

<b>BSC6.05</b>		<b>Magnetoencephalography/Magnetic Source Imaging</b>	
<b>Original Policy Date:</b>	June 1, 2004	<b>Effective Date:</b>	October 1, 2024
<b>Section:</b>	6.0 Radiology	<b>Page:</b>	Page 1 of 15

**Policy Statement**

- I. Magnetoencephalography/magnetic source imaging as part of the preoperative evaluation of individuals with drug-resistant epilepsy (seizures refractory to at least 2 first-line anticonvulsants) may be considered **medically necessary** when standard techniques, magnetic resonance imaging (MRI) and electroencephalogram (EEG), do not provide satisfactory localization of epileptic lesion(s).
- II. Magnetoencephalography/magnetic source imaging for the purpose of determining the laterality of language function, as a substitute for the Wada test, may be considered **medically necessary** in individuals being prepared for surgery for **any** of the following indications:
  - A. Brain tumors
  - B. Epilepsy
  - C. Other indications requiring brain resection
- III. Magnetoencephalography/magnetic source imaging is considered **investigational** for all other indications.

NOTE: Refer to [Appendix A](#) to see the policy statement changes (if any) from the previous version.

**Policy Guidelines**

**Coding**  
See the [Codes table](#) for details.

**Description**

Magnetoencephalography (MEG) is a noninvasive functional imaging technique that records weak magnetic forces. When this information is superimposed on an anatomic image of the brain, typically a magnetic resonance imaging scan, the image is referred to as magnetic source imaging (MSI). MSI has been used to localize epileptic foci and to identify "eloquent" areas of the brain for neurosurgical planning.

**Related Policies**

- Functional Magnetic Resonance Imaging of the Brain

**Benefit Application**

Benefit determinations should be based in all cases on the applicable contract language. To the extent there are any conflicts between these guidelines and the contract language, the contract language will control. 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.

Some state or federal mandates (e.g., Federal Employee Program [FEP]) prohibits plans from denying Food and Drug Administration (FDA)-approved technologies as investigational. In these

instances, plans may have to consider the coverage eligibility of FDA-approved technologies on the basis of medical necessity alone.

## Regulatory Status

The Food and Drug Administration regulates MEG devices as class II devices cleared for marketing through the 510(k) process. The Food and Drug Administration product codes OLX and OXY are used to identify the different components of the devices. OLX-coded devices are source localization software for electroencephalography or MEG; the software correlates the electrical activity of the brain using various neuroimaging modalities. This code does not include electrodes, amplitude-integrated electroencephalography, automatic event-detection software used as the only or final electroencephalograph analysis step, electroencephalography software with comparative databases (normal or otherwise), or electroencephalography software that outputs an index, diagnosis, or classification.

OLY-coded devices are magnetoencephalographs that acquire, display, store, and archive biomagnetic signals produced by electrically active nerve tissue in the brain to provide information about the location of active nerve tissue responsible for certain brain functions relative to brain anatomy. This includes the magnetoencephalograph recording device (hardware, basic software).

The intended use of these devices is to "non-invasively detect and display biomagnetic signals produced by electrically active nerve tissue in the brain. When interpreted by a trained clinician, the data enhance the diagnostic capability by providing useful information about the location relative to brain anatomy of active nerve tissue responsible for critical brain functions."<sup>1</sup> More recent approval summaries add: "MEG is routinely used to identify the locations of visual, auditory, somatosensory, and motor cortex in the brain when used in conjunction with evoked response averaging devices. MEG is also used to noninvasively locate regions of epileptic activity within the brain. The localization information provided by MEG may be used, in conjunction with other diagnostic data, in neurosurgical planning."<sup>2</sup>

The MagView Biomagnetometer System (Tristan Technologies) has the unique intended use for patient populations who are neonates and infants and those children with head circumferences of 50 cm or less.<sup>3</sup>

Table 1 summarizes relevant MEG devices (hardware, software).

**Table 1. Magnetoencephalography Devices Cleared by the FDA (Product Codes OLX and OLY)**

Device	Manufacturer	Date Cleared	510(k) No.
Neuromagneometer	Biomagnetic Technologies	Feb 1986	K854466
700 Series Biomagnetometer	Biomagnetic Technologies	Jun 1990	K901215
Neuromag-122	Philips Medical Systems	Oct 1996	K962764
Magnes 2500 Wh Biomagnetometer	Biomagnetic Technologies	May 1997	K962317
CTF Systems, Whole-Cortex Meg System	CTF Systems	Nov 1997	K971329
Magnes II Biomagnetometer	Biomagnetic Technologies	May 1998	K941553
Image Vue EEG	Sam Technology	Aug 1988	K980477
Electroencephalograph Software eemagine	eemagine Medical Imaging Solutions	Oct 2000	K002631
Curry Multimodal Neuroimaging Software	Neurosoft	Feb 2001	K001781
Neurosoft's Source	Neurosoft	Sep 2001	K011241
Megvision Model Eq1000c Series	Eagle Technology	Mar 2004	K040051
Elekta Oy	Elekta Neuromag Oy	Aug 2004	K041264
MaxInsight	eemagine Medical Imaging Solutions	Jul 2007	K070358
Elekta Neuromag With Maxfilter	Elekta Neuromag Oy	Oct 2010	K091393

Device	Manufacturer	Date Cleared	510(k) No.
Geosource Babymeg Biomagnetometer System	Electrical Geodesics	Dec 2010	K092844
(also called Artemis 123 Biomagnetometer)	Tristan Technologies	Jul 2014	K133419
MagView Biomagnetometer System	Tristan Technologies	Apr 2016	K152184

EEG: electroencephalogram; FDA: Food and Drug Administration.

In 2000, Biomagnetic Technologies acquired Neuromag and began doing business as 4- D NeuroImaging. The latter company ceased operations in 2009.

## Rationale

### Background

#### Magnetoencephalography

MEG is a noninvasive functional imaging technique that records weak magnetic forces associated with brain electrical activity. Using mathematical modeling, recorded data are then analyzed to provide an estimated location of electrical activity. This information can be superimposed on an anatomic image of the brain, typically a magnetic resonance imaging (MRI) scan, to produce a functional/anatomic image of the brain, referred to as magnetic source imaging (MSI). The primary advantage of MSI is that, while conductivity and thus a measurement of electrical activity as recorded by electroencephalogram is altered by the surrounding brain structures, magnetic fields are not. Therefore, MSI permits a high-resolution image.

Detection of weak magnetic fields requires gradiometer detection coils coupled to a superconducting quantum interference device, which requires a specialized room shielded from other magnetic sources. Mathematical modeling programs based on idealized assumptions are then used to translate detected signals into functional images. In its early evolution, clinical applications were limited by the use of only one detection coil requiring lengthy imaging times, which, because of body movement, also were difficult to match with the MRI. However, more recently, the technique has evolved to multiple detection coils in an array that can provide data more efficiently over a wide extracranial region.

#### Applications

One clinical application is the localization of epileptic foci, particularly for the screening of surgical candidates and surgical planning. Alternative techniques include MRI, positron emission tomography, or single-photon emission computed tomography scanning. Anatomic imaging (i.e., MRI) is effective when epilepsy is associated with a mass lesion, such as a tumor, vascular malformation, or hippocampal atrophy. If an anatomic abnormality is not detected, patients may undergo a positron emission tomography scan. In a small subset of patients, extended electrocorticography or stereotactic electroencephalography with implanted electrodes is considered the criterion standard for localizing epileptogenic foci. MEG/MSI have principally been investigated as a supplement to or an alternative to invasive monitoring.

Another clinical application is the localization of the pre- and postcentral gyri as a guide to surgical planning in patients scheduled to undergo neurosurgery for epilepsy, brain neoplasms, arteriovenous malformations, or other brain lesions. These gyri contain the "eloquent" sensorimotor areas of the brain, the preservation of which is considered critical during any type of brain surgery. In normal situations, these areas can be identified anatomically by MRI, but frequently, anatomy is distorted by underlying disease processes. In addition, the location of eloquent functions varies, even among healthy people. Therefore, localization of the eloquent cortex often requires such intraoperative invasive functional techniques as cortical stimulation with the patient under local anesthesia or somatosensory-evoked responses on extended electrocorticography. Although these techniques can be done at the same time as the planned resection, they are cumbersome and can add up to 45 minutes of anesthesia time. Furthermore, these techniques can sometimes be limited by the small

surgical field. A preoperative test, which is often used to localize the eloquent hemisphere, is the Wada test. MEG/MSI has been proposed as a substitute for the Wada test.

### **Literature Review**

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.

### **Localization of Seizure Foci**

#### **Clinical Context and Test Purpose**

The purpose of magnetoencephalography (MEG) and magnetic source imaging (MSI) in the mapping of epileptic foci is to facilitate surgical treatment planning for persons with drug-resistant epilepsy.

The question addressed in this evidence review is: Does the use of MEG/MSI enhance localization of epileptic foci in conjunction with other noninvasive testing or replace invasive testing and, thus, result in changes in clinical management and improvement in health outcomes?

The following PICO was used to select literature to inform this review.

#### ***Patients***

The relevant population of interest is patients with drug-resistant epilepsy who are being evaluated for resective surgery.

#### ***Interventions***

The intervention of interest is MEG/MSI used to map epileptic foci. MEG/MSI is primarily used as a preoperative adjunct to other noninvasive tests used in clinical practice for epileptic foci localization. These tests include electroencephalography (EEG), magnetic resonance imaging, positron emission tomography, and single-photon emission computerized tomography.

#### ***Comparators***

The following practice is currently being used to make decisions about managing drug-resistant epilepsy: standard evaluation for seizure focus localization.

#### ***Outcomes***

Outcomes of interest are diagnostic accuracy (e.g., test sensitivity and specificity) and clinical utility (e.g., consideration of avoidance of invasive testing).

#### **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).

This section of the review is based on a TEC Special Report (2008) that reviewed the evidence on MEG for localization of epileptic lesions.<sup>3</sup> MEG has been proposed as a method for localizing seizure foci for patients with normal or equivocal magnetic resonance imaging and negative video-electroencephalogram (EEG) examinations, so-called "nonlesional" epilepsy. Such patients often undergo MEG, positron emission tomography, or ictal single-photon emission computed tomography to localize the seizure focus. They then often undergo invasive intracranial EEG (IC-EEG), a surgical procedure in which electrodes are inserted next to the brain. Definitive proof that MEG is effective would be comparative evidence that when compared with not using MEG, it improved patient outcomes. Such improvement in outcomes would include more patients being rendered seizure-free, use of a less invasive and morbid diagnostic workup, and overall improved patient outcomes. This is a complicated array of outcomes that have not been thoroughly evaluated in a comprehensive manner. Because MEG is used to make decisions regarding further diagnostic testing, which may affect the decision to have surgery and the extent of surgery, solely examining surgical outcomes excludes the assessment of outcomes of patients who did not have surgery.

Ideally, a randomized trial comparing the outcomes of patients who receive MEG as part of their diagnostic workup compared with patients who do not receive MEG could determine whether MEG improves patient outcomes. However, almost all of the studies evaluating MEG have been retrospective, where MEG, other tests, and surgery have been selectively applied to patients. Because patients often drop out of the diagnostic process before having IC-EEG, and many patients ultimately do not undergo surgery, most studies of associations between diagnostic tests and between diagnostic tests and outcomes are biased by selection and ascertainment biases. For example, studies that evaluate the correlation between MEG and IC-EEG invariably do not account for the fact that MEG information was sometimes used to deselect a patient from undergoing IC-EEG. In addition, IC-EEG findings only imperfectly correlate with surgical outcomes, meaning that it is an imperfect reference standard.

Numerous studies have shown associations between MEG findings and other noninvasive and invasive diagnostic tests, including IC-EEG, and between MEG findings and surgical outcomes. However, such studies do not allow any conclusions on whether MEG added incremental information to aid the management of such patients and whether patients' outcomes were improved as a result of the additional diagnostic information.

A representative study of MEG by Knowlton et al (2008) demonstrated many of the problematic issues of evaluating MEG.<sup>4</sup> In this study of 160 patients with nonlesional epilepsy, all had MEG but only 72 proceeded to IC-EEG. The calculations of diagnostic characteristics of MEG are biased by incomplete ascertainment of the reference standard. However, even examining the diagnostic characteristics of MEG using the 72 patients who underwent IC-EEG, sensitivities, and specificities were well below 90%, indicating the likelihood of both false-positive and false-negative studies. Predictive values based on these sensitivities and specificities mean that MEG can neither rule in nor rule out a positive IC-EEG and that MEG cannot be used as a triage test before IC-EEG to avoid potential morbidity in a subset of patients.

One study more specifically addressed whether MEG can improve the yield of IC-EEG, thus, allowing more patients to receive surgery. In another study by Knowlton et al (2009), MEG results modified the placement of electrodes in 18 (23%) of 77 patients who were recommended to have IC-EEG.<sup>5</sup> Seven (39%) of 18 patients had positive intracranial seizure recordings involving additional electrode placement because of MEG results. It was concluded that 4 (5%) patients were presumed to have had surgery modified as a result of the effect of MEG electrode placement.

### **Section Summary: Clinically Valid**

There are no clinical trials or other high-quality studies demonstrating the diagnostic accuracy of MEG in determining the location of seizure foci. Available evidence on diagnostic accuracy is limited by ascertainment and selection biases because MEG findings were used to select and deselect

patients in the diagnostic pathway, thus making it difficult to determine the role of MEG for the purpose of seizure localization.

### 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 randomized controlled trials.

Several studies have correlated MEG findings with surgical outcomes. Lau et al (2008) performed a systematic review of 17 such studies.<sup>6</sup> In this review, sensitivity and specificity had unorthodox definitions. Sensitivity was the proportion of patients cured with surgery in whom the MEG-defined epileptic region was resected, and specificity was the proportion of patients not cured with surgery in whom the MEG-defined epileptic region was not resected. Pooled sensitivity was 84%, meaning that, among the total number of cured patients, 16% occurred despite the MEG-defined region not being resected. Pooled specificity was 52%, meaning that, among 48% of patients not cured, the MEG-localized region was resected. Another more recent systematic review by Mouthaan et al (2019) from the E-PILEPSY consortium which used a more conservative analytic approach to pool data from a smaller subset of studies found similar but slightly lower MSI sensitivity (79% vs 84%) and specificity (46% vs 52%).<sup>7</sup> These results are consistent with an association between resection of the MEG-defined region and surgical cure but that it is an imperfect predictor of surgical success. However, it does not address the question of whether MEG contributed original information to improve the probability of cure. In a retrospective review of 22 children with medically intractable focal epilepsy (median age at epilepsy surgery, 11 years), Kim et al (2013) used a cutoff of 70% or more for the number of MEG identified spike dipole sources located within the resection margin to define a positive study.<sup>8</sup> Sensitivity, specificity, and positive and negative predictive values for seizure-free status post-operatively were 67%, 14%, 63%, and 17%, respectively.

### 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.

Other studies have implied value of MEG but it is difficult to make firm conclusions regarding its value. In a study by Schneider et al (2013), 14 patients with various findings on MEG, IC-EEG, and interictal single-photon emission computed tomography underwent surgery for nonlesional neocortical focal epilepsy.<sup>9</sup> Concordance between IC-EEG and MEG occurred in 5 patients, 4 of whom became seizure-free. This concordance of the 2 tests was the best predictor of becoming seizure-free. Although this was prognostic for success, whether this would actually change surgical decision making, such as declining to operate where there is no such concordance, is uncertain. A similar study by Widjaja et al (2013) showed that concordance between MEG findings and the location of surgical resection correlated with better seizure outcomes.<sup>10</sup> However, the authors acknowledged that MEG was entrenched in clinical practice, and the decision to proceed further in diagnostic and therapeutic endeavors was based on results of MEG and other tests.

Other case series of surgical patients have suggested value to MEG. A study by Albert et al (2014) reviewed a series of pediatric patients undergoing surgery for epilepsy who had only undergone noninvasive monitoring prior to surgery.<sup>11</sup> MEG was proposed to have avoided the need for the morbidity associated with invasive monitoring. Of 16 patients, 62.5% were seizure-free following surgery, and 20% experienced improvement. Two cases required additional surgery with invasive monitoring. Although most patients improved, it could not be determined whether the outcomes

were equivalent to the standard practice of pre-resection invasive monitoring. A study by Wang et al (2015) compared fluorine 18 fluorodeoxyglucose positron emission tomography with MEG in identifying the epileptogenic zone, using invasive monitoring as the reference standard.<sup>12</sup> Fluorodeoxyglucose positron emission tomography identified the zone in 8 (50%) of patients and MEG identified the zone in 12 (75%) of patients. Although MEG was more sensitive than fluorodeoxyglucose positron emission tomography in this study, it still missed epileptogenic areas identified by invasive monitoring. Another study, by Koptelova et al (2013), compared MEG with video-EEG monitoring in 22 patients.<sup>13</sup> Of 75 "irritative" zones identified in the 22 patients by either method, a higher proportion was identified by MEG. Note that there is no true reference standard in this type of analysis. However, in analyses of intraoperative EEG, several zones identified only with this method were only identified by MEG, confirming to some extent increased sensitivity over video-EEG. These recent studies have suggested clinical utility for MEG in the evaluation of epilepsy patients, but, due to the aforementioned problems, firm conclusions about the clinical utility of MEG cannot be determined.

The American Clinical Magnetoencephalography Society (2009) released a position statement that supported the routine clinical use of MEG/MSI for presurgical evaluation of patients with medically intractable seizures.<sup>14</sup> This statement cited a study by Sutherling et al (2008) as being a "milestone class I study." Class I evidence usually refers to randomized comparisons of treatment. However, the authors of Sutherling et al (2008) study described it as a "prospective, blinded crossover-controlled, single-treatment, observational case series."<sup>15</sup> The study attempted to determine the proportion of patients in whom diagnostic or treatment strategy was changed as a consequence of MEG. They concluded the test provided nonredundant information in 33% of patients, changed treatment in 9% of surgical patients, and benefited 21% of patients who had surgery. There was no control group in this study. The benefit of MEG was inferred by assumptions of what might have occurred in the absence of MEG results. Less than half of 69 enrolled patients went on to receive IC-EEG; thus, there appeared to be incomplete accounting for outcomes of all patients in the study. A similar study by De Tiege et al (2012) also attempted to determine the number of patients in whom management decisions were altered based on MEG results.<sup>16</sup> They concluded that clinical management was altered in 13% of patients.

### **Section Summary: Clinically Useful**

Evidence supporting the effect of MEG on patient outcomes is indirect and incomplete. Surgical management may be altered in a minority of patients based on MEG, but the evidence does not support the conclusion that outcomes are improved as a result of these management changes. Trials with a control group are needed to determine whether improved outcomes can be attributed to the change in management induced by knowledge of MEG findings.

## **Localization of Eloquent and Sensorimotor Areas**

### **Clinical Context and Test Purpose**

The purpose of MEG/MSI in the localization of eloquent and sensorimotor areas of the brain in persons with cortical brain lesions is to create a precise surgical plan for resective procedures to avoid postoperative speech, sensory, and motor dysfunction where possible.

The question addressed in this evidence review is: Does the use of MEG/MSI to map eloquent and sensorimotor brain areas accurately localize these areas and reduce postoperative functional impairment and, thus, result in changes in management and improvement in health outcomes?

The following PICO was used to select literature to inform this review.

### ***Patients***

The relevant population of interest is patients with brain lesions who are being evaluated for resective surgery.



### ***Interventions***

The intervention of interest is the use of MEG/MSI to map eloquent and sensorimotor brain areas. MEG/MSI is a noninvasive alternative to the preoperative Wada test (intracarotid sodium amobarbital procedure) used to map eloquent brain areas.

### ***Comparators***

The following test and practice are currently being used to make decisions about localization of eloquent function areas: the Wada test and other standard evaluations.

### ***Outcomes***

Outcomes of interest are diagnostic accuracy (e.g., test sensitivity and specificity) and clinical utility (e.g., consideration of avoidance of invasive testing).

### **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).

A TEC Assessment (2003) of MEG/MSI concluded that evidence for this particular indication was insufficient to demonstrate efficacy.<sup>17</sup> At that time, studies reviewed had relatively weak designs and small sample sizes. There are 2 ways to analyze the potential utility of MEG for this indication: MEG could potentially be a noninvasive substitute for the Wada test, which is a standard method of determining hemispheric dominance for language. The Wada test requires catheterization of the internal carotid arteries, which carries the risk of complications. The determination of language laterality is important to know to determine the suitability of a patient for surgery and what types of additional functional testing might be needed before or during surgery. If MEG provided concordant information with the Wada test, then such information would be obtained in a safe, noninvasive manner.

Several studies have shown high concordance between the Wada test and MEG. In the largest study (n=85), Papanicolaou et al (2004) reported concordance between the MEG and Wada tests in 74 (87%) patients.<sup>18</sup> In no cases were the tests discordant in a way that the findings were completely opposite. Discordant cases occurred mostly when the Wada test indicated left dominance and MEG indicated bilateral language function. In an alternative type of analysis, when the test is being used to evaluate the absence or presence of language function in the side in which surgical treatment is being planned, using the Wada procedure as the criterion standard, MEG was 98% sensitive and 83% specific. Thus, if the presence of language function in the surgical site requires intraoperative mapping and/or a tailored surgical approach, use of MEG rather than Wada would have "missed" one case where such an approach would be needed (false-negative MEG), and resulted in 5 cases where such an approach was unnecessary (false-positive MEG). However, it should be noted that the Wada test is not a perfect reference standard, and some discordance may reflect inaccuracy of the reference standard. In another study, Hirata et al (2004) reported that MEG and the Wada test agreed in 19 (95%) of 20 cases.<sup>19</sup>

### **Section Summary: Clinically Valid**

Available evidence comprises studies that correlate the results of MEG with results of the Wada test, which is an alternative method for localization. Evidence has generally shown that concordance between MEG and the Wada test is high. However, the studies have not been replicated and their generalizability is limited.



### 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 randomized controlled trials.

One potential use of MEG would be to map the sensorimotor area of the brain to avoid such areas in the surgical resection area. Intraoperative mapping just before resection is generally done as the reference standard. Preoperative mapping as potentially done by MEG might aid in determining the suitability of the patient for surgery or for assisting in the planning of other invasive testing. Similar to the situation for localization of epilepsy focus, the literature is problematic in terms of evaluating the comprehensive outcomes of patients due to ascertainment and selection biases. Studies tend to be limited to correlations between MEG and intraoperative mapping. Intraoperative mapping would be performed anyway in most resection patients. Several studies evaluated in the TEC Assessment (2003) showed good to high concordance between MEG/MSI findings and intraoperative mapping.<sup>17</sup> A technology assessment of functional brain imaging prepared by the Ontario Ministry of Health (2006) reviewed 10 studies of MEG and invasive functional mapping and showed good to high correspondence between the 2 tests.<sup>20</sup> However, these studies did not demonstrate that MEG would replace intraoperative mapping or reduce the morbidity of such mapping by allowing a more focused procedure.

### 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.

Studies of the use of MEG in localizing the sensorimotor area provide only indirect evidence of utility. Niranjana et al (2013) reviewed the results of 45 patients in whom MEG was used for localizing the somatosensory function.<sup>21</sup> In 32 patients who underwent surgery, surgical access routes were planned to avoid regions identified as somatosensory by MEG. All patients retained somatosensory function. It is unknown to what extent MEG provided unique information not provided by other tests. In a study by Tarapore et al (2012), 24 patients underwent MEG, transcranial magnetic stimulation, and intraoperative direct cortical stimulation to identify the motor cortex.<sup>22</sup> MEG and navigated transcranial magnetic stimulation both identified several areas of motor function and the median distance between corresponding motor areas was 4.71 mm. When comparing MEG with direct cortical stimulation, the median distance between corresponding motor sites (12.1 mm) was greater than the distance between navigated transcranial magnetic stimulation and direct cortical stimulation (2.13 mm). This study did not determine whether MEG provided unique information that contributed to better patient outcomes.

### Section Summary: Clinically Useful

There are no clinical trials that demonstrate the clinical utility of using MEG for localization and lateralization of eloquent and sensorimotor regions of the brain. Because MEG is a less invasive alternative to the Wada test, this evidence indicates that it is a reasonable alternative. There is also some evidence that the correlation between MEG and intraoperative mapping of eloquent and sensorimotor regions is high but the test has not demonstrated sufficient accuracy to replace intraoperative mapping.

### Summary of Evidence

For individuals who have drug-resistant epilepsy and are being evaluated for possible resective surgery who receive MEG/MSI, the evidence for MEG/MSI as an adjunct to standard clinical workup

includes various types of case series. Relevant outcomes are test accuracy and clinical utility. Published evidence on MEG is suboptimal, with no clinical trials demonstrating clinical utility. The literature on diagnostic accuracy has methodologic limitations, primarily selection, and ascertainment bias. Studies of functional outcomes do not fully account for the effects of MEG, because subjects who received MEG were not fully accounted for in the studies. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have a planned brain resection who require localization of eloquent function areas who receive MEG/MSI, the evidence includes comparative studies. Relevant outcomes include test accuracy and clinical utility. Available studies have reported that this test has high concordance with the Wada test, which is currently the main alternative to localize eloquent functions. While management is changed in some patients based on MEG testing, it has not been demonstrated that these changes lead to improved outcomes. The evidence is insufficient to determine the effects of the technology on health outcomes.

### **Supplemental Information**

#### **Clinical Input From Physician Specialty Societies and Academic Medical Centers**

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

In response to requests, input was received from 2 physician specialty societies (5 reviewers) and 2 academic medical centers in 2011. There was support for use of magnetoencephalography and magnetic source imaging for localization of language function and as part of the preoperative evaluation of intractable seizures. Those providing input indicated that use of magnetoencephalography and magnetic source imaging in the preoperative evaluation leads to the identification of additional people whose epilepsy may be cured using a surgical approach.

### **Practice Guidelines and Position Statements**

#### **American Clinical Magnetoencephalography Society**

The American Clinical Magnetoencephalography Society (ACMS, 2009) released a position statement supporting the routine clinical use of magnetoencephalography (MEG) plus magnetic source imaging for presurgical evaluation of patients with medically intractable seizures (see Rationale section).<sup>14</sup>

The ACMS (2011) issued a series of practice guidelines on magnetic evoked fields addressing different aspects of this technology (recording and analysis of spontaneous cerebral activity,<sup>23</sup> presurgical functional brain mapping using magnetic evoked fields,<sup>24</sup> MEG and electroencephalogram reporting<sup>25</sup>, and qualifications of MEG-electroencephalogram personnel).<sup>26</sup> Methods of guideline development were not described.

Guideline 2 on presurgical functional brain mapping indicated that:

"Magnetoencephalography shares with EEG high temporal resolution, but its chief advantage in presurgical functional brain mapping is in its high spatial resolution. Magnetic evoked fields are therefore done for localization; unlike electrical evoked potentials (EPs), [magnetic evoked fields] latencies and latency asymmetries are not typically used to detect abnormalities."<sup>24</sup>

Proposed indications for MEG included localization of somatosensory, auditory, language, and motor evoked fields.<sup>24</sup>

The ACMS (2017) issued another position statement supporting the routine use of MEG/magnetic source imaging for obtaining noninvasive localizing or lateralizing information regarding eloquent cortices (somatosensory, motor, visual, auditory, and language) in the presurgical evaluation of patients with operable lesions preparing for surgery.<sup>27</sup>

**U.S. Preventive Services Task Force Recommendations**

Not applicable.

**Medicare National Coverage**

There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

**Ongoing and Unpublished Clinical Trials**

A search of ClinicalTrials.gov on August 3, 2020 did not identify any ongoing or unpublished trials that would likely influence this review.

**References**

1. Food and Drug Administration (FDA). Devices@FDA: CTF Systems, Inc. Whole-Cortex MEG system (with optional EEG subsystem) (K971329). 1997; <https://www.accessdata.fda.gov/scripts/cdrh/devicesatfda/index.cfm?db=pmn&id=K971329>. Accessed September 19, 2024.
2. Food and Drug Administration. Section 510(k) Premarket Notification K152184 MagView Biomagnetometer. 2016; [https://www.accessdata.fda.gov/cdrh\\_docs/pdf15/k152184.pdf](https://www.accessdata.fda.gov/cdrh_docs/pdf15/k152184.pdf). Accessed September 19, 2024.
3. Blue Cross and Blue Shield Association Technology Evaluation Center (TEC). Special Report: Magnetoencephalography and magnetic source imaging for the purpose of presurgical localization of epileptic lesions--a challenge for technology evaluation. TEC Assessments. 2008;Volume 23:Tab 8.
4. Knowlton RC, Elgavish RA, Limdi N, et al. Functional imaging: I. Relative predictive value of intracranial electroencephalography. *Ann Neurol*. Jul 2008; 64(1): 25-34. PMID 18412264
5. Knowlton RC, Razdan SN, Limdi N, et al. Effect of epilepsy magnetic source imaging on intracranial electrode placement. *Ann Neurol*. Jun 2009; 65(6): 716-23. PMID 19557860
6. Lau M, Yam D, Burneo JG. A systematic review on MEG and its use in the presurgical evaluation of localization-related epilepsy. *Epilepsy Res*. May 2008; 79(2-3): 97-104. PMID 18353615
7. Mouthaan BE, Rados M, Boon P, et al. Diagnostic accuracy of interictal source imaging in presurgical epilepsy evaluation: A systematic review from the E-PILEPSY consortium. *Clin Neurophysiol*. May 2019; 130(5): 845-855. PMID 30824202
8. Kim H, Kankirawatana P, Killen J, et al. Magnetic source imaging (MSI) in children with neocortical epilepsy: surgical outcome association with 3D post-resection analysis. *Epilepsy Res*. Sep 2013; 106(1-2): 164-72. PMID 23689013
9. Schneider F, Irene Wang Z, Alexopoulos AV, et al. Magnetic source imaging and ictal SPECT in MRI-negative neocortical epilepsies: additional value and comparison with intracranial EEG. *Epilepsia*. Feb 2013; 54(2): 359-69. PMID 23106128
10. Widjaja E, Shamma A, Vali R, et al. FDG-PET and magnetoencephalography in presurgical workup of children with localization-related nonlesional epilepsy. *Epilepsia*. Apr 2013; 54(4): 691-9. PMID 23398491
11. Albert GW, Ibrahim GM, Otsubo H, et al. Magnetoencephalography-guided resection of epileptogenic foci in children. *J Neurosurg Pediatr*. Nov 2014; 14(5): 532-7. PMID 25238627
12. Wang Y, Liu B, Fu L, et al. Use of interictal (18)F-fluorodeoxyglucose (FDG)-PET and magnetoencephalography (MEG) to localize epileptogenic foci in non-lesional epilepsy in a cohort of 16 patients. *J Neurol Sci*. Aug 15 2015; 355(1-2): 120-4. PMID 26066558
13. Koptelova AM, Arkhipova NA, Golovtsev AL, et al. [Magnetoencephalography in the presurgical evaluation of patients with drug-resistant epilepsy]. *Zh Vopr Neurokhir Im N Burdenko*. 2013; 77(6): 14-21. PMID 24558750
14. Bagic A, Funke ME, Ebersole J. American Clinical MEG Society (ACMEGS) position statement: the value of magnetoencephalography (MEG)/magnetic source imaging (MSI) in noninvasive

- presurgical evaluation of patients with medically intractable localization-related epilepsy. *J Clin Neurophysiol.* Aug 2009; 26(4): 290-3. PMID 19602984
15. Sutherling WW, Mamelak AN, Thyerlei D, et al. Influence of magnetic source imaging for planning intracranial EEG in epilepsy. *Neurology.* Sep 23 2008; 71(13): 990-6. PMID 18809834
  16. De Tiege X, Carrette E, Legros B, et al. Clinical added value of magnetic source imaging in the presurgical evaluation of refractory focal epilepsy. *J Neurol Neurosurg Psychiatry.* Apr 2012; 83(4): 417-23. PMID 22262910
  17. Blue Cross and Blue Shield Association Technology Evaluation Center (TEC). Magnetoencephalography (MEG) and magnetic source imaging (MSI): presurgical localization of epileptic lesions and presurgical function mapping. *TEC Assessments.* 2003;Volume 18:Tab 6.
  18. Papanicolaou AC, Simos PG, Castillo EM, et al. Magnetocephalography: a noninvasive alternative to the Wada procedure. *J Neurosurg.* May 2004; 100(5): 867-76. PMID 15137606
  19. Hirata M, Kato A, Taniguchi M, et al. Determination of language dominance with synthetic aperture magnetometry: comparison with the Wada test. *Neuroimage.* Sep 2004; 23(1): 46-53. PMID 15325351
  20. Medical Advisory Secretariat. Functional brain imaging: an evidence-based analysis. *Ont Health Technol Assess Ser.* 2006; 6(22): 1-79. PMID 23074493
  21. Niranjana A, Laing EJ, Laghari FJ, et al. Preoperative magnetoencephalographic sensory cortex mapping. *Stereotact Funct Neurosurg.* 2013; 91(5): 314-22. PMID 23797479
  22. Tarapore PE, Tate MC, Findlay AM, et al. Preoperative multimodal motor mapping: a comparison of magnetoencephalography imaging, navigated transcranial magnetic stimulation, and direct cortical stimulation. *J Neurosurg.* Aug 2012; 117(2): 354-62. PMID 22702484
  23. Bagic AI, Knowlton RC, Rose DF, et al. American Clinical Magnetoencephalography Society Clinical Practice Guideline 1: recording and analysis of spontaneous cerebral activity. *J Clin Neurophysiol.* Aug 2011; 28(4): 348-54. PMID 21811121
  24. Burgess RC, Funke ME, Bowyer SM, et al. American Clinical Magnetoencephalography Society Clinical Practice Guideline 2: presurgical functional brain mapping using magnetic evoked fields. *J Clin Neurophysiol.* Aug 2011; 28(4): 355-61. PMID 21811122
  25. Bagic AI, Knowlton RC, Rose DF, et al. American Clinical Magnetoencephalography Society Clinical Practice Guideline 3: MEG-EEG reporting. *J Clin Neurophysiol.* Aug 2011; 28(4): 362-3. PMID 21811123
  26. Bagic AI, Barkley GL, Rose DF, et al. American Clinical Magnetoencephalography Society Clinical Practice Guideline 4: qualifications of MEG-EEG personnel. *J Clin Neurophysiol.* Aug 2011; 28(4): 364-5. PMID 21811124
  27. Bagic AI, Bowyer SM, Kirsch HE, et al. American Clinical MEG Society (ACMEGS) Position Statement #2: The Value of Magnetoencephalography (MEG)/Magnetic Source Imaging (MSI) in Noninvasive Presurgical Mapping of Eloquent Cortices of Patients Preparing for Surgical Interventions. *J Clin Neurophysiol.* May 2017; 34(3): 189-195. PMID 28059855

## Documentation for Clinical Review

### Please provide the following documentation:

- History and physical and/or consultation notes including:
  - Diagnosis and reason for imaging
  - Previous treatment plan and response
  - Diagnostic imaging reports, if applicable
  - Surgical plan, if applicable

### Post Service (in addition to the above, please include the following):

- Magnetoencephalography or magnetic source imaging report

## Coding

*This Policy relates only to the services or supplies described herein. Benefits may vary according to product design; therefore, contract language should be reviewed before applying the terms of the Policy.*

*The following codes are included below for informational purposes. Inclusion or exclusion of a code(s) does not constitute or imply member coverage or provider reimbursement policy. Policy Statements are intended to provide member coverage information and may include the use of some codes for clarity. The Policy Guidelines section may also provide additional information for how to interpret the Policy Statements and to provide coding guidance in some cases.*

Type	Code	Description
CPT®	95965	Magnetoencephalography (MEG), recording and analysis; for spontaneous brain magnetic activity (e.g., epileptic cerebral cortex localization)
	95966	Magnetoencephalography (MEG), recording and analysis; for evoked magnetic fields, single modality (e.g., sensory, motor, language, or visual cortex localization)
	95967	Magnetoencephalography (MEG), recording and analysis; for evoked magnetic fields, each additional modality (e.g., sensory, motor, language, or visual cortex localization) (List separately in addition to code for primary procedure)
HCPCS	S8035	Magnetic source imaging

## Policy History

This section provides a chronological history of the activities, updates and changes that have occurred with this Medical Policy.

Effective Date	Action
06/01/2004	BCBSA Medical Policy Adoption
04/01/2005	Administrative Review
04/05/2007	Policy Revision
09/12/2008	Policy Revision Policy revision
10/07/2011	Policy revision without position change
07/14/2014	Policy revision with position
02/27/2015	Policy revision without position change
04/01/2016	Policy revision without position change
06/01/2017	Policy revision without position change
11/01/2017	Policy revision without position change
11/01/2018	Policy revision without position change
11/01/2019	Policy revision without position change
11/01/2020	Annual review. No change to policy statement. Literature review updated.
11/01/2021	Annual review. No change to policy statement.
11/01/2022	Annual review. No change to policy statement.
10/01/2023	Annual review. Policy statement updated.
10/01/2024	Annual review. No change to policy statement.

## Definitions of Decision Determinations

**Medically Necessary:** Services that are Medically Necessary include only those which have been established as safe and effective, are furnished under generally accepted professional standards to treat illness, injury or medical condition, and which, as determined by Blue Shield, are: (a) consistent with Blue Shield medical policy; (b) consistent with the symptoms or diagnosis; (c) not furnished primarily for the convenience of the patient, the attending Physician or other provider; (d) furnished at the most appropriate level which can be provided safely and effectively to the patient; and (e) not more costly than an alternative service or sequence of services at least as likely to produce equivalent therapeutic or diagnostic results as to the diagnosis or treatment of the Member's illness, injury, or disease.

**Investigational/Experimental:** A treatment, procedure, or drug is investigational when it has not been recognized as safe and effective for use in treating the particular condition in accordance with generally accepted professional medical standards. This includes services where approval by the federal or state governmental is required prior to use, but has not yet been granted.

**Split Evaluation:** Blue Shield of California/Blue Shield of California Life & Health Insurance Company (Blue Shield) policy review can result in a split evaluation, where a treatment, procedure, or drug will be considered to be investigational for certain indications or conditions, but will be deemed safe and effective for other indications or conditions, and therefore potentially medically necessary in those instances.

## Prior Authorization Requirements and Feedback (as applicable to your plan)

Within five days before the actual date of service, the provider must confirm with Blue Shield that the member's health plan coverage is still in effect. Blue Shield reserves the right to revoke an authorization prior to services being rendered based on cancellation of the member's eligibility. Final determination of benefits will be made after review of the claim for limitations or exclusions.

Questions regarding the applicability of this policy should be directed to the Prior Authorization Department at (800) 541-6652, or the Transplant Case Management Department at (800) 637-2066 ext. 3507708 or visit the provider portal at [www.blueshieldca.com/provider](http://www.blueshieldca.com/provider).

We are interested in receiving feedback relative to developing, adopting, and reviewing criteria for medical policy. Any licensed practitioner who is contracted with Blue Shield of California or Blue Shield of California Promise Health Plan is welcome to provide comments, suggestions, or concerns. Our internal policy committees will receive and take your comments into consideration.

For utilization and medical policy feedback, please send comments to: [MedPolicy@blueshieldca.com](mailto:MedPolicy@blueshieldca.com)

*Disclaimer: This medical policy is a guide in evaluating the medical necessity of a particular service or treatment. Blue Shield of California may consider published peer-reviewed scientific literature, national guidelines, and local standards of practice in developing its medical policy. Federal and state law, as well as contract language, including definitions and specific contract provisions/exclusions, take precedence over medical policy and must be considered first in determining covered services. Member contracts may differ in their benefits. Blue Shield reserves the right to review and update policies as appropriate.*

Appendix A

POLICY STATEMENT (No changes)	
BEFORE	AFTER
<p><b>Magnetoencephalography/Magnetic Source Imaging BSC6.05</b></p> <p><b>Policy Statement:</b></p> <ul style="list-style-type: none"> <li>I. Magnetoencephalography/magnetic source imaging as part of the preoperative evaluation of individuals with drug-resistant epilepsy (seizures refractory to at least 2 first-line anticonvulsants) may be considered <b>medically necessary</b> when standard techniques, magnetic resonance imaging (MRI) and electroencephalogram (EEG), do not provide satisfactory localization of epileptic lesion(s).</li>   <li>II. Magnetoencephalography/magnetic source imaging for the purpose of determining the laterality of language function, as a substitute for the Wada test, may be considered <b>medically necessary</b> in individuals being prepared for surgery for <b>any</b> of the following indications:                             <ul style="list-style-type: none"> <li>A. Brain tumors</li> <li>B. Epilepsy</li> <li>C. Other indications requiring brain resection</li> </ul> </li>   <li>III. Magnetoencephalography/magnetic source imaging is considered <b>investigational</b> for all other indications.</li> </ul>	<p><b>Magnetoencephalography/Magnetic Source Imaging BSC6.05</b></p> <p><b>Policy Statement:</b></p> <ul style="list-style-type: none"> <li>I. Magnetoencephalography/magnetic source imaging as part of the preoperative evaluation of individuals with drug-resistant epilepsy (seizures refractory to at least 2 first-line anticonvulsants) may be considered <b>medically necessary</b> when standard techniques, magnetic resonance imaging (MRI) and electroencephalogram (EEG), do not provide satisfactory localization of epileptic lesion(s).</li>   <li>II. Magnetoencephalography/magnetic source imaging for the purpose of determining the laterality of language function, as a substitute for the Wada test, may be considered <b>medically necessary</b> in individuals being prepared for surgery for <b>any</b> of the following indications:                             <ul style="list-style-type: none"> <li>A. Brain tumors</li> <li>B. Epilepsy</li> <li>C. Other indications requiring brain resection</li> </ul> </li>   <li>III. Magnetoencephalography/magnetic source imaging is considered <b>investigational</b> for all other indications.</li> </ul>