94%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specificity: 89% (81% to 94%)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>NR</td>
<td>Diagnostic accuracy, AD vs other dementia</td>
<td>• Sensitivity: 92% (84% to 96%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specificity: 78% (69% to 85%)</td>
</tr>
<tr>
<td>Yuan et al (2009)</td>
<td>6</td>
<td>280</td>
<td>Diagnostic accuracy</td>
<td>• Sensitivity: 89% (92% to 94%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specificity: 85% (78% to 90%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• PLR: 4.6 (3.2 to 6.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• NLR: 0.15 (0.05 to 0.48)</td>
</tr>
</tbody>
</table>
Study | Studies | N | Outcomes | Estimate (95% CI)
--- | --- | --- | --- | ---
Matchar et al (2001) | 15 | 729 | Diagnostic accuracy | • Sensitivity: 88% (79% to 94%)
• Specificity: 87% (77% to 93%)

3 | 289 | Diagnostic accuracy, distinguishing AD from non-AD dementia | • Sensitivity range: 86% to 95%
• Specificity range: 61% to 74% |

AD: Alzheimer disease; CI: confidence interval; FDG-PET: fluorine 18 fluorodeoxyglucose positron emission tomography; LBD: Lewy body dementia; MCI: mild cognitive impairment; NLR: negative likelihood ratio; NR: not reported; PLR: positive likelihood ratio.

**Retrospective Studies**

In a study published after the systematic reviews, Pagani et al (2017) tested the accuracy of FDG-PET to discriminate between patients with MCI who progressed to AD and those who did not progress. The study population consisted of 42 normal elderly patients without MCI, 27 patients with MCI who had not converted to AD after a follow-up of at least 5 years since the first FDG-PET scan (mean follow-up, 7.5 years), and 95 patients with MCI who converted to AD within 5 years of the baseline FDG-PET (mean time to conversion, 1.8 years). The group that progressed to AD within five years showed significantly lower FDG-PET uptake values in the temporoparietal cortex than the other groups. Baseline FDG-PET identified patients who converted to AD with an accuracy of 89%.

**Clinically Useful**

A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

**Direct Evidence**

Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from RCTs.

Motara et al (2017) assessed the accuracy of dual-trained radiologists and nuclear medicine physicians to diagnose the type of cognitive impairment based on FDG-PET/CT images. Records of patients who had undergone FDG-PET/CT because of cognitive impairment (AD, frontotemporal dementia, mixed dementia, and dementia with Lewy bodies) following a negative CT or MRI scans were reviewed (n=136). Questionnaires were sent to the referring physicians to gather information on the final clinical diagnosis, usefulness of the PET/CT report, and whether the report impacted clinical management. The response rate was 72% (98/136) and mean patient follow-up was 471 days. For the diagnosis of AD, using the final clinical diagnosis as the reference standard, the sensitivity, specificity, PPV, and NPV were 87%, 97%, 93%, and 91%, respectively. Questionnaires received from the 98 physicians indicated that PET/CT: was useful (78%); had an impact on clinical management (81%); added confidence to the pretest clinical diagnosis (43%); reduced the need for further investigations (42%); changed the pretest clinical diagnosis (35%); and led to a change in therapy (32%).

**Section Summary: Suspected AD**

Several systematic reviews offer evidence on FDG-PET for diagnosing AD in people with cognitive impairment and for differentiating between AD and other dementias. Studies included in these reviews were generally poor quality. There is no standard cutoff for positive amyloid findings on PET scanning for diagnosing AD, and many studies did not include postmortem confirmation of AD as the reference standard. These limitations lead to uncertainty about estimates of
performance characteristics. Although it appears that FDG-PET has high sensitivity and specificity, the evidence does not compare the performance characteristics of clinical diagnosis with PET to clinical diagnosis without PET, so the incremental value of adding PET to the standard clinical diagnosis is unclear. No studies reported on clinical outcomes of patients diagnosed with vs without FDG-PET. A single study was identified that surveyed physicians on the clinical utility of FDG-PET/CT in managing patients with cognitive impairment. In general, the physicians found the FDG-PET/CT helpful but no clinical outcomes of patients were reported.

**Suspected Large Vessel Vasculitis**

**Clinical Context and Test Purpose**

The purpose of FDG-PET in patients with suspected LVV is to confirm a diagnosis or to inform the decision on selecting treatment regimens.

The question addressed in this evidence review is: Does the use of FDG-PET improve the net health outcome in individuals with suspected LVV?

The following PICOs were used to select literature to inform this review.

**Patients**

The populations of interest include patients with suspected LVV.

LVV causes granulomatous inflammation primarily of the aorta and its major branches. There are two major types of LVV: giant cell arteritis (GCA) and Takayasu arteritis (TA). Classification criteria for GCA and TA were developed by American College of Rheumatology in 1990. The definitions have since been refined by the International Chapel Hill Consensus Conference on the Nomenclature of Vasculitides (2012). Biopsy and angiography are considered the criterion standard techniques for diagnosis but they are invasive and detect changes that occur late in the disease. In practice, the diagnosis is challenging because patients tend to have nonspecific symptoms such as fatigue, loss of appetite, weight loss, and low-grade fever as well as nonspecific lab findings such as increased C-reactive protein or erythrocyte sedimentation rate. Misdiagnosis is common particularly during the early stages of the disease. Unfortunately, late diagnosis can lead to serious aortic complications and death. Since activated inflammatory cells accumulate glucose, FDG-PET may be able to detect and visualize early inflammation in vessel walls and facilitate early diagnosis thereby allowing treatment with glucocorticoids before irreversible arterial damage has occurred.

**Interventions**

The intervention of interest is FDG-PET.

For patients with suspected LVV, FDG-PET would be performed following inconclusive clinical examinations and standard radiographs.

**Comparators**

Clinical diagnosis without FDG-PET is currently being used to make decisions about suspected LVV.
Outcomes
For patients with suspected LVV, the main outcomes interest are disease-related morbidity and mortality. Other outcomes of interest include test accuracy, test validity, symptoms, change in disease status, functional outcomes, health status measures, QOL, hospitalizations, medication use, and resource utilization.

Study Selection Criteria
Methodologically credible studies were selected using the principles described in the first indication.

Technically Reliable
Assessment of technical reliability focuses on specific tests and operators and requires a review of unpublished and often proprietary information. Review of specific tests, operators, and unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

Clinically Valid
A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

Summaries of characteristics and results of several meta-analyses of FDG-PET that have been published on the diagnosis and management of LVV are shown in Tables 5 and 6 and are briefly described below.

Table 5. Characteristics of Systematic Reviews on Use of FDG-PET for Large Vessel Vasculitis

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Studies</th>
<th>N (Range)</th>
<th>Design</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee et al (2016)39</td>
<td>Up to 2015</td>
<td>8</td>
<td>400 (21-93)</td>
<td>OBS</td>
<td>Diagnostic accuracy for GCA and TA</td>
</tr>
<tr>
<td>Treglia et al (2011)42</td>
<td>Up to 2011</td>
<td>32</td>
<td>604</td>
<td>OBS</td>
<td>Diagnostic accuracy for GCA and TA; assessment of disease activity; monitor treatment response</td>
</tr>
<tr>
<td>Besson et al (2011)43</td>
<td>Up to 2011</td>
<td>14</td>
<td>Unclear</td>
<td>OBS</td>
<td>Diagnostic accuracy for GCA</td>
</tr>
</tbody>
</table>

FDG-PET: fluorine 18 fluorodeoxyglucose positron emission tomography; GCA: giant cell arteritis; OBS: observational; TA: Takayasu arteritis.

Lee et al (2016) performed a meta-analysis of the diagnostic accuracy of FDG-PET and PET/CT for LVV.39 The search included studies indexed in PubMed, EMBASE or Cochrane Library that used the American College of Rheumatology (ACR) classification system as the reference standard diagnosis. Eight studies (total n=400 participants) were identified for inclusion. Five studies included participants with both GCA and TA while three included only GCA. Five studies evaluated FDG-PET and three evaluated FDG-PET/CT. Pooled estimates of sensitivity, specificity, positive likelihood ratio and negative likelihood ratio were calculated using a random-effects model and are shown in Table 6. Interpretation of these results was limited by the use of ACR as the reference standard and the varying levels of disease activity in selected studies.
Soussan et al (2015) conducted a literature review assessing the role of FDG-PET in the management of LVV, focused on 3 issues: determining the FDG-PET criteria for diagnosing vascular inflammation; establishing the performance of FDG-PET for the diagnosis of large-vessel inflammation in GCA patients; and defining the performance of FDG-PET to evaluate the disease inflammatory activity in patients with TA. The MEDLINE, Cochrane Library, and EMBASE databases were searched for articles that evaluated the value of FDG-PET in LVV. Selection criteria included the use of the ACR classification for GCA or TA, the definition of a positive amyloid threshold for PET, and more than four cases included. The sensitivity and specificity of FDG-PET for the diagnosis of large-vessel inflammation were calculated from each selected study and then pooled for meta-analysis with a random-effects model. Disease activity was assessed with the National Institutes of Health Stroke Scale, or another activity assessment scale. Twenty-one studies (413 patients, 299 controls) were included in the systematic review. FDG-PET showed FDG vascular uptake in 70% (288/413) of patients and 7% (22/299) of controls. Only vascular uptake equal to or greater than the liver uptake differed significantly between GCA plus TA patients and controls (p<0.001). A summary of the results is shown in Table 6. FDG-PET showed good performances in the diagnosis of large-vessel inflammation, with higher accuracy for diagnosing GCA patients than for detecting activity in TA patients. Although a vascular uptake equal to or greater than the liver uptake appears to be a good criterion for diagnosing vascular inflammation, further studies would be needed to define the threshold of significance as well as the clinical significance of the vascular uptake.

A systematic review by Puppo et al (2014) included studies of FDG-PET in GCA comparing the diagnostic performance of qualitative and semiquantitative methods of FDG-PET interpretation. Reviewers selected 19 studies (442 cases, 535 controls) found in PubMed or Cochrane Library. The selected studies had various reference standards. Ten used qualitative FDG uptake criteria to characterize inflammation, six used semiquantitative criteria, and three used both. Meta-analyses were not performed. Overall, qualitative methods were more specific but less sensitive, than semiquantitative methods. Diagnostic performance varied by vessel and by thresholds (cutoffs) for positivity. Results are shown in Table 6.

Treglia et al (2011) published a systematic review of PET and PET/CT in patients with LVV. Reviewers searched MEDLINE and Scopus for publications on the role of FDG-PET in LVV. Reviewers identified 32 studies (total n=604 vasculitis patients). Selected publications related to diagnosis, assessment of disease activity, the extent of disease, response to therapy, and prediction of relapse or complications. Reviewers did not pool findings. They concluded that: (1) PET and PET/CT may be useful for initial diagnosis and assessment of severity of disease; (2) appeared to be superior to MRI in the diagnosis of LVV, but not in assessing disease activity under immunosuppressive treatment, in predicting relapse, or in evaluating vascular complications; (3) the role of these imaging methods in monitoring treatment response is unclear. Reviewers also concluded that "given the heterogeneity between studies with regard to PET analysis and diagnostic criteria, a standardization of the technique is needed." The studies cited in support of using PET for diagnosing LVV had small sample sizes.

Besson et al (2011) published a systematic review to assess use of FDG-PET for patients with suspected GCA; reviewers searched the MEDLINE, EMBASE, and the Cochrane databases. Studies were included if they evaluated the performance of FDG-PET for the diagnosis of GCA, had at least eight participants, used ACR criteria as the reference standard to confirm diagnosis of GCA, and included a control group. Fourteen studies were identified; the number of
participants in those studies was unclear. Six studies with 283 participants (101 vasculitis, 182 controls) were included in a meta-analysis. The meta-analysis calculated pooled estimates of sensitivity, specificity, PPV, NPV, positive and negative likelihood ratio, and diagnostic accuracy using a random-effects model. Results are shown in Table 6. There was statistically significant between-study heterogeneity for sensitivity, PPV, and NPV. All studies in the meta-analysis were small case-control studies.

Table 6. Results of Systematic Reviews Assessing Use of FDG-PET for LVV

<table>
<thead>
<tr>
<th>Study</th>
<th>Studies</th>
<th>N</th>
<th>Outcomes</th>
<th>Estimate (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee et al (2016)²⁹</td>
<td>8</td>
<td>400</td>
<td>Diagnostic accuracy of PET and PET/CT for GCA and TA</td>
<td>Sensitivity: 76% (68% to 82%) Specificity: 93% (89% to 96%) PLR: 7.27 (3.71 to 14.24) NLR: 0.30 (0.23 to 0.40)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>133</td>
<td>Diagnostic accuracy of PET and PET/CT for GCA</td>
<td>Sensitivity: 83% (72% to 91%) Specificity: 90% (80% to 96%) PLR: 7.11 (2.91 to 17.4) NLR: 0.20 (0.11 to 0.34)</td>
</tr>
<tr>
<td>Soussan et al (2015)³⁰</td>
<td>4</td>
<td>233</td>
<td>Diagnostic accuracy for GCA</td>
<td>Sensitivity: 89.5% (78.5% to 96.0%) Specificity: 97.7% (94% to 99%) PLR: 28.7 (11.5 to 71.6) NLR: 0.15 (0.07 to 0.29)</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>237</td>
<td>Diagnostic accuracy for disease activity in TA</td>
<td>Sensitivity: 87% (78% to 93%) Specificity: 73% (63% to 81%) PLR: 4.2 (1.5 to 12) NLR: 0.2 (0.1 to 0.5)</td>
</tr>
<tr>
<td>Puppo et al (2014)³¹</td>
<td>10</td>
<td>633</td>
<td>Diagnostic accuracy for GCA</td>
<td>Sensitivity range: 56%-77% Specificity range: 77%-100% PPV range: 93%-100% NPV range: 70%-82%</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>282</td>
<td>Diagnostic accuracy for GCA</td>
<td>Sensitivity range: 58%-90% Specificity range: 42%-95% PPV range: 79%-89% NPV range: 95%-98%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>72</td>
<td>Diagnostic accuracy for GCA</td>
<td>Sensitivity range: 65%-100% Specificity range: 45%-100%</td>
</tr>
<tr>
<td>Treglia et al (2011)³²</td>
<td>32</td>
<td>604</td>
<td>Diagnostic accuracy for GCA and TA; assessment of disease activity; monitor treatment response</td>
<td>No pooling; concluded that FDG-PET is useful &quot;in the initial diagnosis and in the assessment of activity and extent of disease in patients with LVV&quot;</td>
</tr>
<tr>
<td>Besson et al (2011)³³</td>
<td>6</td>
<td>283</td>
<td>Diagnostic accuracy for GCA</td>
<td>Sensitivity: 80% (63% to 91%) Specificity: 89% (78% to 94%) PPV: 85% (62% to 95%) NPV: 88% (72% to 95%) PLR: 6.73 (3.55 to 12.77) NLR: 0.25 (0.13 to 0.46)</td>
</tr>
</tbody>
</table>

CI: confidence interval; CT: computed tomography; FDG: fluorine 18 fluorodeoxyglucose; GCA: giant cell arteritis; LVV: large vessel vasculitis; NLR: negative likelihood ratio; NPV: negative predictive value; PET: positron emission tomography; PLR: positive likelihood ratio; PPV: positive predictive value; TA: Takayasu arteritis.

Clinically Useful
A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.
**Direct Evidence**
Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from RCTs.

No RCTs identified assessed the evidence on the clinical utility of FDG-PET for diagnosing LVV.

**Chain of Evidence**
Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

Because the clinical validity of FDG-PET for diagnosing LVV has not been established, a chain of evidence supporting its clinical utility cannot be constructed.

**Section Summary: Suspected LVV**
Several systematic reviews have evaluated the diagnosis and management of GCA using FDG-PET. Most studies included were small, many lacked controls, and all results were heterogeneous. Studies comparing PET with the true reference standard (biopsy or angiography) are rare. There are no consensus criteria to define the presence of vascular inflammation by FDG-PET in LVV, and different parameters with visual and semiquantitative methods have been reported. Studies demonstrating changes in management based on PET results or improvements in clinical outcomes are lacking.

**Diverse Noncardiac or Nononcologic Conditions**

**Clinical Context and Test Purpose**
The purpose of FDG-PET in patients with diverse noncardiac or nononcologic conditions is to confirm a diagnosis or to inform the decision on selecting treatment regimens.

The question addressed in this evidence review is: Does the use of FDG-PET improve the net health outcome in individuals with diverse noncardiac or nononcologic conditions?

The following PICOs were used to select literature to inform this review.

**Patients**
The populations of interest include patients with diverse noncardiac or nononcologic conditions (eg, central nervous system, pulmonary, and musculoskeletal diseases).

**Interventions**
The intervention of interest is FDG-PET.

For patients with diverse noncardiac or nononcologic conditions, FDG-PET would be performed following inconclusive clinical examinations and standard radiographs.

**Comparators**
CT, radiograph, and MRI are currently being used to make decisions about managing diverse noncardiac or nononcologic conditions.
Outcomes
For patients with diverse noncardiac or nononcologic conditions, the main outcomes of interest are disease-related morbidity and mortality. Other outcomes of interest include test accuracy, test validity, symptoms, change in disease status, functional outcomes, health status measures, QOL, hospitalizations, medication use, and resource utilization.

For patients with other suspected noncardiac or nononcologic conditions, FDG-PET would be performed following inconclusive clinical examinations and standard radiographs.

Study Selection Criteria
Methodologically credible studies were selected using the principles described in the first indication.

Technically Reliable
Assessment of technical reliability focuses on specific tests and operators and requires review of unpublished and often proprietary information. Review of specific tests, operators, and unpublished data are outside the scope of this evidence review and alternative sources exist. This evidence review focuses on the clinical validity and clinical utility.

Clinically Valid
Numerous systematic reviews have described the use of PET in patients with carotid stenosis; inflammatory diseases; fever of unknown origin; hyperinsulinemic hypoglycemia; spinal infections; mycobacterium infection; Creutzfeldt-Jakob disease; vascular prosthetic graft infection; prosthetic infection after knee or hip arthroplasty; inflammatory bowel disease; atypical parkinsonism; and Huntington disease. Many studies cited in these reviews were small, retrospective, and lacked standard definitions of PET interpretation and positivity; many did not directly compare one modality with another in the same patient group or correlate the PET results in individual patients to improve clinical outcomes.

Yin et al (2018) published a systematic review and meta-analysis of studies comparing diagnostic values of 18F-FDG-PET and MRI for patients with spondylitis. Six studies (range of participants, 6–68), published between 2002 and 2017, were included. For 18F-FDG-PET and MRI, respectively, sensitivity was 0.96 (95% CI 0.84–0.99) and 0.76 (95% CI 0.65-0.84; p=0.034), specificity was 0.90 (95% CI 0.79-0.96) and 0.62 (95% CI 0.45-0.77; p=0.006), positive likelihood ratio was 9.83 (95% CI 4.39-22.03) and 2.01 (95% CI 1.36-2.98; p<0.001), negative likelihood ratio was 0.05 (95% CI 0.01–0.19) and 0.39 (95% CI 0.27-0.56; p=0.003), and diagnostic odds ratio was 124.08 (95% CI 39.04-394.34 and 124.08 (95% CI 39.04-394.34; p<0.001). The following limitations were reported: diagnostic values of 18F-FDG-PET and MRI for detecting spondylitis in patients with specific characteristics were not compared because numerous clinical characteristics were not available, the diagnostic criteria for spondylitis was not available in some studies, and the study was based on pooled data because individual data on characteristics were not available.

A systematic review by Treglia et al (2011) addressed the use of FDG-PET in evaluating disease activity in patients with sarcoidosis. It did not include a quality assessment of individual studies. Only three small studies of nine reviewed included data from a comparator imaging modality; thus, conclusions about comparative diagnostic performance cannot be reached.
In a systematic review of FDG-PET to diagnose prosthetic joint infection following hip or knee replacement, Kwee et al (2008) reported on a pooled sensitivity and specificity of 82.1% (95% CI, 68.0% to 90.8%) and 86.6% (95% CI, 79.7% to 91.4%), respectively. Reviewers noted significant heterogeneity among the 11 studies analyzed. Differences in performance were based on the location of prostheses (hip vs knee) and whether filtered back projection or iterative reconstruction was used. This meta-analysis and a study by Reinartz (2009) on the same clinical issue found that the specificity of PET was significantly greater for hip prostheses than for knee prostheses. Both author groups also noted that these results were based on the use of PET alone. CT is generally not useful in evaluating potential infections around joint prostheses because of the artifacts caused by the metallic implants, so additional research would be needed on combined PET/CT. The 2009 study compared the accuracy of PET with a triple-phase scan and with WBC imaging.

**Clinically Useful**

A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

**Direct Evidence**

Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from RCTs.

Numerous systematic reviews have been used to describe the use of FDG-PET in patients with diverse noncardiac or nononcologic conditions. However, most studies cited in these reviews were small, retrospective, and lacked standard definitions of PET interpretation and positivity; many did not directly compare one modality with another in the same patient group or correlate the PET results in individual patients to improve clinical outcomes.

No RCTs identified assessed the evidence on the clinical utility of FDG-PET for diagnosing diverse noncardiac or nononcologic conditions.

**Chain of Evidence**

Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

Because the clinical validity of FDG-PET for diagnosing diverse noncardiac or nononcologic condition has not been established, a chain of evidence supporting its clinical utility cannot be constructed.

**Section Summary: Diverse Noncardiac and Nononcologic Conditions**

Systematic reviews have assessed the use of FDG-PET or FDG-PET/CT for diagnosing or managing carotid stenosis, various inflammatory and immune-mediated diseases, fever of unknown origin, and various infections. However, studies included in these reviews are mostly small, retrospective, and lack standard definitions of PET interpretation and positive findings. Few studies have compared PET with other diagnostic modalities and no studies have reported on patient clinical outcomes.
Summary of Evidence
For individuals who have epileptic seizures who are candidates for surgery who have FDG-PET, the evidence includes systematic reviews (following the publication of three TEC Assessments). The relevant outcomes are symptoms, change in disease status, functional outcomes, health status measures, QOL, hospitalizations, medication use, and resource utilization. The TEC Assessments and Program in Evidence-based Care PET recommendation report all concluded that FDG-PET accurately localizes the seizure focus compared with appropriate reference standards. A recent systematic review suggested it was difficult to discern the incremental value of FDG-PET in patients who have foci well localized by ictal scalp electroencephalography and MRI. The evidence on whether FDG-PET has a predictive value for a good surgical outcome is mixed. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have suspected chronic osteomyelitis who receive FDG-PET, the evidence includes meta-analyses and a prospective study published after the meta-analyses. The relevant outcomes are test accuracy and validity, other test performance measures, change in disease status, functional outcomes, QOL, and hospitalizations. One systematic review and meta-analysis from 2013, 9 studies revealed that FDG-PET and FDG-PET plus CT were useful for diagnosing suspected osteomyelitis in the foot of patients with diabetes. The results of another meta-analysis (2005) showed that FDG-PET was the most accurate mode (pooled sensitivity, 96%; pooled specificity, 91%) for diagnosing chronic osteomyelitis. The results appear to be robust across fairly diverse clinical populations, which strengthen the conclusions. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have suspected AD who receive FDG-PET to diagnose the disease, the evidence includes systematic reviews of observational studies. The relevant outcomes are test accuracy and validity, other test performance measures, symptoms, QOL, and hospitalizations. The studies included in the reviews were generally of poor quality. There is no standard cutoff for PET positivity for diagnosing AD, and many studies have not included postmortem confirmation of AD as the reference standard, leading to uncertainty about estimates of performance characteristics. FDG-PET may have high sensitivity and specificity for diagnosing AD, but there is little evidence comparing the performance characteristics of clinical diagnosis using PET with the clinical diagnosis not using PET; therefore, the incremental value of adding PET to the standard clinical diagnosis is unclear. No studies have reported on clinical outcomes of patients diagnosed with and without FDG-PET. For individuals who have suspected Alzheimer disease who receive FDG-PET to determine the prognosis of their disease and to differentiate the disease from other dementias, the evidence includes systematic reviews of observational studies and a retrospective study assessing clinical utility. The relevant outcomes are test accuracy and validity, other test performance measures, symptoms, QOL, and hospitalizations. The studies included in the reviews were generally of poor quality. The evidence is insufficient to determine the effects of the technology on health outcomes for these indications.

For individuals who have suspected LVV who receive FDG-PET, the evidence includes five systematic reviews of observational studies. The relevant outcomes are test accuracy and validity, other test performance measures, symptoms, morbid events, QOL, hospitalizations, and treatment-related morbidity. Most studies included in the reviews were small and lacked controls. The reported performance characteristics were heterogeneous but reviewers were unable to
determine the source of heterogeneity. Studies comparing PET with the true reference standard of biopsy or angiography are rare. There are no consensus criteria to define the presence of vascular inflammation by FDG-PET in LVV, and different parameters with visual and semiquantitative methods have been reported. Studies demonstrating changes in management based on PET results or improvements in clinical outcomes are lacking. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have diverse noncardiac or nononcologic conditions (eg, central nervous system, pulmonary, and musculoskeletal diseases) who receive FDG-PET, the evidence includes a few systematic reviews. The relevant outcomes are overall survival, symptoms, change in disease status, functional outcomes, health status measures, QOL, hospitalizations, medication use, and resource utilization. Many studies cited in the reviews were small, retrospective, and published in the 1990s to early 2000s; further, many studies did not directly compare a modality with another in the same patient group nor did they correlate PET results in individual patients with improved clinical outcomes. Additional studies are needed to demonstrate FDG-PET results can change management, and therefore improve patient outcomes to support the utility of FDG-PET. The evidence is insufficient to determine the effect of the technology on health outcomes.

**Practice Guidelines and Position Statements**

**American Academy of Neurology**

Evidence-based practice parameters from the American Academy of Neurology are summarized in Table 7.

<table>
<thead>
<tr>
<th>Practice Parameter</th>
<th>Date</th>
<th>PET Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosis of dementia</td>
<td>2004: reaffirmed</td>
<td>PET imaging not recommended for routine use in diagnostic evaluation of dementia (LOR: moderate clinical certainty)</td>
</tr>
<tr>
<td>Early detection of dementia</td>
<td>2003: reaffirmed</td>
<td>Not addressed</td>
</tr>
<tr>
<td>Diagnosis of new-onset PD</td>
<td>2006: reaffirmed 2013; retired 2016</td>
<td>Evidence insufficient to support or refute FDG-PET as a means of distinguishing PD from other parkinsonian syndromes</td>
</tr>
<tr>
<td>Evaluation of depression, psychosis, and dementia in PD</td>
<td>2006; retired 2018</td>
<td>Not addressed</td>
</tr>
<tr>
<td>Mild cognitive impairment</td>
<td>2001; 2017; 2018</td>
<td>Not addressed</td>
</tr>
</tbody>
</table>

FDG: fluorine 18 fluorodeoxyglucose; LOR: level of recommendation; PD: Parkinson disease; PET: positron emission tomography.

**American Academy of Orthopaedic Surgeons**

The American Academy of Orthopaedic Surgeons (2010) published evidence-based, consensus guidelines. Fluorine 18 fluorodeoxyglucose positron emission tomography (FDG-PET) was considered:

"an option in patients in whom diagnosis of periprosthetic joint infection has not been established and are not scheduled for reoperation. (Strength of recommendation: limited [quality of the supporting evidence is unconvincing, or well-conducted studies show little clear advantage of one approach over another])"

**American College of Radiology**

Evidence- and consensus-based appropriateness criteria from the American College of Radiology are summarized in Table 8.
Table 8. Appropriateness Criteria for Miscellaneous Indications of FDG-PET/CT

<table>
<thead>
<tr>
<th>Appropriateness Criteria</th>
<th>Last Reviewed</th>
<th>FDG-PET/CT Criteria</th>
</tr>
</thead>
</table>
| Suspected osteomyelitis, septic arthritis, or soft tissue infection (excluding spine and diabetic foot) | 2017              | • Usually not appropriate for (1) suspected osteomyelitis with soft tissue or juxta-articular swelling with cellulitis and a skin lesion, injury, wound, ulcer, or blister; or (2) suspected osteomyelitis with pain and swelling or cellulitis associated with site of previous nonarthroplasty hardware.  
  • Usually not appropriate for suspected osteomyelitis with soft-tissue or juxta-articular swelling with a history of surgery, though “this is promising new technology but data are limited.” |
| Diagnosis of dementia                                                                   | 2001, reaffirmed 2004 | PET imaging not recommended for routine use in diagnostic evaluation of dementia (LOR: moderate clinical certainty)                                                                                                                                                                                                                           |
| Early detection of dementia                                                             | 2001, reaffirmed 2003, 2015 | Not addressed                                                                                                                                                                                                                                                                                                                                 |
| Diagnosis of new onset-PD                                                                | 2006: reaffirmed 2013; retired 2016 | Evidence insufficient to support or refute FDG-PET as a means of distinguishing PD from other parkinsonian syndromes                                                                                                                                                                                                                                 |
| Evaluation of depression, psychosis, and dementia in PD                                  | 2006              | Not addressed                                                                                                                                                                                                                                                                                                                                 |
| Dementia and movement disorders                                                         | 2016              | May be appropriate in patients with possible or probable AD and to differentiate suspected FTD, LBD, CD, or vascular dementia; usually not appropriate in patients with suspected HD, clinical features of PD or hemochromatosis, or motoneuron disease                                                                                                                                                                  |
| Imaging after total knee arthroplasty                                                     | 2017              | Usually not appropriate for routine follow-up of asymptomatic patient, in work-up for suspected periprosthetic infection, or for evaluation of prosthetic loosening                                                                                                                                                                                                 |
| Seizures and epilepsy                                                                   | 2014              | Usually appropriate for surgical planning in medically refractory epilepsy; may be appropriate for new-onset seizure unrelated to trauma in adults (age ≥18 y) and for posttraumatic (subacute or chronic), new-onset seizure; otherwise, usually not appropriate for new-onset seizure |
| Crohn disease                                                                           | 2014              | Usually not appropriate                                                                                                                                                                                                                                                                                                                                 |
| Fever without source - child                                                             | 2015              | May be appropriate. This procedure should not be used as the initial study. Consider if extensive clinical and imaging work-up is negative.                                                                                                                                                                                                                  |
| Suspected osteomyelitis of the foot in patients with DM                                  | 2012; revised 2019 | Usually not appropriate for initial imaging. May be appropriate for soft-tissue swelling with or without ulcer, suspected osteomyelitis or early neuropathic arthropathy changes of the foot in patients with DM, suspected osteomyelitis of the foot in patients with DM without neuropathic arthropathy, and additional imaging following radiographs. |

AD: Alzheimer disease; CID: Creutzfeldt-Jakob disease; CT: computed tomography; DM: diabetes mellitus; FDG: fluorine 18 fluorodeoxyglucose; FTD: frontotemporal dementia; HD: Huntington disease; LBD: Lewy body disease; LOR: level of recommendation; PD: Parkinson disease; PET: positron emission tomography.

Infectious Diseases Society of America
The Infectious Diseases Society of America (IDSA; 2015) published evidence-based, consensus guidelines on the diagnosis and treatment of native vertebral osteomyelitis in adults. The guidelines stated that PET "is highly sensitive for detecting chronic osteomyelitis. A negative PET scan excludes the diagnosis of osteomyelitis, including native vertebral osteomyelitis, as the sensitivity of the test is expected to be very high in view of the high concentration of red marrow in the axial skeleton."

The IDSA (2013) published evidence-based, consensus guidelines on the diagnosis and management of prosthetic joint infections. The guidelines concluded that PET should not be
routinely used to diagnose prosthetic joint infection (strength of recommendation: B [based on moderate evidence]; quality of evidence: III [expert opinion and descriptive studies]).

The IDSA (2012) published evidence-based, consensus guidelines on the diagnosis and treatment of diabetic foot infections. The guidelines concluded that the role of FDG-PET in evaluating a diabetic foot infection has not been established.

The IDSA (2018) will be publishing guidelines on the diagnosis and management of bone and joint infections in children.

**U.S. Preventive Services Task Force Recommendations**
Not applicable.

**Ongoing and Unpublished Clinical Trials**
Currently, ongoing and unpublished trials that might influence this review are listed in Table 9.

### Table 9. Summary of Key Trials

<table>
<thead>
<tr>
<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ongoing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCT00811122</td>
<td>Biodistribution of 11C-PIB PET in Alzheimer's Disease,</td>
<td>30</td>
<td>Apr 2018 (unknown)</td>
</tr>
<tr>
<td></td>
<td>Frontotemporal Dementia, and Cognitively Normal Elderly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCT03022968</td>
<td>Tau Brain Imaging in Typical and Atypical Alzheimer's Disease</td>
<td>24</td>
<td>Sep 2018 (unknown)</td>
</tr>
<tr>
<td>NCT02084147</td>
<td>PET-MRI: Evaluation, Optimization and Clinical Implementation</td>
<td>530</td>
<td>Oct 2018 (suspended [interim analysis])</td>
</tr>
<tr>
<td>NCT00194298</td>
<td>FDG-PET Imaging in Complicated Diabetic Foot</td>
<td>240</td>
<td>Jan 2020</td>
</tr>
<tr>
<td>NCT02771483</td>
<td>Giant Cell Arteritis and PET Scan (GAPS) Study - Improving the Diagnosis</td>
<td>50</td>
<td>Feb 2020</td>
</tr>
<tr>
<td></td>
<td>and Prognostication of Giant Cell Arteritis Through the Novel Use of Positron Emission Tomography and Immune Biomarkers</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unpublished</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCT00329706</td>
<td>Early and Long-Term Value of Imaging Brain Metabolism</td>
<td>710</td>
<td>Jan 2017 (completed)</td>
</tr>
</tbody>
</table>

NCT: national clinical trial.

**CODING**

The following codes for treatment and procedures applicable to this policy are included below for informational purposes. Inclusion or exclusion of a procedure, diagnosis or device code(s) does not constitute or imply member coverage or provider reimbursement. Please refer to the member’s contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

**CPT/HCPCS**

- 78608 Brain imaging, positron emission tomography (PET); metabolic evaluation
- 78609 Brain imaging, positron emission tomography (PET); perfusion evaluation
- 78811 Positron emission tomography (PET) imaging; limited area (eg, chest, head/neck)
- 78812 Positron emission tomography (PET) imaging; skull base to mid-thigh
- 78813 Positron emission tomography (PET) imaging; whole body
Positron emission tomography (PET) with concurrently acquired computed tomography (CT) for attenuation correction and anatomical localization imaging:
- limited area (e.g., chest, head/neck)
- skull base to mid-thigh
- whole body

Fluorodeoxyglucose F-18 FDG, diagnostic, per study dose, up to 45 millicuries

 PET imaging, any site, not otherwise specified

A PET scan essentially involves 3 separate activities:
1) manufacture of the radiopharmaceutical, which may be manufactured on site, or at a regional delivery center with delivery to the institution performing PET;
2) actual performance of the PET scan; and
3) interpretation of the results.

ICD-10 Diagnoses (Effective October 1, 2015)

- G40.011 Localization-related (focal) (partial) idiopathic epilepsy and epileptic syndromes with seizures of localized onset, intractable, with status epilepticus
- G40.019 Localization-related (focal) (partial) idiopathic epilepsy and epileptic syndromes with seizures of localized onset, intractable, without status epilepticus
- G40.111 Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with simple partial seizures, intractable, with status epilepticus
- G40.119 Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with simple partial seizures, intractable, without status epilepticus
- G40.211 Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, intractable, with status epilepticus
- G40.219 Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, intractable, without status epilepticus
- M86.311 Chronic multifocal osteomyelitis, right shoulder
- M86.312 Chronic multifocal osteomyelitis, left shoulder
- M86.321 Chronic multifocal osteomyelitis, right humerus
- M86.322 Chronic multifocal osteomyelitis, left humerus
- M86.331 Chronic multifocal osteomyelitis, right radius and ulna
- M86.332 Chronic multifocal osteomyelitis, left radius and ulna
- M86.341 Chronic multifocal osteomyelitis, right hand
- M86.342 Chronic multifocal osteomyelitis, left hand
- M86.351 Chronic multifocal osteomyelitis, right femur
- M86.352 Chronic multifocal osteomyelitis, left femur
- M86.361 Chronic multifocal osteomyelitis, right tibia and fibula
- M86.362 Chronic multifocal osteomyelitis, left tibia and fibula
- M86.371 Chronic multifocal osteomyelitis, right ankle and foot
- M86.372 Chronic multifocal osteomyelitis, left ankle and foot
- M86.38 Chronic multifocal osteomyelitis, other site
- M86.39 Chronic multifocal osteomyelitis, multiple sites
- M86.411 Chronic osteomyelitis with draining sinus, right shoulder
- M86.412 Chronic osteomyelitis with draining sinus, left shoulder
M86.421  Chronic osteomyelitis with draining sinus, right humerus
M86.422  Chronic osteomyelitis with draining sinus, left humerus
M86.431  Chronic osteomyelitis with draining sinus, right radius and ulna
M86.432  Chronic osteomyelitis with draining sinus, left radius and ulna
M86.441  Chronic osteomyelitis with draining sinus, right hand
M86.442  Chronic osteomyelitis with draining sinus, left hand
M86.451  Chronic osteomyelitis with draining sinus, right femur
M86.452  Chronic osteomyelitis with draining sinus, left femur
M86.461  Chronic osteomyelitis with draining sinus, right tibia and fibula
M86.462  Chronic osteomyelitis with draining sinus, left tibia and fibula
M86.471  Chronic osteomyelitis with draining sinus, right ankle and foot
M86.472  Chronic osteomyelitis with draining sinus, left ankle and foot
M86.48  Chronic osteomyelitis with draining sinus, other site
M86.49  Chronic osteomyelitis with draining sinus, multiple sites
M86.511  Other chronic hematogenous osteomyelitis, right shoulder
M86.512  Other chronic hematogenous osteomyelitis, left shoulder
M86.521  Other chronic hematogenous osteomyelitis, right humerus
M86.522  Other chronic hematogenous osteomyelitis, left humerus
M86.531  Other chronic hematogenous osteomyelitis, right radius and ulna
M86.532  Other chronic hematogenous osteomyelitis, left radius and ulna
M86.541  Other chronic hematogenous osteomyelitis, right hand
M86.542  Other chronic hematogenous osteomyelitis, left hand
M86.551  Other chronic hematogenous osteomyelitis, right femur
M86.552  Other chronic hematogenous osteomyelitis, left femur
M86.551  Other chronic hematogenous osteomyelitis, right femur
M86.561  Other chronic hematogenous osteomyelitis, right tibia and fibula
M86.562  Other chronic hematogenous osteomyelitis, left tibia and fibula
M86.571  Other chronic hematogenous osteomyelitis, right ankle and foot
M86.572  Other chronic hematogenous osteomyelitis, left ankle and foot
M86.58  Other chronic hematogenous osteomyelitis, other site
M86.59  Other chronic hematogenous osteomyelitis, multiple sites
M86.60  Other chronic osteomyelitis, unspecified site
M86.611  Other chronic osteomyelitis, right shoulder
M86.612  Other chronic osteomyelitis, left shoulder
M86.621  Other chronic osteomyelitis, right humerus
M86.622  Other chronic osteomyelitis, left humerus
M86.631  Other chronic osteomyelitis, right radius and ulna
M86.632  Other chronic osteomyelitis, left radius and ulna
M86.641  Other chronic osteomyelitis, right hand
M86.642  Other chronic osteomyelitis, left hand
M86.651  Other chronic osteomyelitis, right thigh
M86.652  Other chronic osteomyelitis, left thigh
M86.661  Other chronic osteomyelitis, right tibia and fibula
M86.662  Other chronic osteomyelitis, left tibia and fibula
M86.671  Other chronic osteomyelitis, right ankle and foot
M86.672  Other chronic osteomyelitis, left ankle and foot
M86.68  Other chronic osteomyelitis, other site
M86.69  Other chronic osteomyelitis, multiple sites
Miscellaneous (Non-cardiac, Non-oncologic) Applications of PET Scanning was originally part of the Positron Emission Tomography (PET) medical policy. Miscellaneous (Non-cardiac, Non-oncologic) Applications of PET Scanning was separated out and placed into a separate medical policy, Positron Emission Tomography (PET) Scanning: Miscellaneous (Non-cardiac, Non-oncologic) Applications. The medical policy language was unchanged.

In Coding section:
- Added ICD-10 Diagnosis codes (Effective October 1, 2014)

In Coding section:
- Added HCPCS code A9599 (Effective January 1, 2014)

In Policy section:
- In Item B added the following indications to the experimental / investigational list:
  " Central Nervous System Diseases
  1. Autoimmune disorders with central nervous system (CNS) manifestations, including:
     a. Behçet syndrome
     b. lupus erythematosus
  2. Cerebrovascular diseases, including:
     a. arterial occlusive disease (arteriosclerosis, atherosclerosis)
     b. carotid artery disease
     c. cerebral aneurysm
     d. cerebrovascular malformations (arteriovenous malformation and Moya-Moya disease)
     e. hemorrhage
     f. infarct
     g. ischemia
  3.  a. amyotrophic lateral sclerosis
     e. progressive supranuclear palsy
     f. Shy-Drager syndrome
     g. spinocerebellar degeneration
     h. Steele-Richardson-Olszewski syndrome
     i. Tourette syndrome
  6.  Developmental, congenital, or inherited disorders, including:
     a. adrenoleukodystrophy
     b. Down syndrome
     c. Huntington’s chorea
     d. kinky-hair disease (Menkes disease)
     e. Sturge-Weber syndrome (encephalofacial angiomatosis) and the phakomatoses
  7. Miscellaneous
     a. chronic fatigue syndrome
     b. sick building syndrome
     c. posttraumatic stress disorder
  8. Nutritional or metabolic diseases and disorders, including:
     a. acanthocytosis
     b. hepatic encephalopathy
     c. hepatolenticular degeneration
     d. metachromatic leukodystrophy
     e. mitochondrial disease
     f. subacute necrotizing encephalomyelopathy
## REVISIONS

9. a. affective disorders  
b. depression  
c. obsessive-compulsive disorder  
d. psychomotor disorders  
e. schizophrenia  
10. a. aspergillosis  
b. encephalitis  
11. Substance abuse, including the CNS effects of alcohol, cocaine, and heroin  
12. Trauma, including brain injury and carbon monoxide poisoning  
14. Mycobacterium infection  
15. Migraine  
16. Anorexia nervosa  
17. Assessment of cerebral blood flow in newborns  
a. Vegetative versus "locked-in" state  
Pulmonary Diseases  
18. Adult respiratory distress syndrome  
19. Diffuse panbronchiolitis  
21. Obstructive lung disease  
22. Pneumonia  
Musculoskeletal Diseases  
23. Spondylodiscitis  
24. Joint replacement follow-up  
Other  
25. Giant cell arteritis  
26. Vasculitis  
27. Vascular prosthetic graft infection  
28. Inflammatory bowel disease  
29. Sarcoidosis  
30. Fever of unknown origin  
31. Inflammation of unknown origin”

In Policy Guidelines:
- Removed "1. For this policy, PET scanning is discussed for the following 4 applications in oncology."

**Diagnosis**  
Diagnosis refers to use of PET as part of the testing used in establishing whether or not a patient has cancer.

**Staging**  
This refers to use of PET to determine the stage (extent) of the cancer at the time of diagnosis, before any treatment is given. Imaging at this time is generally to determine whether or not the cancer is localized. This may also be referred to as initial staging.

**Restaging**  
This refers to imaging following treatment in 2 situations. Restaging is part of the evaluation of a patient in whom a disease recurrence is suspected based on signs and/or symptoms. Restaging also includes determining the extent of malignancy following completion of a full course of treatment.

**Surveillance**  
This refers to use of imaging in asymptomatic patients (patients without objective signs or symptoms of recurrent disease). This imaging is completed 6 months or more (12 months or more for lymphoma) following completion of treatment.

2. As with any imaging technique, the medical necessity of positron emission tomography (PET) scanning depends in part on what imaging techniques are used either before or after the PET scanning. Due to its expense, PET scanning is typically considered after other techniques, such as computed tomography (CT), magnetic resonance imaging (MRI), or ultrasonography, provide inconclusive or discordant results. In patients with melanoma or lymphoma, PET scanning may be considered an initial imaging technique. If so, the medical necessity of subsequent imaging during the same diagnostic evaluation is unclear.
REVISIONS

Thus, PET should be considered for the medically necessary indications above only when standard imaging, such as CT or MRI, is inconclusive or not indicated.

Rationale section updated

In Coding section:
- Added coding notations.

References updated

11-26-2018


Changed title to "Positron Emission Tomography (PET) Scanning: Miscellaneous (Non-cardiac, Non-Oncologic) Applications of Fluorine 18 Fluorodeoxyglucose" from "Positron Emission Tomography (PET) Scanning: Miscellaneous (Non-cardiac, Non-Oncologic) Applications"

Description section updated

In Policy section:
- In Item B added "FDG" to read "The use of FDG-PET for all other miscellaneous indications is experimental / investigational including but not limited to:""
- In Item 11 revised "CNS" to "central nervous system"
- In Item 13 a revised "acquired immune deficiency syndrome (AIDS)" to "HIV / AIDS"
- In Item 17 a revised "state" to "syndrome"
- Updated Policy Guidelines

Rationale section updated

In Coding section:
- Nomenclature revised on CPT Codes: 78814, 78815, 78816
- Removed HCPCS Codes: A9526, A9580, G0219 (Not applicable to the policy)
- Deleted HCPCS Code: A9599 (Termed effective 01-01-2018)
- Removed ICD Codes: M86.8x0, M86.8x1, M86.8x2, M86.8x3, M86.8x4, M86.8x5, M86.8x6, M86.8x7, M86.8x8, M86.8x9
- Updated Coding notations.

References updated

06-12-2020

Description section updated

Rationale section updated

References updated

REFERENCES


Contains Public Information


Other References
1. Blue Cross and Blue Shield of Kansas, Medical Advisory Committee meeting, April 24, 2003 (see Blue Cross and Blue Shield of Kansas Newsletter, Blue Shield Report MAC–02-03).
2. Blue Cross and Blue Shield of Kansas, Oncology Liaison Committee meeting, February 18, 2003 (see Blue Cross and Blue Shield of Kansas Newsletter, Blue Shield Report MAC–02-03).
3. Blue Cross and Blue Shield of Kansas, Radiology Liaison Committee meeting, February 11, 2003 (see Blue Cross and Blue Shield of Kansas Newsletter, Blue Shield Report MAC–02-03).
4. MCMC, Medical Care Ombudsman Program (MCOP), August 11, 2006, MCOP ID 1071-0720.
6. Blue Cross and Blue Shield of Kansas Radiology Liaison Committee, February 2009.