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## Relative Function: Nuclear Brain Imaging in United States Courts


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## Relative Function: Nuclear Brain Imaging in United States Courts

### Abstract

Neuropsychological testing—medical imaging of the brain structure and function—allows the expert to inform the court on the brain structure and function of the forensic examinee. Supported by extensive clinical use, neuropsychological testing and structural imaging in the form of computerized tomography and structural magnetic resonance imaging have achieved general acceptance in court. However, functional imaging such as functional MRI and nuclear medicine techniques, such as positron emission tomography (PET), have faced more admissibility challenges. While functional imaging is becoming an increasingly important tool in assessing neuropsychiatric illness, we surmise that evidentiary challenges are largely related to the phase of trial in which the nuclear study is offered as evidence. This article will review the basic science of functional nuclear imaging including PET and single photon emission computed tomography. We will then review cases where admissibility of these techniques has been challenged and consider whether and how nuclear brain imaging can influence the outcome of the trial.

### Keywords

CT scan, fMRI scan, MRI scan, nuclear imaging, PET scan, SPECT scan

### Disciplines

Bioethics and Medical Ethics | Neuroscience and Neurobiology | Neurosciences



## Relative function: Nuclear brain imaging in United States courts

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*Neuropsychological testing—medical imaging of the brain structure and function—allows the expert to inform the court on the brain structure and function of the forensic examinee. Supported by extensive clinical use, neuropsychological testing and structural imaging in the form of computerized tomography and structural magnetic resonance imaging have achieved general acceptance in court. However, functional imaging such as functional MRI and nuclear medicine techniques, such as positron emission tomography (PET), have faced more admissibility challenges. While functional imaging is becoming an increasingly important tool in assessing neuropsychiatric illness, we surmise that evidentiary challenges are largely related to the phase of trial in which the nuclear study is offered as evidence. This article will review the basic science of functional nuclear imaging including PET and single photon emission computed tomography. We will then review cases where admissibility of these techniques has been challenged and consider whether and how nuclear brain imaging can influence the outcome of the trial.*

KEY WORDS: CT scan, fMRI scan, MRI scan, nuclear imaging, PET scan, SPECT scan.

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Positron emission tomography (PET) and single photon emission computed tomography (SPECT) are nuclear medicine techniques that use energy emitted during radioactive decay to produce three-dimensional images of internal organs, including the brain. The ability of radiolabeled biological compounds to enter brain structures provides valuable information on the inner workings or impairments of the brain structure under analysis. Since PET and SPECT are sensitive to functional changes on the order of seconds and minutes, they are considered “functional” imaging techniques.

### **Clinical PET of the brain**

Fluorine-18 (18F) labeled glucose is the radioligand most commonly used in clinical brain PET. Glucose is radiolabeled with 18F by substituting the hydroxyl group with 18F to create the radioligand 2-deoxy-2-(18F)-fluoro-D-glucose (18FDG). 18FDG is taken up by brain cells in the same way as unlabeled glucose, but after phosphorylation to 18FDG-6-phosphate it cannot continue glycolysis and becomes trapped in the brain cell. The PET scanner detects the amount of labeled glucose taken up by the brain. Other elements such as oxygen and nitrogen can be radiolabeled and their metabolism imaged. As nuclear medicine studies based on the metabolism of these compounds are rarely admitted in court, they will not be discussed in detail here.

18FDG-PET is a universally accepted clinical test in the diagnosis and follow up of malignancy (Bomanji, Costa, & Ell, 2001; Necib et al., 2011), myocardial viability, epilepsy (Kim, Lee, Lee, Chung, Chung, & Lee, 2002; Kim et al., 2003), and degenerative brain disease (Desgranges et al., 2002; Ishii et al., 2001; Jeong et al., 2005; Juh, Kim, Moon, Coe, & Suh, 2004; Newberg & Alavi, 2005). Other relatively common clinical uses include pre-surgical planning, post-stroke evaluation (Ances, Liebeskind, Newberg, Jacobs, & Alavi, 2004), and evaluation of moderate to severe traumatic

brain injury (Bergsneider et al, 2000; Ruff et al., 1994). PET is commonly used by forensic medicine practitioners to demonstrate diffuse axonal injury, which is characteristic of mild traumatic brain injury (Mehr & Gerdes, 2001; Rao, Turski, Polcyn, Nickels, & Flynn, 1984).

### **Clinical SPECT of the brain**

The most common clinical use of brain SPECT is to analyze regional brain-blood perfusion. Blood flow is relevant to the brain as it delivers the elements essential to brain function, such as oxygen and glucose, to the brain regions associated with specific cognitive and behavioral processes. SPECT compounds are typically low-molecular weight and lipophilic, allowing them to easily cross the blood-brain barrier (Westera, 2003). The blood flow (perfusion) tracers are distributed in the brain in accordance with regional blood flow over a known period of time, usually measured in minutes, providing an average image of brain perfusion over a fixed time period of a few minutes. The gamma ray-emitting isotope most commonly used in brain SPECT radioligands is technetium-99m ( $^{99m}\text{Tc}$ ) (Castronovo, 1975). The most common clinical uses of brain SPECT is to characterize neurodegenerative disorders such as dementia, as well as perfusion abnormalities associated with stroke, seizures, inflammation and trauma (Dougall, Bruggink, & Ebmeier, 2004).

### **PET and SPECT basics**

Both PET and SPECT utilize the energy of photons emitted during nuclear decay for image formation, but differ in the source and nature of these photons. In SPECT, a single photon is emitted in the decay of  $^{99m}\text{Tc}$  and detected by two or three gamma cameras rotating around the patient (Tukington & Gilland, 2003). With PET, the process is more

complicated: PET isotopes undergo radioactive decay via a process known as positron emission or positive beta decay. During this decay a positron and a neutrino are emitted from the radiotracer. The emitted positron travels through the tissue, until it collides with a random electron and both are annihilated. During annihilation, two gamma photons with energy of 511 keV are released in opposite directions at a 180° angle from each other and are detected by the PET scanner cameras that are arranged in a stationary ring around the patient.

In SPECT the gamma camera contains a collimator, a crystal, and an array of photomultiplier tubes. The collimator design ensures that the camera records only the photons that come directly from the patient. The crystal is a material that emits flashes of visible light known as scintillations when high-energy X-ray or  $\gamma$ -ray photons strike it. The light emitted by the scintillator hits the surface of the nearest photomultiplier tube. The photomultiplier tube converts a flash of light into an electrical signal that allows measurement of the energy of the incoming  $\gamma$  photon. A series of images are produced as the cameras move around the patient and record data from multiple angles. The more angles obtained by the camera, the better the resolution of the image. The total scan time is typically around 20 minutes. Patient motion and the amount and specific activity of the radiopharmaceutical affect image quality (Zaidi & Hasegawa, 2006).

In PET, timing rather than a collimator is used to record only the photons that come directly from the patient. A PET scanner contains an extremely precise clock allowing a determination of whether two rays hit detectors at the same time, a process known as coincidence detection. Only photons that arrive within a few nanoseconds of one another are recorded as coincidental hits. Once a coincidental hit is registered, a computer calculates the straight line between the two rays, called a line of response; the positron that generated the coincidence rays originated somewhere along

the line of response. By counting millions of these coincidental hits around a large number of cross-bearings, the size and position of the structure that has taken up the radioligand is determined. By combining the lines of response from many different angles, the data can be reconstructed into cross-sectional images, and form the basis of creation of the 3-D image (Shepp & Logan, 1974).

### **Detecting brain abnormalities using nuclear medicine imaging**

There are two main approaches to diagnosing a brain abnormality using nuclear scans. First, an evaluatee's nuclear medicine study can be compared to a previously obtained study of the same individual. Second, the study can be compared to a preexisting normative study or a group average (Provenzano, Jordan, Tikofsky, Saxena, Van Heertum, & Ichise, 2010; Zhang, Mitsis, Chu, Newmark, Hazlett, & Buchsbaum, 2010). In order to validly diagnose metabolic or blood flow abnormalities, there must be a clearly defined normal population. Each facility should have an accessible database of normal controls to which nuclear medicine studies are compared (Mehr & Gerdes, 2001). Such databases are commercially available or can be generated at each individual site. Typically at least 10 subjects are needed to generate a database, though more subjects will improve the ability of the database to differentiate normal intersubject variability from disease (Chen et al., 2008; Iseki et al, 2010). When quantitative comparisons are made to normal databases, the patient's image data must first be coregistered to the normal database. Because the brains of each individual subject are of different shapes and sizes, nonlinear transformation of the image data to force all the images into the same shape is necessary in order to perform quantitative comparisons between any two brains or an individual brain and a control group. Most clinical nuclear medicine study reports are the result of a semiquantitative



analysis in which the results are based on regional concentrations of measured radioactivity, normalized to an internal reference standard, such as whole brain activity, corrected to the actual time of imaging. This is known as the standardized uptake value (Silverman & Alavi, 2005). The technique may involve warping the patient's anatomic structure obtained in the MRI to PET to obtain regions of interest on PET. The regions of interest can then be compared to whole brain glucose metabolism, yielding the region of interest to whole brain ratio (Resnick, Karp, Turetsky, & Gur, 1993).

A number of factors must be considered when comparing metabolic patterns across brains. For standardization purposes, gender, age, handedness, environmental conditions at time of the study, level of alertness, presence of medications, serum glucose levels, and the amount of tracer that passes into the brain are all important variables that must be considered when comparing one individual's brain scan to a group of controls.

### **Use of nuclear imaging in criminal trials**

For the last decade there has been much debate concerning the admissibility and the appropriateness of expert witnesses discussing brain scans in the courtroom (Appelbaum, 2009; Greely & Illes, 2007). Legal scholars have expressed fears that colorful pictures will distract jurors from the true legal issues they must decide (Gurley & Marcus, 2008). As this debate has waged, brain imaging has become an important tool used clinically by physicians to detect potential brain-based explanations for abnormal behavior. Not all abnormal behavior is criminal behavior; some is, and there is potential for criminal behavior to follow abnormal behavior. We predict that as nuclear imaging and other modes of functional brain imaging such as fMRI enter the realm of standard medical practice, the rate of admission of

functional brain scans into evidence will increase dramatically. At present, the phase of trial during which the functional brain scan is offered as evidence is an important variable in whether an admissibility challenge will be raised. Prior to discussing specific examples of evidentiary challenges, we will review basic information about criminal law and criminal trials.

There are two elements to a crime—the physical act that the state or governing body defines as illegal (*actus reus*) and the mental state that the person had at the time he or she committed the act (*mens rea*). In order to convict an individual of a crime, the state must prove that the person in custody (the defendant) committed the charged act and that the person knew or should have known that the behavior was wrong. The government can prosecute, convict, and punish a person in the criminal justice system if the person committed the crime, was responsible at the time of the crime, and therefore deserves punishment. When enumerating illegal acts, states also determine the specific penalty or range of penalties associated with each crime.

A criminal trial is divided into two phases: the guilt phase and the sentencing phase. In criminal trials a jury will issue a verdict on a defendant's guilt or innocence and a judge will then issue the corresponding sentence. In capital murder trials, a jury will determine guilt or innocence. If a defendant is found guilty, a jury will then take part in a second hearing known as the penalty phase, where they will sentence the defendant to life in prison without the possibility of parole, or to death.

In order to escape a mandatory punishment for a given crime, a guilty (or risk-averse, innocent) defendant may waive his right to a trial on the issue of guilt and plead to a lesser crime, which is associated with a lesser sentence. The legal term for this is a “plea bargain.” Most criminal cases in the United States result in a plea bargain. In cases that do

move forward to trial, attorneys may engage private investigators, psychologists, psychiatrists, and other experts to assist the court in understanding the defendant's state of mind and reasoning at the time the crime was committed. If a defendant was not thinking rationally due to mental illness or extreme emotional distress, he may be less blameworthy under the law (Morse, 2011). At present, functional brain imaging is not a tool used clinically to determine whether patients are in a rational state of mind or if they are mentally ill. As functional brain imaging moves from the research setting into standard clinical practice, these tools may become standard in diagnosing mental illness, but at present they are not used clinically to diagnose mental illnesses, unless brain damage, cancer, epilepsy, stroke, or dementia is suspected as the underlying cause for the abnormal behavior. When functional imaging is offered for diagnoses other than those for which there are well established patterns an evidentiary challenge is likely to arise.

The Federal Rules of Evidence govern the introduction of evidence in civil and criminal proceedings in Federal courts. The rules of evidence used in many states have been closely modeled on these provisions. Rule 702 addresses Testimony by Experts and reads as follows:

If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case. (Fed. Rule Evid. 702)

Rule 702 was amended in 2000 to reflect case law including *Daubert v. Merrell Dow Pharmaceuticals* (1995), which held that Rule 702 of the Federal Rules of Evidence did not incorporate the *Frye* "general acceptance" test (*Frye v. United States*, 1923) as a basis for assessing the admissibility of scientific expert testimony. Despite this change to the

federal rules of evidence, the *Frye* standard is maintained in many states including Alabama, Arizona, California, Florida, Illinois, Kansas, Maryland, Michigan, Minnesota, New Jersey, New York, Pennsylvania, and Washington. Scientific procedures, principles or techniques that may be discussed by the expert during trial must be “generally accepted” by the relevant scientific community. A question that may arise during trial in a *Frye* state could be: Would other psychiatrists or nuclear medicine physicians also rely on PET for diagnosing or evaluating this disorder? The opposing side could then refute general acceptance by calling an expert who would testify that many psychiatrists and nuclear medicine physicians would not agree that PET could be used to evaluate the condition in question.

The *Daubert* standard was initially touted as a more lenient standard for admission of scientific evidence, but time has proven it effective at limiting admission of scientific evidence that falls short of its criteria. Prior to trial, the judge will review the submitted evidence and determine whether the scientific method or reasoning is valid and could be properly applied to the facts at issue in the case. The judge must consider whether the theory or technique in question can be and has been tested; whether it has been subjected to peer review and publication; its known or potential error rate and the existence and maintenance of standards controlling its operation; and whether it has attracted widespread acceptance within a relevant scientific community. The majority of states' evidentiary standards are based on the *Daubert* standard.

When a party wants to prevent the introduction of scientific evidence to the jury, the party will file a motion *in limine* before trial begins to attempt to exclude presentation of the evidence. Motion *in limine* will be discussed further in the case examples that follow.

In the following section, we will discuss specific case examples in which an evidentiary challenge has arisen to

admission of functional brain imaging data. The following case examples were obtained through a search of the medical literature and court documents. No individual discussed below was clinically evaluated by the authors.

### **Pre-trial, competence to stand trial**

A defendant must possess a rational and factual understanding of his charges and the legal process, and he must be able to communicate with counsel to be competent to stand trial (*Dusky v. U.S.*, 1960). Mental illness, brain injury, dementia, and mental retardation can significantly affect these abilities. If a defendant is found incompetent to stand trial, the trial is delayed until the defendant becomes competent to respond to the charge. However, there are some conditions that cannot be remedied and therefore neither the passage of time nor treatment is likely to restore competence. In these cases the prosecutor may choose not to pursue certain charges or may commit a defendant to a mental facility to attempt restoration of competence. The U.S. Supreme Court established the current legal standard for determining competency to stand trial in *Dusky v. United States* (1960), and subsequently every jurisdiction has adopted this standard into their competency statutes. The issue of the ultimate fate of incompetent defendants was not addressed until several years later. In *Jackson v. Indiana* (1972), the Supreme Court held that a defendant committed to a mental facility solely on the basis of incompetency “cannot be held more than the reasonable period of time necessary to determine whether there is a substantial probability that he will attain that capacity in the foreseeable future.” Physicians will be asked to predict whether a defendant’s competence to stand trial can be restored. There will be cases in which it will be clear to a reasonable degree of medical certainty that capacity cannot be restored. In some cases functional imaging may be part of the medical work up to determine the severity of a brain-based cause for incompetence.

Consider the case of a person with dementia. Use of structural MRI and PET is commonly used clinically to confirm the presence of degenerative brain disease (Desgranges et al., 2002; Ishii et al., 2001; Jeong et al., 2005; Juh, Kim, Moon, Coe, & Suh, 2004; Newberg & Alavi, 2005). Conditions such as Alzheimer's disease, frontotemporal dementia (Pick's Disease) and Parkinson's disease are irreversible and incurable. While medications may slow the progression of these diseases, patients are not expected to improve from cognitive deficits caused by these illnesses. In cases where cognitive decline is present and a person is unable to work with their defense attorney, a finding of incompetence to stand trial is possible. Depending on the severity of the crime the prosecuting attorney may require more evidence to support the alleged irreversible diagnosis.

Vincent Gigante, an alleged mafia boss, was found guilty of a number of federal criminal charges including conspiracy and racketeering. Mr. Gigante was examined by several psychiatrists who found that he suffered from dementia on clinical examination. A PET study was submitted in support of this finding. Mr. Gigante claimed that he was incompetent to be sentenced due to his dementia. The court admitted the PET evidence but declined to rely upon it. The court noted that the scan was of "excellent technical quality but [offered] a number of difficulties in interpretation." Specifically the court was concerned that the controls in the study were not treated with the same psychotropic drugs that Mr. Gigante was prescribed, including chlorpromazine, nortryptiline, diazepam, temazepam, and flurazepam. The court noted that if Mr. Gigante were taking these medications, they would have a profound effect on the PET metabolic images; however, it was impossible to say what the combined effect would be. Ultimately, Mr. Gigante was found competent for sentencing and was sentenced to 12 years in federal prison in 1997.

In 2011, California capital murder defendant Miguel Carrizalez offered a PET study to support his claim that he was incompetent to stand trial. A Kelley-Frye hearing was held and the study was admitted into evidence. The judge stated that PET studies are “generally accepted in the scientific community and ... are certainly accepted as tools used in clinical settings. And in forensic settings it seems ... there could be testimony as to the areas of the brain that are relevant to the issue of [trial competency]” (*California v. Carrizalez*, 2010).

### **Plea bargaining**

Likewise, in some cases evidence of a medical illness or explanation for criminal behavior can lead prosecutors to offer a plea bargain when they may not have done so without this evidence. Consider the case of Herbert Weinstein, a 65-year-old man who strangled his wife to death in their Manhattan apartment and then threw her body out of their 12th story apartment window. Weinstein was promptly arrested and charged with 2nd degree murder, which carries a sentence of 25 years to life in prison. PET was performed and showed a large arachnoid cyst pressing on the brain and immensely altering the expected glucose uptake. The prosecution tried to prevent evidence of the arachnoid cyst from being admitted at the 1992 trial, as the technology was new and not widely accepted (*People v. Weinstein*, 1992). The judge ruled that the defense could show the brain scans with the cyst but would not allow the defense witnesses to tell jurors that arachnoid cysts were associated with violence (Rosen, 2007). Shortly after the ruling on the admissibility hearing, the prosecution offered Weinstein a plea bargain in which he pled guilty to manslaughter, which carried a sentence of 7 to 21 years in prison.

## **Guilt phase**

When nuclear images are admitted into evidence to prove a *prima facie* element of the crime, namely *mens rea*, admissibility challenges are more likely to arise. Challenges are less likely to prevail if the incomplete defense of diminished capacity or a variant thereof is at issue. When a defendant raises a diminished capacity defense it is to suggest that he was deprived of a normal level of mental wherewithal. Not every state employs this partial defense. In states that do, it can function to reduce the charge of the offense and could be thought of as a non-plea-bargain way to receive a discounted sentence. For example a finding of diminished capacity could reduce a murder charge to manslaughter. In contrast, a finding of insanity is a complete defense to a crime and will result in a finding of “not guilty by reason of insanity” (NGRI). SPECT has been used to support a claim of “diminished actuality” (similar to diminished capacity) in a California murder trial (Sneed, 2006). Mr. Peter Chiesa was a 65-year-old man with multiple medical problems including vascular dementia, epilepsy, strokes, and a complicated coronary artery bypass surgery. Chiesa called 911 informing police of his plan shortly before he shot and killed two female neighbors in 2002. The defense used SPECT to illustrate to the jury how Mr. Chiesa's brain was “misshapen” and “contained holes” to argue against a premeditated first degree murder charge. The jury did find diminished actuality and Mr. Chiesa was convicted of two counts of second degree murder (Lasden, 2004).

To defeat an admissibility challenge, functional brain imaging must demonstrate information that is not otherwise available to the clinician. In *People v. Goldstein* (2005), the defendant Goldstein pushed a woman in front of an oncoming subway train, killing her. All parties agreed that defendant Goldstein had schizophrenia. PET was offered by a defense expert witness to show that Goldstein's brain imaging was consistent with schizophrenia. As PET was not



offered to further probe into the impact of schizophrenia on the defendant's cognition and behavior, it was excluded from evidence (Moriarty, 2008).

An expert's attempt to introduce functional imaging for novel purposes, or in ways that are not standard in clinical medical practice, can be risky. In *Jackson v. Calderon* (2000), the court stated that PET is not a generally accepted tool used to diagnose chronic PCP use and excluded the evidence. In *United States v. Mezvinsky* (2002), PET was not admitted into evidence as the expert planned to use it to show that the defendant, a former congressman charged with 66 counts of fraud, was incapable of deception, an element necessary to prove fraud. In these cases the court opined that the relevance of the evidence was outweighed by its capacity to mislead the jury.

In most death-penalty sentencing cases any evidence likely to persuade the jury to take mercy on the defendant is admitted and nuclear studies of the brain, such as PET or SPECT, are almost always admitted at sentencing when offered by the defendant. However, in the case of capital defendant Lisa Montgomery, PET was not admitted. We surmise that the attempt to admit PET during the guilt phase of the trial excluded its use in sentence mitigation.

Lisa Montgomery had an online friendship with her pregnant victim Bobbie Jo Stinnett. The two had engaged in email exchanges about their respective "pregnancies." Montgomery arranged to meet Stinnett and buy a puppy from her. Montgomery strangled the expectant mother, performed a cesarean section and kidnapped Stinnett's premature baby. Stinnett died but her premature daughter survived. Montgomery crossed state lines with the baby, making her crime a federal offense. In Montgomery's defense, expert witnesses planned to testify that Montgomery suffered from pseudocyesis, or false pregnancy, which could have led to a diminished capacity

finding. Pseudocyesis is a psychiatric condition listed in the DSM IV Somatoform Disorder Not Otherwise Specified (DSM-IV-TR 300.82) (American Psychiatric Association, 2000). While pseudocyesis has long been hypothesized to be caused by an imbalance in pituitary-ovarian function and dysregulation of the hypothalamus (Brown & Barglow, 1971), neuroimaging confirmation of such dysregulation is virtually never sought in clinical practice.

Though Ms. Montgomery's PET did indeed show increased activity in the hypothalamus, the scan was deemed inadmissible. On appeal the court considered whether Ms. Montgomery was harmed by the failure of PET admission during the guilt phase of her trial. The court stated "The PET scan was not used as a diagnostic aid for pseudocyesis, and as conceded by [defense expert witness], the abnormalities do not predict behavior and they did not cause Montgomery to commit the crime. Accordingly, any error in excluding the evidence that Montgomery's PET scan showed abnormalities in the limbic and somatomotor regions of the brain was harmless" (U.S. v. Montgomery, 2011).

## **Sentencing**

In *Lockett v. Ohio* (1978), the Supreme Court decreed that a defendant facing the death penalty is entitled to present any aspect of character or record, and any circumstance of the offense that might serve as a basis for a sentence less than death, regardless of whether the evidence supports a statutorily authorized mitigating factor. In *Tennard v. Dretke* (2004) the Supreme Court stated that any cognitive or neuropsychological impairment may be considered a mitigating factor even if the impairment bears no direct link with the homicidal behavior. Evidence of a structural or metabolic brain abnormality could be included as evidence of a severe mental disturbance, a prong that most states and the federal government include as a mitigating factor in the

death penalty statute. Further, most states allow a defendant to present any “other factor” in the defendant's background, record, or character or any other circumstance of the offense that mitigate against imposition of a death sentence (18 U.S.C. § 3592 (1994)). Evidence of brain damage or brain dysfunction can be offered under the other factor prong as well. Functional images of the brain are commonly admitted in death penalty litigation to demonstrate brain abnormalities that a jury could find mitigating (Sneed, 2006).

## Appeal

If an attorney fails to present mitigating evidence including evidence of mental illness or extreme emotional distress, a case can be remanded for ineffective assistance of counsel. The U.S. Supreme Court established a two-part test for ineffective assistance of counsel in *Strickland v. Washington* (1984). A case may be remanded if a criminal defendant can show that counsel's performance fell below an objective standard of reasonableness, and that counsel's performance gave rise to a reasonable probability that, if counsel had performed adequately, the result of the trial or sentencing would have been different.

Defendant Fernando Caro's death sentence was vacated and remanded for retrial in California, because his attorney failed to investigate and present evidence of the impact that exposure to neurotoxicants and child abuse had on his brain (*Caro v. Calderon*, 1999). The court stated that attorneys must cast a wide net for all relevant mitigating evidence at capital sentencing hearing because “the Constitution prohibits imposition of the death penalty without adequate consideration of factors which might evoke mercy” (p. 1227). In detailing the sort of evidence that should have been considered, the court does not state that neuroimaging is needed. Rather, it gives an extensive list of circumstances that were likely to lead to brain damage, including that Caro

spent his childhood working and playing in pesticide-soaked fields; that he bathed in and was fed food cooked in water contaminated with pesticides. The court notes that Caro worked as a “flagger” for a crop-dusting company and at a company that made toxic pesticides. He was regularly exposed to organophosphates, solvents, organochlorines, and carbamates, and he was poisoned by a number of toxic chemicals at the plant. In addition, Caro has suffered serious physical abuse and head injuries. Both parents beat Caro throughout his childhood, hitting him with closed fists, sticks, belts, work boots, and tools. Caro also sustained several head injuries as a child: he was born with a three inch lump on his head due to the use of forceps during his difficult delivery; a water cooler fell on his head at the age of three; and he was hit by a car later that year. If brain damage resulted from these multiple neurologic insults, the damage could be demonstrated with PET or SPECT. In *Caro*, the court suggests that it is adequate for counsel to obtain a corroborated injury history listing factors that led to demonstrated cognitive impairment. *Caro* does not penalize counsel for failing to obtain or present neuroimaging; however, other cases have (*Hoskins v. State*, 1997; *Smith v. Mullin*, 2004).

SPECT has been used as mitigating evidence in criminal trials for capital murder. In *Smith v. Mullin* (2004), the court ordered a resentencing hearing for Mr. Smith, a man found guilty and sentenced to death for murdering his wife and her four children from a prior relationship. The court found that the defendant was prejudiced by his counsel's failure to present evidence of his cognitive abilities and brain damage. The court noted that evidence of his brain damage was shown in SPECT authorized by the court, but not raised by counsel in the original trial.

In Florida, defendant Hoskins challenged the trial court's judgment convicting him of multiple felonies, including first-degree murder, as well as the imposition of the death

sentence (*Hoskins v. State*, 1997). Mr. Hoskins had an IQ of 71 and an examining physician recommended that PET be ordered as part of the work-up for brain damage. The trial court refused to grant defendant's motion seeking transport to a hospital to have a brain scan performed. This denial limited his defense expert's ability to evaluate the degree of his mental impairment, which is a statutory mitigating factor under Florida law (Fla. Stat. Ann. §921.141 (1995)). The appellate court remanded the case, ordering that a brain scan be obtained and consideration of a new penalty phase, in effect overturning Hoskins' death sentence.

The decision in this case has led attorneys to seek nuclear medicine studies for many death eligible defendants in Florida. When an attorney requests a nuclear scan, the role of the expert remains the same—to evaluate the defendant for symptoms and medical history that would spark clinical suspicion for brain damage. We discourage experts from issuing prescriptions for nuclear medicine studies without first evaluating the patient and from offering explanations for an abnormal study result without obtaining clinical history.

Francis Hernandez' death sentence was vacated because his attorney failed to consult a neurologist, neuropsychologist or neuropsychiatrist, or to arrange for a neurological examination of petitioner, despite the fact that he wrote notes in his legal file suggesting that he planned to do so. On appeal the lawyer stated that “evidence of neurological impairment is the type of evidence I wanted because it would have helped to explain and mitigate Francis's state of mind at the time of the killings” (*Hernandez v. Martel*, 2011).

### **Civil liability: Torts**

SPECT is commonly utilized in “toxic tort” cases, in which a plaintiff claims brain damage due to chemical exposure, as well as in personal injury litigation, such as in a claim of

brain damage following an automobile accident. Many plaintiffs have been successful in introducing SPECT into evidence even when admissibility was subject to a *Daubert*, *Frye*, or other scientific evidentiary challenge.

In *Penney v. Praxair* (1997), a personal injury case, the defense presented evidence that PET results can be affected by a person's age, medical history, and medications. The plaintiff Mr. Penney was a 66-year-old man with cardiac issues. Mr. Penney's scan was compared to a control group consisting of 31 individuals ranging from 18 to 70-years-old. The court felt that the control groups' wide age range was not an accurate comparison for the brain metabolism of the 66-year-old plaintiff. Further, Mr. Penney was taking his regular dose of heart medications at the time of the PET. The court acknowledged that it was not clear whether the medication impacted the results, but found that the plaintiff had failed to carry his burden of establishing a reliable foundation for his PET reading compared to controls, who were not taking medications. PET was not admitted into evidence.

SPECT has been used to support the presence of brain injury in toxic tort cases. In determining whether or not to admit a nuclear medicine study into evidence, the judge will determine whether the evidence is likely to assist the jury in determining a fact in issue during the trial. In *Rhilinger v. Jancsics et al.* (1998), the issue before the court was whether Ms. Rhilinger sustained brain injury after exposure to fumes emanating from chemicals stored in the basement of her apartment building. A motion *in limine* sought to exclude admission of SPECT into evidence. The judge stated that there was no dispute that SPECT can show abnormalities in brain function. He acknowledged that there is no dispute that SPECT cannot conclusively establish the existence or nonexistence of toxic solvent encephalopathy in a patient. The judge emphasized that the plaintiff's experts did not opine that SPECT did, in fact, establish the

diagnosis of toxic solvent encephalopathy, but that SPECT was a tool that could be used to investigate this claim. SPECT was admitted into evidence.

Likewise, in *Fini v. General Motors Corp. et al.* (2003), the court concluded that the use of SPECT may have important implications for classification and management of patients with mild head trauma, such as closed head injury, providing "clinical correlation" for the physical examination. In Ms. Fini's case, SPECT was used to show "massive frontal lobe brain damage" sustained in a motor vehicle accident.

In contrast, in *Summers v. Missouri Pacific Railroad System* (1995), the court did not admit SPECT into evidence in a Federal Employers Liability Act case where plaintiffs were railway workers exposed to diesel exhaust fumes. The plaintiffs were diagnosed with "chemical sensitivity," an injury to the central nervous and respiratory systems. SPECT was offered to support the diagnosis. The defense raised a *Daubert* objection claiming that the true diagnosis of plaintiff's expert is "multiple chemical sensitivity," a diagnosis which is not supported by sound scientific reasoning or methodology, and which should be excluded under *Daubert*. The defense was persuasive in its argument, and SPECT was not admitted into evidence.

Further, an expert's testimony and nuclear medicine study are likely to be excluded if the expert overstates the causal links that can be inferred. In the case of *Palazzolo v. Hoffman la Roche Inc.* (2010), a products liability case, the plaintiff's expert witness claimed that PET could provide evidence linking a patient's depression and subsequent suicide to a medication, Accutane, that the patient used to treat his acne. Prior to trial, plaintiffs and defendants had stipulated that PET was not a tool used in the diagnosis of depression. As the expert's line of reasoning was in conflict with the stipulation, PET was excluded from evidence.

Nuclear studies are also increasingly being admitted into evidence in civil trials where brain injury is claimed. In fact, there have been cases in which litigants may have been penalized for failing to undergo nuclear studies. *Harris v. U.S.* (2005) was brought by a law student, who was struck by a U.S. Postal Service truck while driving to his law school final exam. He filed a claim under the Federal Tort Claims Act asking for damages based on his diagnosis of mild traumatic brain injury (TBI) resulting from the accident. The court noted that although PET or SPECT could be used to confirm a diagnosis of mild TBI, Harris had not offered either as evidence of his injury. In part due to the lack of neuroimaging evidence, the court found that the plaintiff failed to prove that he suffers from continued cognitive impairment as a result of the accident. The case illustrates the courts' fear that a sophisticated plaintiff could "fake" a neurocognitive deficit on clinical interview and on pen-and-paper-based tests. In *Harris* it appears that the court assumes that it would be difficult or impossible to manipulate brain blood flow and metabolism during a nuclear study, therefore making malingering less of a risk if a scan supports a clinical suspicion of brain damage.

## **Conclusion**

Nuclear medicine studies can assist the court by allowing it a view of the inner working of the brain of the plaintiff in civil trials or the defendant in criminal trials. This view is not given the same level of relevance in every court phase. As discussed above, the Supreme Court has determined that a defendant's cognitive and neuropsychological limitations must be considered in all death penalty cases. Failure to present evidence of brain damage has been a factor in overturning death sentences as evidence of brain damage could assist a jury in understanding the defendant's limitations and could result in a sentence other than death. PET and SPECT can demonstrate functional abnormalities



in brain metabolism. As such, brain imaging introduced as mitigating evidence during the sentencing phase of a capital murder trial is unlikely to face an admissibility challenge. However, the judge may exclude functional brain imaging during the guilt phase of the trial if he or she believes that the expert will use the evidence to mislead the jury.

Presentation of brain imaging studies during the guilt phase of a criminal trial is more likely to evoke an evidentiary challenge. Nuclear studies cannot assist the trier of fact in determining whether the defendant committed the act in question. Similarly, brain images will be unable to assist in detailing the mindset of the defendant at the time of the crime with a few important exceptions. A brain study can demonstrate structural abnormalities such as cysts, tumors, strokes, and tissue atrophy that could lead to functional deficits and as such reduce the defendant's capacity for self-control. Diminished capacity for self-control is not a complete defense to a crime, but will decrease criminal culpability and the associated penalty.

Brain damage is a common claim in civil trials. PET and SPECT are generally admissible to support claims of brain damage. However, when claimed injuries are not injuries which have well-accepted imaging characteristics, it will be difficult to overcome an admissibility challenge. As discussed earlier in the article, to withstand a Frye challenge the specific type of a nuclear medicine evidence (i.e., 18-FDG-PET, Tc99m ECD-SPECT, etc.) must be "generally accepted" by the relevant medical community as a means for evaluating the disease or disorder in question. To withstand a *Daubert* challenge, in addition to widespread acceptance within a relevant scientific community, the method must have a known error rate and be scientifically tested with results reported in peer-reviewed publications. In cases involving brain damage secondary to trauma or toxic exposure, plaintiffs are likely to overcome evidentiary challenge to nuclear medicine evidence, because of the preponderance of available medical

data. When the injury claimed involves a syndrome with less peer-reviewed data available, evidentiary challenges are more likely to prevail until additional data become available to support or reject the diagnostic relevance and validity of a specific nuclear medicine study for the syndrome in question. The legal and forensic community should strive to increase its knowledge of and involvement with the continued improvement of the diagnostic nuclear medicine imaging that could serve the purposes of justice.

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