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Imaging the Mind, Minding the Image: An Historical Introduction to Brain Imaging and the Law

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I. INTRODUCTION

Since ancient times, people have yearned to attribute human behaviors to a physical source within the head. Recently, neuroimaging technologies have given us the technical ability to look at the living brain, its structures, and some of its functions without the need for invasive procedures. However, the science has a long way to go before these technologies can allow us fully to appreciate the anatomical and physiologic underpinnings of human thoughts, states of mind, motives, will, or behaviors.

In this Article, we use an historical overview to introduce the various new technologies for imaging the brain. Today, the goal of medical science is the same as it has always been: to make medical technologies valid, useful, effective, and safe; and to guide appropriate uses while protecting the public from the misuse of them. Brain images are particularly vulnerable to misuse because they are so visually attractive. This visual power can easily result in misunderstanding about what the images show and what they mean. History shows, however, that legitimate science and unfettered showmanship have always proceeded on parallel tracks. Currently, there is great need for guidance on the appropriate uses of brain imaging within medicine, but also in fields outside of medicine, and particularly in the courtroom in aid of judges who must determine whether the images, and expert testimony about them, can be admitted into evidence. In Part II of this Article, we discuss the discovery and growth of these technologies. In Part III, we discuss some of the dilemmas that have been raised by the use of brain imaging in the courtroom, highlighting criminal cases in which the outcome was strongly swayed by jurors who misinterpreted the meaning of the images. We argue that brain images be admitted into evidence only for the purpose of linking a structural abnormality to a specific deficit, and that functional brain images not be admitted for the purpose of establishing responsibility for, motivation for, or propensity to commit a particular behavior, or to show an inability to

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control a particular behavior. For example, the current use of fMRI findings to establish the cause of certain behaviors, or responsibility, motivation, or propensity for them, is premature and ignores the complexity of brain function. Indeed, given the current state of medical and scientific knowledge about the brain, once admitted as evidence, the courtroom is an inadequate forum for determining the "truth" of such evidence. The importance to judges of obtaining careful scientific guidance on these technologies cannot be understated, and we argue that professional medical societies could provide invaluable assistance by issuing guidance for judges faced with the task of evaluating the evidentiary value of brain images and the testimony of the expert witnesses who will interpret them. In Part IV, we conclude that a body such as the Institute of Medicine could serve the courts and the public by conducting periodic reviews of current brain imaging research, convening scholarly committees to consider various uses and needs for the technology both within medicine and in related fields. We further suggest that the President's Council on Bioethics continue to serve an educational role as a multidisciplinary advisory body on these issues, and as a forum and resource to the public on the ethical issues raised by the use of these technologies.

II. IMAGING THE MIND: A BRIEF HISTORY OF BRAIN IMAGING

What is Mind?
It does not Matter.
What is Matter?
Never Mind!

-Anonymous

Since antiquity, scientists have searched for the source of our reason, emotions, and behavior. Hippocrates, a trained Pythagorean, chose the head as the place where reasoning resides because it resembled a globe—the ideal geometric shape.[1] Observing that patients with depressed skull fractures had convulsions, Hippocrates hypothesized that certain behavioral disorders were influenced from the head. Indeed, his observations that the convulsions occurred in the body side opposite to the side of the head injury led to the beginning of the principle of "cruciate conduction" (meaning that the right side of the body controls the left side, and vice-versa) in the nervous system.[2] People, however, have always viewed the issue of how the brain relates to the mind through their understanding of the science of their time. In Hippocrates' time, aqueducts were the predominant mode of transport for water. Thus, it is not surprising that cerebral spinal fluid and the ventricles of

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[1] Shahram Khoshbin, M.D. (notes on file with the author). *See* LOUISE H. MARSHALL & H.W. MAGOUN, DISCOVERIES IN THE HUMAN BRAIN: NEUROSCIENCE PREHISTORY, BRAIN STRUCTURE, AND FUNCTION 27 (1998) (quoting HIPPOCRATES, THE GENUINE WORKS OF HIPPOCRATES 334 (Francis Adams trans., Charles Darwin ed., Dover 1868) ("[From the brain] come joys, delights, laughter and sports, and sorrows, grief, despondency, and lamentations. And by this, in an especial manner, we acquire wisdom and knowledge, and see and hear, and know what we fail and what are fair.").

[2] Loannis G. Panourias et al., Hippocrates: A Pioneer in the Treatment of Head Injuries, 57 NEUROSURGERY 181, 188 (2005).

the brain became the focus of their studies.[3] This spawned the "cell theory," which held that the ventricles were the source of brain function.[4] (Interestingly, the first modern neuroimaging technology would outline the ventricles (ventriculography)).

With the Renaissance came a new understanding of human anatomy, including that of the brain. The exquisite drawings of Vesalius (1514-1564) in his book, *De Humani Corporis Fabrica Libri Septum* (*De Fabrica*), were responsible for raising additional interest in brain structure.[5] Rene Descartes (1596-1650) took these developments one step further when he described the human body and brain as a machine.[6] He placed the soul/mind in the only brain structure that is unitary and not doubled—the pineal gland.[7] He envisioned the cortex ("bark") as a shield that encapsulates the pineal and protects it.[8] His theory of the brain as a machine was based on the principles of hydraulics.[9] He posited a mind that works in synergy but is physically separate from the body: a non-material "ghost" in the machine.[10] He recognized, however, that his model was insufficient. He wrote: "even a complete understanding of the brain will not bring a complete understanding of behavior."[11] Still, the mind-body dichotomy persists in modern thought, as does interest in correlating brain structure with human behavior. Indeed, there is an old maxim in medical lore that still holds true: philosophers and neuroscientists do the same thing—philosophers look at their own brains while neuroscientists look at other people's brains.

Following Descartes, seventeenth- and eighteenth-century interest in the attributes of the face and head gave rise to the fields of physiognomy and phrenology. Physiognomy was popularized by the works of philosophers like Johan Kasper-Lavater (1714-1801),[12] (and later by the nineteenth century work of Cesare Lombroso (1835-1909) in his book, *L'uomo Delinquente* (*The*

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[3] MARSHALL & MAGOUN, *supra* note 1, at 27-32 (discussing the focus on ventricles from the fifth century B.C. to the eighteenth c. A.D.). The authors note the writings of Poseidolonius, a Byzantine surgeon of the fourth century B.C., whose observations led him to conclude that damage to the ventricles could result in changes in mental function. *Id.* at 28.

[4] *Id.* at 41. *See* RONALD L. EISENBERG, RADIOLOGY: AN ILLUSTRATED HISTORY 326-331 (1992) (describing Walter Dandy's work).

[5] These drawings are a testament to his fascination with the brain. *Id.* at 30 (noting that Vesalius rejected the medieval view that the ventricles were the site of the soul, and instead posited that the brain was the "main organ of intelligence, movement, and sensation."); *see also* MARSHALL & MAGOUN, *supra* note 1, at 63 (noting that Vesalius was responsible for the trend toward brain tissue, rather than brain water (ventricles), as the source of thought).

[6] EISENBERG, *supra* note 4, at 31, describing Descartes' writings about the effect of movement of ventricular fluid on the pineal gland; *see also* Renato G. Mazzolini, *Schemes and Models of the Thinking Machine (1662-1672)*, *in* THE ENCHANTED LOOM: CHAPTERS IN THE HISTORY OF NEUROSCIENCE 70-71 (Pietro Corsi ed. 1991).

[7] EISENBERG, *supra* note 4, at 31; *see also* Mazzolini, *supra* note 6, at 71-143.

[8] EISENBERG, *supra* note 4, at 31.

[9] Mazzolini, *supra* note 6, at 71 (describing Descartes' hypothesis that all mental faculties are the result of the interaction of flowing "spirits" within the ventricles with the soul).

[10] *Id.*

[11] *Id.*

[12] Claudio Pogliano, *Between Form and Function: A New Science of Man*, *in* THE ENCHANTED LOOM: CHAPTERS IN THE HISTORY OF NEUROSCIENCE 144-203 (Pietro Corsi ed. 1991).

Criminal Man)).[13] Physiognomy, the study of the shape of the body, head and face, raised questions about the possible biological basis of many behaviors, including criminality.[14] It attributed features of the head and face to not only aberrant behavior, but also to intelligence.[15]

Phrenology was a major subsequent development that began with the work of Franz Joseph Gall (1758-1828) and Joahanne Casper Spurzheim (1776-1832).[16] Their work correlated brain functions and character traits with protuberances on the skull, and generated much popular interest.[17] Gall spent considerable time studying criminals, parricide, cruelty, and sadism.[18] He and other like-minded scientists attempted to confirm their hypotheses by studying sculptures and paintings of famous criminals.[19] Soon, the field of cranioscopy (literally, "looking at the skull"), like physiognomy, became a standard in criminology. The work of phrenologists informed the work of scientists such as Pierre Paul Broca (1824-1888).[20] Broca is credited with discovering the area of the brain responsible for language while studying a patient named Leborgne (known in medical literature as "Tan"), who died in April 17, 1861.[21] This and other discoveries led to the era of localization. Soon afterward, the German neurologist Carl Wernicke (1848-1904) first posited that there are "centers" in the brain, and this became known as localization theory.[22] Of course, scientists who believed in a more "holistic" model of brain function criticized the localization theorists. Major neurologists such as John Hughlings Jackson (1835-1911) criticized the "centers" theory as too simplistic.[23] Jackson proposed a hierarchical system subserving most behavior function.[24] However, the concept of localization underlies the use of brain imaging techniques to this day.[25] Also, as recently as the early twentieth century, major research was still being directed toward finding a biological source of criminality and a correlation between criminality and the physical appearance and shape of criminals' heads. This included a large study by the Harvard scientist Ernest Hooton, who published a book on the American criminal in 1939.[26]

In 1895, Wilhelm Konrad Roentgen (1845-1923) revolutionized all of

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[13] Adalbert Albrecht, *Cesare Lombroso: A Glance At His Life's Work*, 1 J. AM. INST. CRIM. L. & CRIMINOLOGY 71, 71-72 (1910).

[14] *Id.* at 72.

[15] *Id.* at 74.

[16] MARSHALL & MAGOUN, *supra* note 1, at 51 (Gall); Pogliano, *supra* note 12, at 152 (Spurzheim).

[17] MARSHALL & MAGOUN, *supra* note 1, at 52.

[18] *Id.*

[19] Pogliano, *supra* note 12, at 154 (describing Gall's extensive collection of skulls and casts).

[20] MARSHALL & MAGOUN, *supra* note 1, at 66-67.

[21] *Id.*

[22] *Id.* at 69 (discussing Wernicke's discovery of the locus of speech).

[23] *Id.* at 71.

[24] *Id.*

[25] An example is functional magnetic resonance imaging (fMRI), a technique that attempts to elucidate "regions of interest" (ROI) based on the lesion method. G. Fernandez et al., *Intrasubject Reproducibility of Presurgical Language Lateralization and Mapping Using fMRI*, 60 NEUROLOGY 969, 969 (2003).

[26] H. L. Shapiro, *Earnest Albert Hooton 1887-1954*, 56 AM. ANTHROPOLOGIST 1081 (1954), *available at* http://www.aaanet.org/gad/history/083hootonobit.pdf.

medicine with his dramatic discovery of the X-ray.[27] The medical importance of his discovery was apparent almost immediately: it was now possible to see physical structures within the body without surgery.[28] Within months, Roentgen became a world phenomenon.[29] His discovery inflamed competition on this side of the Atlantic. In order not to be left behind, William Randolph Hearst cabled Thomas Edison on February 5, 1896: "Will you as an especial favor to the Journal undertake to make cathodograph of human brain kindly telegraph answer at our expense."[30] Edison agreed, becoming the first person to attempt imaging the brain. Promptly, in his own inimitable style, Edison cleared his calendar and dedicated his entire laboratory to picturing the brain.[31] However, he quit just nine days later on February 14, 1896.[32] This may have been because he recognized the dangers of radiation.[33] Edison told the New York Daily Tribune that he doubted his attempts to image the brain would be successful: "[T]he bony structure of the cranium would offer insuperable obstacles."[34]

Meanwhile, the technology for illuminating structures in the body continued to explode, partly because of the technical ease of producing X-rays. In November 1896, Harvey Cushing (1869-1939) produced an X-ray of a bullet that had lodged in a patient's neck.[35] Later, Cushing also demonstrated calcification in the brain of a patient with Sturge-Weber disease; a fact probably not lost on President Eliot of Harvard who had Sturge-Weber Syndrome and who recruited Cushing from Hopkins to become a professor of surgery at Harvard.[36] The next 20 years were devoted to work on x-ray images of the brain, during which time the field was led by Arthur Schuller (1874-1957).[37] Walter Dandy (1886-1946), a neurosurgeon at Johns Hopkins, introduced air into the ventricles of the brain and invented ventriculography, after learning from his teacher William Halsted (1851-1922) that gas in the

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27 EISENBERG, *supra* note 4, at 323.

28 *Id.*

29 Roentgen was born on March 27, 1845. *Id.* at 32. He died on February 10, 1923. *Id.* at 38. He discovered the X-ray at 23. *Id.* at 28-32. He prepared a manuscript on his discovery for the Wurzburg Physical Medical Society on December 28, 1895, copies of which he sent to well-known colleagues. *Id.* at 28. By January 6, 1896, the news was already being published, along with commentary on its medical significance. *Id.* at 28-29.

30 EISENBERG, *supra* note 4, at 323 (quoting E. BRECHER & R. BRECHER, THE RAYS: A HISTORY OF RADIOLOGY IN THE UNITED STATES AND CANADA (1969)).

31 BETTYANN H. KEVLES, NAKED TO THE BONE: MEDICAL IMAGING IN THE TWENTIETH CENTURY 36 (1997) (quoting Arthur Fuchs, *Edison and Roentgenology* 57, No. 2 146 (1947)).

32 *Id.* at 36.

33 *Id.* at 38 (noting that Edison became wary, and stopped experimenting with X-rays himself, when he noticed some "reddening around his own eyes" and "strange pitting on his assistant's skin"); *see also* Goodman, Philip C., The New Light: Discovery and Introduction of the X-ray, 165 AJR 1041 (1995) at 1045 (describing the progression of Edison's assistant's radiation burns through to the assistant's death in 1904).

34 David J. DiSantis, *Early American Radiology: The Pioneer Years*, 147 AM. J. ROENTGENOLOGY 850, 851 (1986) (quoting RUTH BRECHER & EDWARD BRECHER, THE RAYS: A HISTORY OF RADIOLOGY IN THE UNITED STATES AND CANADA (1969)).

35 EISENBERG, *supra* note 4, at 323-324.

36 *Sturge-Weber Syndrome*, 3 PEDIATRIC & DEVELOPMENTAL PATHOLOGY 301 (2000).

37 Schuller was a Viennese physician who is considered to be the "father of neuroradiology." EISENBERG, *supra* note 4, at 324-325 (citing W.F. Manges, *Roentgenographic Pelivimetry*, 65 AM. J. OBSTETRIC GYNECOLOGY 622-23 (1912)).

intestines can act as a "contrast" in abdominal X-rays.[38] Dandy later developed pneumoencephalography by introducing air into the subarachnoid space in the skull in order to outline the brain itself.[39] Because the pneumoencephalographs he produced showed the outlines of the ventricles and the surface of the brain and cisterns, neuroscientists consider them to be the first modern neuroimages.[40] Egaz Moniz (1874-1955), who had won the Nobel Prize for his work on frontal lobectomy, discovered that sodium iodide could be used to illuminate blood vessels for X-ray.[41] In his presence, Moniz's student performed the first arteriogram/angiogram of the brain in 1927, as Moniz suffered from gout, and the pain prevented him from performing the procedure himself.[42]

Technecium scanning, another technique for imaging brain circulation, followed. George Moore, a young Minneapolis surgeon, was aware of the ability of the thyroid gland to absorb radioactive iodine, and he wondered if the brain would do the same.[43] That technique involved using a Geiger counter ("gamma camera") and radioactive iodine.[44] Its discovery gave rise to a number of similar scanning technologies involving such "gamma cameras" in the 1960s, including xenon inhalation (isotope xenon 133) brain-blood flow imaging.[45] Two modern imaging techniques owe their origins to the combined use of the "gamma camera" with such radioactive tracers: (1) single photon emission computed tomography (SPECT), and (2) positron emission tomography (PET).[46] PET involves an injection of radionucleide (radio-isotope).[47] The resulting ligands then attach to different neuro-transmitters. PET is used for viewing the metabolism of glucose within the brain.[48] SPECT involves the use of gamma-ray-emitting radioisotopes to measure cerebral blood flow.[49] PET and SPECT were standard for functional imaging, until fMRI came into use.[50]

The keystone discovery in the quest of brain function was the development of the encephalograph, which made it possible to record the electrical activity of the brain. Hans Berger (1873-1941), a psychiatrist in Jena, Germany, made the first recording of electrical brain activity (electroencephalography, or EEG) just after WWI.[51] Soon afterward, as technology improved and powerful amplifiers became available, it became possible to record electrical brain activity from multiple sites over the scalp.[52]

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38 *Id.* at 326-329.

39 *Id.*

40 *Id.* at 329.

41 *Id.* at 337.

42 *Id.*

43 *Id.* at 339.

44 *Id.* at 339-340.

45 *Id.* at 340.

46 *Id.* at 427.

47 *Id.*

48 *Id.*

49 *Id.* at 428.

50 PET and SPECT have several problems; including susceptibility to artifacts, because the scanning takes a long time and the radioligands used do not distribute evenly in the brain. However, in combination with other techniques, these two technologies remain very useful.

51 MARSHALL & MAGOUN, *supra* note 1, at 89.

52 *Id.* at 91.

British and American electroencelphalographers popularized EEG as a medical test.[53] In the early 1970s, physiologists would use computers and mathematical algorithms to make topographic maps of brain electrical activity.[54] These topographic maps and other technologies resulted in the development of quantitative EEG or "QEEG," which allowed study of one brain map as well as a comparison of the maps of individual patients with groups of patients.[55]

The invention of the analog-to-digit converting machine in 1959 made it possible for George Dawson to separate background activity from the signals produced when the brain was stimulated ("evoked potentials"). This was the basis for the development of later technologies that used evoked potentials to map the brain's response to stimuli in addition to QEEG.

Without a doubt, the new era of neuroimaging began with the discovery of computerized axial tomography in 1972 by Godfrey Newbold Hounsfield (1919-2004) and Alan Cormack.[56] They won the Nobel Prize in 1979 for Physiology and Medicine for this discovery. The ideas that eventually culminated in the development of CT-scanning had originated in the 1950s, primarily in the work of astronomers who were trying to map sunspots using two-dimensional projections of X-rays to construct three-dimensional images, and in the work of electron microscopists studying minute viruses.[57] Radiologists using collimated (narrowed) beams of radiation and X-rays made additional contributions. It was these advances that resulted in the development of tomography, which essentially provides a view of "slices" of the brain.[58]

Alan Cormack was a South African scientist who started using a computer to develop three-dimensional images. Godfrey Newbold Hounsfield was a scientist with the Electrical and Music Industry, Limited (EMI), a London-based company best known through their association with The Beatles. (Thus, in a way, we may owe this technology to the Beatles). Both Cormack and Hounsfield immediately recognized the medical implications of their discovery. In his Nobel lecture, Hounsfield recounted the limitations of X-ray methods for brain imaging:

> First, it is impossible to display within the framework of a two dimensional x-ray picture all the information contained in the three-dimensional scene under view. Objects situated in depth, i.e., in the third dimension, superimpose, causing confusion to the viewer.
>
> Second, conventional x-rays cannot distinguish between soft tissues. In general, the radiograph differentiates only between bone and air, as in the lungs. Variations in soft issues such as the liver and pancreas are not discernible at all, and certain other organs may be rendered visible only through the use of radio-

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53 *Id.* at 90-91.

54 *Id.*

55 *Id.*

56 EISENBERG, *supra* note 4, at 467. Hounsfield and Cormack won the Nobel Prize for Physiology and Medicine in 1979 for their discoveries. *Id.*

57 *Id.* at 468.

58 *Id.* at 467.

> opaque dyes.
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> Third, when conventional x-ray methods are used, it is not possible to measure in a quantitative way the separate densities of the individual substances through which the x-rays pass. The radiograph records the mean absorption by all the various tissues which the x-ray has penetrated. This is of little use for quantitative measurements.
>
> Computer tomography, on the other hand, measures the attenuation of x-ray beams passing through sections of the body from hundreds of different angles, and then, from the evidence of these measurements, a computer is able to reconstruct pictures of the body's interior.
>
> Pictures are based on the separate examination of a series of contiguous cross sections, as though we looked at the body separated into a series of thin "slices." By doing so, we virtually obtained total three-dimensional information about the body.
>
> However, the technique's most important feature is its enormously greater sensitivity. It allows soft tissue such as the liver and kidneys to be clearly differentiated, which radiographs cannot do.
>
> It can also very accurately measure the value of x-ray absorption of tissues, thus enabling the nature of the tissue to be studied.[59]

At first, Hounsfield's goal was to detect small tumors in the body, but soon the lure of the brain led him to perform a brain scan on a patient with a frontal lobe brain tumor in 1971.[60] He did the first scan at Atkinson Morley's Hospital in London. His scanner used a rotating collimated X-ray beam.[61] It collected information with a sodium iodide scintillator detector that rotated around the patient's head, one degree at a time, for 180 degrees.[62] The EMI company showed this product in England, and it became a commercial success almost immediately.[63] In the United States, the Mayo Clinic and the Massachusetts General Hospital (MGH) each purchased one of these scanners.[64]

In July of 1974, one of the authors of this Article attended a presentation at the Peter Bent Brigham Hospital (now the Brigham and Women's Hospital, or BWH) by a radiologist from the MGH, reporting on the uses of the new imaging machine that MGH had recently acquired. As a new house officer, the significance of the day was nearly lost on the author (and on some of his colleagues). At the end of the talk, however, we noticed that a deep silence had fallen over the conference room. None of our professors were making any comments. The radiologist smiled and told the audience that he had received this very same response everywhere that he had talked about this new

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59 *Id.*

60 KEVLES, *supra* note 31, at 159.

61 *Id.*

62 *Id.* at 159-160.

63 *Id.* at 160.

64 EISENBERG, *supra* note 4, at 469-470.

technology. Then, a professor declared, "neurology will never be the same again."

Within five years, this technology produced pictures that showed us every part of the brain. They were dramatic at the time, but quite crude by today's standards. Second, third, and fourth-generation CT scanners enabled pictures with even clearer definition than post-mortem examination of the brain. Not only did CT revolutionize diagnostic neurology; it offered a way to perform non-invasive investigations in other fields of medicine. Further innovations reduced the amount of time needed for a CT scan.[65] High-speed CT scans allowed imaging of organs such as the heart.[66] Later, the ability to make thinner slices,[67] the development of "spiral" CT, and the development of three-dimensional reconstruction, further advanced the technology.[68]

CT technology also became the first target of public criticism concerning the rising cost of medicine.[69] Government agencies tried to limit the number of CT scans purchased by health centers in an attempt to rein in what they called "CAT fever."[70] However, the value of the technology was undeniable, and it was not long before the entire world, including the Nobel Prize committee, recognized that CT was a revolution that not only changed neuroscience, but the face of medicine.

Very soon, the application of nuclear magnetic resonance imaging (NMR) to brain imaging further advanced the ability to look at brain structure and pathology in an unprecedented manner. NMR is a technique for identifying constituents of a chemical by placing the chemical within a magnet and passing a radio wave through it, thereby creating another radio signal, which can be picked up by an antenna.[71] This discovery earned Edward Purcell and Felix Bloch the Nobel Prize in 1952.

NMR was primarily the domain of chemists and physicists, and originated with the work of I. I. Rabi of Columbia and Wolfgang Pauli, both Nobel laureates, who described the magnetic properties of the nuclei of elements.[72] In 1937, Rabi measured the nuclear magnetic moment or "spin" of hydrogen and coined the term "nuclear magnetic resonance."[73] Later, Edward Purcell and Felix Bloch independently invented "NMR spectroscopy," which they used to analyze chemical compounds.[74] Purcell and Bloch showed that the nuclei of elements with odd numbers of protons (such as hydrogen) align themselves when placed in a magnetic field.[75] If a radio frequency is then passed through the compound, a receiver can pick up a signal that can be quantified.[76]

A number of investigators working over a relatively short period of time helped develop NMR spectroscopy from a technique for analyzing compounds

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65 *Id.* at 470-471.

66 *Id.* at 469-470 (illustrating the application of CT scanners to other parts of the body).

67 *Id.* at 470-471.

68 *Id.* at 471.

69 *Id.* at 323.

70 KEVLES, *supra* note 31, at 167, 169.

71 *Id.* at 176.

72 *Id.* at 175-176.

73 *Id.* at 176.

74 *Id.*

75 *Id.*

76 *Id. See also* EISENBERG, *supra* note 4, at 472.

into a technique for imaging structures of the human body. Richard Ernst of Zurich won the Nobel Prize in Chemistry in 1991 for using Fourier transformation in NMR imaging.[77] Raymond Damadian, a New York physician, first utilized NMR technology in the early 1970s to show that tumor cells were different from normal tissue cells, although his technique was not an imaging technique.[78] Paul Lauterbur, a chemist who worked with NMR, did studies with irregularities in magnetic fields.[79] In 1977, Peter Mansfield of Nottingham, England, used similar technology to that used by Lauterbur, but instead of sampling one point at a time, Mansfield developed a technique for sampling one-line at a time and introduced echoplanar imaging, which made NMR imaging possible [80] These discoveries won Lauterbur and Mansfield the Nobel Prize in 2003. In the 1980s, the term "NMR" changed to "magnetic resonance imaging" (MRI) in response to public fears of a technology that might contain "nuclear" materials.[81] Further advances were made rapidly. One advance was the use of superconducting magnets, which made the test faster and more affordable.[82] Another advance was the introduction of paramagnetic contrast media.[83] Magnetic resonance visualizing of blood vessels led to the development of magnetic resonance arteriography (MRA).

The discovery of blood oxygen level-dependent imaging (BOLD) by Seiji Ogawa, a physicist at the Bell Laboratories, made fMRI possible.[84] The underlying principle here is that neurons, when activated, convert oxyhemoglobin to deoxyhemoglobin as they utilize oxygen, which can be detected by MRI to indicate an increase in neuronal activity when compared to surrounding tissues.[85] Investigators might then conclude that utilization of oxygen is linked to neuronal activity, which is linked to whatever function is under study. These advances in MRI imaging were available commercially almost instantaneously, and this allowed neuroscientists and behavioral scientists at all levels of experience to make conclusions about structure and function.[86] Indeed, immediately they started using them in a number of clinical applications, and applied them to the study of complex human behaviors.[87]

New brain imaging technologies related to MRI continue to appear. One of the most important recent discoveries is "volumetric analysis," a technique

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77 EISENBERG, *supra* note 4, at 474.

78 *Id.* at 474. Damadian's technique "stimulated more skepticism than interest because the NMR signals were extremely weak and susceptible to noise interference from a variety of sources." *Id.*

79 *Id.* at 474.

80 *Id.*

81 *Id.*

82 *Id.*

83 *Id.*

84 *New Magnetic Imaging Technique Can Show Brain Activity*, http://www.onelife.com/evolve/att.html (last visited May 11, 2004).

85 Oliver Ganslandt et al., *Magnetic Source Imaging Combined with Image-Guided Frameless Stereotaxy: A New Method in Surgery Around the Motor Strip*, 41 NEUROSURGERY 621 (1997).

86 *See id.*

87 *See* Jani P.A. Katisko & John P. Koivukangas, *Optically Neuronavigated Ultrasonography in an Intraoperative Magnetic Resonance Imaging Environment*, 60 NEUROSURGERY 373 (2007).

for imaging morphology and size of regions of interest (ROI).[88] Others include: (1) Voxel-based morphometry, which allows a systematic review of changes in the gray and white matter across the whole brain,[89] (2) "cortical surface analysis,"[90] (3) studies of "magnetic resonance spectroscopy" (MRS),[91] and (4) "diffusion weighted imaging"(DWI) and, most recently, "diffusion tensor imaging" (DTI), which allow the study of white matter tracts and connectivity within the brain.[92] Of these, DWI has revolutionized research and treatment in the field of stroke, and DTI is giving the promise of further understanding of brain mechanisms underlying behavior.[93]

Investigators are also researching ways to combine different imaging technologies, such as quantitative EEG (QEEG) and magnetic encephalography (MEG), together with functional MRI.[94] Finally, trans-cortical magnetic stimulation of the brain can produce maps of function.[95] These "mapping" technologies reconstruct images to produce a picture by using mathematical algorithms and statistical manipulation of raw data.[96] These efforts are raising expectations for greater and greater understanding of brain structure and function.

Brain imaging techniques are now widely available in medicine and many related fields. Its use in unrelated fields, most significantly in legal proceedings, is widespread and growing fast. The next section explores issues related to its use (and potential misuse) in the courtroom. We also discuss ways that professional medical societies can provide assistance to judges who must determine the admissibility of brain imaging into evidence.

III. MINDING THE IMAGE: BRAIN IMAGES IN THE COURTROOM

The impact that brain-imaging technologies have had on medicine in the last thirty-five years is astounding. In 1972, one of the authors of this Article, as a medical pediatric resident, had a young patient with a collapsed lung

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88 Dirk Rasche et al., *Volumetric Measurement of the Pontomesencephalic Cistern in Patients with Trigeminal Neuralgia and Healthy Controls*, 59 NEUROSURGERY 614, 615 (2006).

89 John Ashburner & Karl J. Friston, *Voxel-Based Morphometry--The Methods*, 11 NEUROIMAGE 805, 806 (2000).

90 *See* Yasushi Miyagi et al., *Inferior Temporal Sulcus as a Site of Corticotomy: Magnetic Resonance Imaging Analysis of Individual Sulcus Patterns*, 49 NEUROSURGERY 1394 (2001).

91 *See* Emmanuel Jouanneau et al., *Very Late Frontal Relapse of Medulloblastoma Mimicking a Meningioma in an Adult: Usefulness of ^{1}H Magnetic Resonance Spetroscopy and Diffusion-perfusion Magnetic Resonance Imaging for Preoperative Diagnosis: Case Report*, 58 NEUROSURGERY 789 (2006).

92 *See id.*

93 *See* Vincent N. Thijs et al., *Is Early Ischemic Lesion Volume on Diffusion-Weighted Imaging an Independent Predictor of Stroke Outcome?: A Multivariable Analysis*, 31 STROKE 2597, 2600-01 (2000).

94 *See generally* Michael Gaetz & Daniel Bernstein, *The Current Status of Electrophysiologic Procedures for the Assessment of Mild Traumatic Brain Injury*, 16 J. HEAD TRAUMA REHABILITATION 386 (2001).

95 *See id.* at 388; *see also* Daphne Simeon et al., *Feeling Unreal: A PET Study of Depersonalization Disorder*, 157 AM. J. PSYCHIATRY 1782, 1783 (2000).

96 *See id.* The technique has several vulnerabilities, including that the statistical manipulations and the algorithm need to be appropriate to what is being measured, while at the same time allowing for sensitivity and validity.

during the night. He personally took an X-ray of the lung and personally developed it. After interpreting the X-ray, he performed a procedure to draw off the misplaced air and to re-inflate the lung. Now, for reasons that will soon become clear, he would have to order the test through the Department of Radiology, where the test would be performed by a trained radiological technician and interpreted by a board-certified radiologist with specialized training on the particular imaging technique and specific hospital credentials for interpreting the test. The explosion of imaging technologies has, in a relatively short time, resulted in a need for such specialized training in producing and interpreting images. This has resulted in medical sub-specialties and sub-sub-specialties, particularly in neurology, neurosurgery, and radiology. Even a neurologist in our hospital would not consider him or herself competent to interpret every type of available test, even if it was very similar to a test that he or she uses regularly. For example, an fMRI expert cannot readily interpret a PET image or a QEEG image, although both tests evaluate the same function, because the fMRI expert lacks specialized training in distinguishing artifacts, false positives, and false negatives unique to each of these technologies.

The necessity for specialized training is just one emerging issue. A related issue is that, despite increased research activity over the past thirty-five years, much work still is needed. At this moment in medical science, not enough is known about motivation for, responsibility for, or propensity for behavior, and their relationship to brain structure or function.

Of course, if all there was to say about brain imaging was that the available technologies have revolutionized the capacity of medicine to view structure and function, but that despite these tremendous developments, science has not yet been able to produce a brain imaging technology that can be used to image motivation, responsibility, or propensity for behavior, there would be no need for this Symposium. The necessity for our Symposium is the fact that brain images made from technologies developed for the purpose of elucidating function, such as blood flow, are being used outside of the context of clinical care and research to make claims of responsibility (or lack thereof) for behavior that has legal consequences for the actor, both civil and criminal. In the courtroom, the guiding premise is that, once evidence has been admitted, the adversarial structure of the courtroom provides a competent forum for evaluating evidence that will lead to "truths" about a litigant's actions and any circumstances that tend to mitigate or worsen it, including his or her capacity to form a requisite state of mind to commit or to inhibit his or her culpable behavior. But when that evidence includes functional brain scans and expert testimony about them, courtrooms may in fact be ill-equipped to accomplish the task for two important reasons. First, brain-images can be profoundly fascinating to view. Visuals, such as pictures or charts, are routinely used in court, but when it comes to functional brain scans such as fMRI, the visual allure of the images in combination with the endorsement of a neuroscientist may result in juries being too easily persuaded of their evidentiary value in a case.[97] Paul Bloom, of Yale, made

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[97] This is particularly true in today's world, where television has fostered a public infatuation with forensic medicine, aptly termed the "CSI factor." We are indebted to Mona

this recent observation:

> Psychologists can be heard grousing that the only way to publish in *Science* or *Nature* is with pretty color pictures of the brain. The media, critical funding decisions, precious column inches, tenure posts, science credibility and the popular imagination have all been influenced by fMRI's seductive but deceptive grasp on our attentions. It's a pervasive influence, and it's not because the science is better.
>
> Why does it affect us so? Probably because fMRI seems more like real science than many of the other things that psychologists are up to. It has all the trappings of work with great lab-cred: big, expensive, and potentially dangerous machines, hospitals and medical centers, and a lot of people in white coats. In a recent study, Deena Skolnick, a graduate student at Yale, asked her subjects to judge different explanations of a psychological phenomenon. Some of these explanations were crafted to be awful. And people were good at noticing that they were awful—unless Skolnick inserted a few sentences of neuroscience. These were entirely irrelevant, basically stating that the phenomenon occurred in a certain part of the brain. But they did the trick: For both the novices and the experts (cognitive neuroscientists in the Yale psychology department), the presence of a bit of apparently-hard science turned bad explanations into satisfactory ones.[98]

Yet, the importance of these tests, particularly in criminal cases, continues to grow. As the President's Council on Bioethics so ably pointed out in a recent paper:

> Law, the embodiment and teacher of many of the community's shared moral practices and norms, seeks to protect the community against dangers and unacceptable behavior by judging misconduct and punishing offenders. Although understanding and judging are different activities, efforts to understand criminal behavior and its causes continue to exert an influence on how society deals with criminals, not only in considering guilt and innocence, but, for example, in sentencing, decisions about parole, and proposals for mandatory treatment, as well as in communal efforts to prevent people from becoming criminals in the first place. In previous generations, people looked to inheritance (genetics), anatomical features (phrenology), a history of emotional trauma or unresolved psychic conflict (psychoanalysis), or socioeconomic deprivation (sociology and economics) to explain why some commit crimes and others do not. Today and tomorrow, it seems that people will

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Cowin of the Middlesex District Attorney's Office for this phrase and for her very helpful suggestions on evidentiary issues in this paper.

[98] Paul Bloom, *Seduced by the Flickering Lights of the Brain*, SEED MAGAZINE, June 27, 2006, at 2-3 (citing Deena Skolnick Weisberg et. al., *The Seductive Allure of Neuroscience Explanations*, J. COGNITIVE NEUROSCIENCE (forthcoming 2007), *available at* http://pantheon.yale.edu/~dls73/Assets/Weisberg-neuro%20explanations.pdf.).

look increasingly to the brain (neuroscience).[99]

Some recent criminal cases highlight the difficulties faced by judges who must determine whether brain images can be admitted, who is qualified to testify about them, and what the content of that testimony can be. Among them are several high profile cases that amply illustrate the difficulties when brain scans are brought to bear on questions of criminal responsibility. John Hinckley's trial for the attempted assassination of President Ronald Reagan in 1981 was probably the most high-publicity insanity defense case in recent American history.[100] As part of Hinckley's defense, his lawyers sought to admit CT scans of Hinckley's brain with the testimony of a consulting psychiatrist in support of the psychiatrist's diagnosis of schizophrenia.[101] The psychiatrist testified that the scans showed a type of atrophy that had been shown in one study to occur in one-third of the schizophrenics studied.[102] The prosecution opposed the admission of this evidence on the grounds that there was no scientific basis to connect the scans to Hinckley's actions.[103] The Court allowed the CT scans along with the testimony of a consulting radiologist, who testified that the CT scans were abnormal but could not be a basis for drawing conclusions about Hinckley's actions.[104] Despite this testimony denying a link between the diagnosis of schizophrenia based on the CT scan and Hinckley's inability to control his actions or appreciate their consequences, the jury found Hinckley not guilty by reason of insanity.[105] In retrospect, many have concluded that the scans in the Hinckley case were likely pivotal to the verdict due to the attention that they received from the jury. More than twenty-five years later, the mere mention of Hinckley's name evokes vivid memories of the scans and the publicity surrounding them.

People v. Weinstein was another high-profile criminal case involving brain imaging.[106] The defense planned to admit PET scans and an MRI of the defendant's brain in the guilt-phase of his murder trial on the issue of whether he should not be held criminally responsible for strangling his wife due to the presence of an arachnoid cyst on the surface of his brain.[107] The defense

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[99] Staff Working Paper, *An Overview of the Impact of Neuroscience Evidence in Criminal Law* (President's Council on Bioethics (Sept. 2004) at www.bioethics.gov/background/neuroscience_evidence.html. In taking note of the increase in testimony using clinical information about the brain in primarily criminal cases, Jennifer Kulynych wrote: "It is now common for a psychiatrist to refer to the physiological state of an individual's brain when evaluating a mental disorder. Moreover, such evaluation increasingly includes a reference to neuroimages. In a legal proceeding, the visual impact of such neuroimages is hard to overstate." Jennifer Kulynych, *Psychiatric Neuroimaging Evidence: A High-Tech Crystal Ball?*, 29 STAN. L. REV. 1249, 1251 (1997).

[100] Stuart Taylor, *Judge Rebukes Hinckley Witness over CAT Scan*, N.Y. TIMES, May 20, 1982, at B13.

[101] *Id.*

[102] *Id.*

[103] *Id.*

[104] Stuart Taylor, *CAT Scans Said to Show Shrunken Hinckley Brain*, N.Y. TIMES, June 2, 1982, at D19.

[105] Stuart Taylor, *Hinkley is Cleared but is Held Insane in Reagan Attack*, N.Y. TIMES, June 22, 1982, at A1.

[106] Mark Pettit, Jr., *FMRI and BF Meet FRE: Brain Imaging and the Federal Rules of Evidence*, 33 Am. J.L. & Med. 319, 334 (2007) (citing People v. Weinstein, 591 N.Y.S.2d 715 (1992)).

[107] *Id.*

evidence included testimony that the cyst may have caused diminished function in the tissue surrounding it.[108] Following a pre-trial hearing on this evidence, the prosecution accepted Weinstein's guilty plea to the reduced charge of manslaughter,[109] perhaps because the prosecution believed that the jury would be unduly persuaded by the scans.[110]

In *McNamara v. Borg*, the defendant was allowed to introduce PET-scan evidence in the sentencing phase of his murder trial.[111] The defendant testified that he was suffering from schizophrenia at the time he committed the crimes.[112] As a result, the jury sentenced him to life in prison rather than to death.[113] Some jurors later admitted that the PET-scan evidence persuaded them to grant leniency.[114]

A recent newspaper article cited in the President's Council on Bioethics Staff Working Paper entitled "The Impact of Neuroscience Evidence in Criminal Law" (hereafter, "Working Paper") underscores the impact that brain images can have in the courtroom:

> Jurors can be dazzled by the display. Christopher Plourd, a San Diego criminal defense attorney, remembers well the first time he used PET scans in the early 1990s during a murder trial. "Here was this nice color image we could enlarge, that the medical expert could point to," Plourd said. "It documented that this guy had a rotten spot in his brain. The jury glommed onto that."[115]

Meanwhile, the number of cases allowing defendants to present neuroimaging evidence is growing.[116] In insanity defense cases, defendants have a right to have access to the assistance of a psychiatrist, and in at least one case, this right was held to extend to neuroimaging tests.[117] This development adds to the pressure on judges who must make evidentiary determinations in such cases. Since *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[118] in most state courts and in all federal courts, judges have the burden of determining admissibility of evidence, serving as "gatekeepers" in evaluating the validity, relevance, and potential prejudicial effect of the evidence and accompanying testimony.[119] Under *Daubert*, which provides the current standard for application of Federal Rule of Evidence 702 (which applies to expert witness testimony), a witness must be "qualified as an expert by knowledge, skills, experience, training, or education" to testify to "scientific, technical, or other specialized knowledge" if that knowledge "will assist the

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108 Staff Working Paper, *supra* note 99, at 9.
109 *Id.*
110 *Id.*
111 *Id.* (citing McNamara v. Borg, 923 F.2d 862 (9th Cir. 1991)).
112 Staff Working Paper, *supra* note 99, at 12.
113 *Id.*
114 *Id.* at 10.
115 *Id.* at 12 (citing Eric Bailey, *California and the West; Defense Probing Brain to Explain Yosemite Killings; Crime: Cary Stayner is among a Number of Defendants Whose Lawyers are Looking for Physical Explanations for Brutal Murders*, L.A. TIMES, June 15, 2000, at A-1-3).
116 Staff Working Paper, *supra* note 99, at 12.
117 *Id.* at 7 (citing People v. Jones, 620 N.Y.S.2d 656 (1994)).
118 509 U.S. 579 (1993).
119 Kulynych, *supra* note 99, at 1260 (citing Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579, 597 (1993)); *see* Pettit, *supra* note 106, at 323 (citing FED. R. EVID. 104).

trier of fact to understand the evidence or to determine a fact in issue."[120] Judges have the burden of determining whether the images and testimony about them meet those criteria—a daunting task in an era of rapid advances in these technologies, and in their clinical and research applications.[121] Moreover, regardless of whether a jurisdiction applies the *Frye* test (the standard that predominated before *Daubert*),[122] or the *Daubert* test, judges must not only determine the validity of the science, but must also weigh the relevance of the evidence against its potential to unduly prejudice the jury.[123] The potential for undue prejudice is always an issue with medical and scientific evidence, but it is of particular importance with brain imaging because of the potential for misunderstanding that may be evoked in jurors by the visual attractiveness of the images and the presence of the neuroscientist who serves as the expert.[124]

In her 1997 Law Review Note, Jennifer Kulynych noted the unique challenges presented by brain images (and expert testimony about them) for courts, and recommended that litigants provide information on core scientific concepts and the status of research in the field relevant to the evidence.[125] If anything, in the years since she wrote, the task for judges making admissibility determinations has grown in complexity and importance.

In our view, at the present time, the use of brain images in the courtroom should be limited only to cases in which the images are to be admitted to show an association between a particular structural lesion (injury) or abnormality with a deficit of some kind, interpreted by a qualified neuroscientist. An example would be a plaintiff in a personal injury case who seeks to admit an image for the purpose of linking a brain injury sustained in an accident to some kind of loss, such as paralysis of a limb. We disagree with the use of functional brain images for the purpose of linking secondary evidence of brain activity (such as blood flow or utilization of oxygen as evidence of neuronal function) to aberrations in human thought, will, motivation or propensity for culpable behavior, or to show an incapacity to inhibit that behavior, because such linkages assume that these complex functions of the brain are subserved by a modular brain that has "centers" for each one. The reason that those links cannot be made with presently available functional neuroimaging technologies (such as fMRI) is that these technologies are currently incapable of showing the multiple networks, each with multiple "centers" and

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[120] Pettit, *supra* note 106, at 323 (quoting Fed. R. Evid. 702). In Massachusetts, the standard for admissibility of scientific evidence is given by Commonwealth v. Lanigan, 641 N.E.2d 1342 (Mass. 1994) ("Lanigan II"). Lanigen held that the gatekeeper role of a judge is to make a preliminary assessment of whether reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts at issue. Lanigan, 641 N.E.2d. at 1349 (citing *Daubert*, 509 U.S. at 594).

[121] *See* S.I. Gatowski, et al., *Asking the Gatekeepers: A National Survey of Judges on Judging Expert Evidence in a Post-Daubert World*, 25 LAW & HUMAN BEHAVIOR 433 (2001) (noting that in a survey of 400 state judges, results demonstrate that judges overwhelmingly support the 'gatekeeping' role as defined in Daubert, whether or not followed in their state.).

[122] Frye v. United States, 293 F. 1013 (D.C. Cir. 1923).

[123] *Id.*

[124] Deena Skolnick Weisberg et. al., *The Seductive Allure of Neuroscience Explanations*, J. COGNITIVE NEUROSCIENCE (forthcoming 2007), *available at* http://pantheon.yale.edu/~dls73/Assets/Weisberg-neuro%20explanations.pdf.

[125] Kulynych, *supra* note 99, at 1259.

connections creating different systems, which function in space and time. Even primary assessments such as QEEG still are unable to access all networks subserving such complex functions as truth-telling. For something like this ever to be possible would require many more technological developments and parallel developments in expertise and training of investigators and neuroscientists in administering the tests and interpreting them, none of which are available at this time or in the near future. To think otherwise is at best wishful thinking, and at worst, advocating pseudoscience.

Even in the case of evidence sought to be admitted for the limited purpose of linking a structural brain lesion or abnormality to a deficit, we suggest that medicine and neuroscience could provide specific guidance for judges who must make evidentiary determinations in the cases before them. Specifically, guidance on the clinical purposes for which respective imaging techniques have been validated, and the state of research on the validity and reliability of the theories and processes underlying the technologies would be important.[126] At a minimum, such guidance should include information on:

- The technical validity of various imaging techniques, and the current professionally-accepted uses of each technique;
- The current clinical applications for the images obtainable from each type, based on accepted clinical theories and methods;
- The current state of the research for each type;
- Imaging techniques that are not currently professionally accepted within the relevant profession(s); and
- Factors for evaluating the qualifications of experts on each type of imaging.

In making this recommendation, we recognize that it has some shortcomings. The first is determining which professional societies should be involved in providing the guidance. Within medicine, there is currently no consensus on which specialties and sub-specialties have province over which technologies—likely, more than one specialty or sub-specialty should be involved in producing guidance on any one technology. Even within those specialties, however, there is yet no uniform agreement on which professional society effectively "represents" its guild. Further complicating matters is the need for professionals from related scientific fields, such as physics or engineering, to work with those from medicine to create such guidance.

At least one professional medical society has issued a report that is consistent with our proposal. In 1997, the American Academy of Neurology and the American Clinical Neurophysiology Society published the report "Assessment of Digital EEG, Quantitative EEG, and EEG Brain Mapping."[127] At the time the report was released, the use of quantitative EEG and brain mapping technologies had exploded.[128] The goal of the report was to provide

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[126] Indeed, Kulynch hints at this near the end of her paper, suggesting that the judge "perhaps consult additional outside sources" after reviewing briefs of the parties and "assessing the research literature" in preparation for instructing the jury. *Id.* at 1267-1270.

[127] M. Nuwer, *Assessment of Digital EEG, Quantitative EEG, And EGG Brain Mapping: A Report of The American Association Of Neurology And The American Clinical Neurophysiology Society*, 49 NEUROLOGY 277, 277 (1997).

[128] *See id.* at 277. These technologies became commercially available in the 1980s and almost immediately found their way into courtrooms for every purpose imaginable.

guidance for physicians by taking account of various digital EEG techniques and the research that had been done on them over the past several decades.[129] The report began, "Although much scientific literature has been produced after decades of research in this field, there remains controversy about the clinical role of QEEG analysis techniques. This assessment is meant to help the clinician by providing an expert review of the current clinical usefulness of these techniques."[130] The evaluation included a review of each society's previous assessments of the subject.[131] The evaluators contacted members of both societies for information and opinions.[132] They contacted commercial digital EEG vendors and asked them to submit scientific publications supporting clinical uses.[133] They contacted experts in the field for opinions and recommendations concerning relevant scientific publications.[134] They also conducted a literature search for EEG-related topics for the period 1984-1995, and reviewed the references sections of the literature they found. Finally, they circulated draft assessments to outside experts and relied on the experts' opinions and literature citations to make changes to the draft.[135]

The evaluators listed several concepts and elements used in making these evaluations, including: (1) a clear definition of the disease being studied; (2) "explicit, clear, and prospective" criteria for test abnormality; (3) the use of control groups; (4) "multiple assessments of validity and reliability;" (5) comparisons of validity results for other tests already in use; and (6) an evaluation of medical efficacy.[136] Using these factors, a panel of experts prepared summaries of the relevant literature, evaluated the scientific evidence, and made recommendations based on the "quality and consistency of the clinical evidence as well as the magnitude of medical efficacy, and costs."[137] The panel also noted when a particular author had a conflict of interest.[138]

In summary, the report offers a useful assessment of current thought with respect to digital EEG, quantitative EEG, and EEG brain-mapping techniques and their clinical applications and limits. With respect to digital EEG, for example, the report states: "digital EEG is an established substitute for recording, reviewing, and storing a paper EEG record. It is a clear technical advance over previous paper methods."[139] In contrast, it states with respect to QEEG:

> EEG brain mapping and other advanced QEEG techniques should be used only by physicians highly skilled in clinical EEG, and only as an adjunct to and in conjunction with traditional EEG interpretation. These tests may be clinically useful only for patients who have been well selected on the basis of their clinical

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129 Nuwer, *supra* note 127, at 277.
130 *Id.*
131 *Id.*
132 *Id.*
133 *Id.*
134 *Id.*
135 *Id.*
136 *Id.*
137 *Id.* at 277-78.
138 *Id.* at 278.
139 *Id.* at 285.

presentation.[140]

The report then goes on to list the very limited circumstances under which certain types of QEEG techniques (in addition to digital EEG) are acceptable for clinical use, such as techniques for diagnosing certain types of epilepsy.[141] A statement on investigational uses of QEEG follows, including uses with postconcussion syndrome, head injury, learning disabilities, attention disorders, schizophrenia, depression, alcoholism, and drug abuse.[142] The report concludes that "QEEG's clinical usefulness is now quite limited . . . . [A]t this time, most scientific reports more convincingly have demonstrated research applications rather than clinical applications."[143] Finally, a note of caution: "because of the very substantial risk of erroneous interpretations, it is unacceptable for any EEG brain mapping or other QEEG techniques to be used clinically by those who are not physicians highly skilled in clinical EEG interpretation."[144]

The report has two other notable features that would assist a judge in evaluating brain-imaging evidence. First, it speaks to the qualifications of potential experts and their competence to interpret various tests.[145] Greater guidance is needed, however, to help judges determine whether an expert is qualified, such as a list of qualifications and recommended training.

Second, the report provides an explicit recommendation against the use of QEEG evidence in legal proceedings: "on the basis of clinical and scientific evidence, opinions of most experts, and the technical and methodological shortcomings, QEEG is not recommended for use in civil or criminal trials."[146] If taken seriously by litigants, this pronouncement could at most amount to a serious hurdle to admission, and at the least deter a litigant from pursuing admission at all.

This type of report should serve as a helpful aid to a judge in evaluating brain-imaging evidence involving QEEG or mapping techniques. The report likely would not be useful as the sole basis for a judge to rule such evidence inadmissible, as opposing counsel could always raise objections as to the authority of the ACNS/AAN. Such a report could, however, provide a judge with helpful context.[147]

Overall, this report illustrates the potential that medical societies have to assist clinicians and judges. Professional medical societies should provide written guidance concerning the validity of brain-imaging techniques and the

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140 *Id.*

141 *Id.*

142 *Id.*

143 *Id.* at 279.

144 *Id.* at 285.

145 *See generally* Nuwer, *supra* note 127.

146 *Id.* at 284.

147 The report was followed by two articles in opposition—one from a competing medical society, and the other by individual researchers. Kerry L. Coburn et al., *The Value of Quantitative Electroencephalography in Clinical Psychiatry: A Report by the Committee on Research of the American Neuropsychiatric Association*, 18 J. NEUROPSYCHIATRY CLINICAL NEUROSCIENCES 460 (2006); Daniel A. Hoffman et al., *Limitations on the American Academy of Neurology and American Clinical Neurophysiology Society Paper on QEEG*, 11 J. NEUOPSYCHIATRY CLINICAL NEUROSCIENCE 401 (1999). Research did not reveal a more recent report from the AAN and ACNS than the 1997 Nuwer report, and to the best of our knowledge it still represents the official position of the AAN and ACNS with respect to these technologies.

professionally-accepted clinical purposes for which those techniques may be used. They should also provide specific guidance for evaluating the training and professional qualifications of expert witnesses. This guidance would be especially useful in jurisdictions in which a court may choose and appoint its own expert.[148]

Because many other disciplines besides law, such as psychology and social science, use brain imaging technologies for research or for other purposes, there is also a need for multidisciplinary guidance from those fields in addition to that provided by medical and scientific societies. We recommend that such guidance come in the form of an independent, scholarly body with authority to work closely with and to direct the work of professional medical societies. The next section makes recommendations with respect to the need for this oversight.

IV. MINDING THE IMAGE: THE FUTURE

We have recommended that even structural brain images be admitted into evidence for very limited purposes at the present time, and that professional medical and scientific societies endeavor to develop periodic guidance on the validity of these technologies, the status of accepted clinical uses, updates on research uses, and guidance on inappropriate uses. In the case of functional imaging, particularly linking such imaging to complex or aberrant behavior, additional and separate guidelines are required for the expert who obtains the image. In addition, we think it equally important that these societies provide guidance on the qualifications of expert witnesses who interpret them and who offer their opinions with respect to causality. Specialty licensing boards could also have a role in developing training programs for brain imaging specialists who serve as expert witnesses. For example, a licensing board might require that a specialist in the interpretation of functional brain imaging in the court might be a psychiatrist with additional training in forensic psychiatry or behavioral neurology in addition to training in imaging.

We suggest that the Institute of Medicine might serve to undertake the task of working with the relevant scientific and medical professional societies on several goals.[149] The first goal is to produce a cohesive review of the status of current research on brain-imaging technologies for the purpose of providing clinical guidance to physicians on their uses, and to clarify future clinical research needs. The second goal is to contribute to guidance on the educational requirements and post-doctoral training needed to qualify specialists to interpret the images produced by each technology. The third goal is to advise on the applicability, and limits, of these technologies to other fields, particularly the social sciences and law. The Institute of Medicine appears to be particularly well-suited for this role in that it is a highly-respected, independent body that advises on wide-ranging issues related to medicine. Its projects are undertaken by committees of volunteers, most of whom are preeminent medical specialists and scholars. Moreover, its procedures involve a "highly structured process of information-gathering,

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[148] FED. R. EVID. 706 ("A court may on its own motion . . . enter an order to show cause why expert witnesses should not be appointed . . .").

[149] We are indebted to Jennifer Kulynych for this suggestion.

deliberation, and peer review."[150]

The President's Council on Bioethics should continue, as it has for many years, to serve an advisory and educational function to the public with respect to policy and ethical issues that may be raised by the use of brain-imaging technologies. The Council was preceded by the President's Commission for the Study of Ethical Problems in Medicine and Biomedicine and Behavioral Research. President Carter established the Commission in 1978 and charged it with reviewing clinical research on death and drafting a statue with a uniform definition of death to guide state law.[151] In its stead, President Bush established the current President's Council on Bioethics in 2001.[152] President Bush charged it with advising "the President on bioethical issues that may emerge as a consequence of advances in biomedical science and technology."[153] In connection with its advisory role, the Council's mission includes the following functions:

1. To undertake fundamental inquiry into the human and moral significance of developments in biomedical and behavioral science and technology;
2. To explore specific ethical and policy questions related to these developments;
3. To provide a forum for a national discussion of bioethical issues;
4. To facilitate a greater understanding of bioethical issues; and
5. To explore possibilities for useful international collaboration on ethical issues.[154]

The multidisciplinary membership of the Council makes it an ideal resource for scholars and the public. The Council is specifically charged with studying ethical issues, including "techniques derived from human genetics or neurosciences . . . ."[155] Consistent with this charge, the Council could convene committees of scholars to study the position statements of various medical professional societies. It could use their findings to advise other disciplines. The Council could also serve as a public resource on the state of the technologies, their clinical applications, and their applications in other fields. The Council has already taken the first step by drafting the recent Staff Working Paper, "An Overview of the Impact of Neuroscience Evidence on Criminal Law."[156]

V. CONCLUSION

The risks of the misuse of brain imaging in the courtroom are undeniable. We have strongly recommended that even structural brain images be used only for the purpose of linking a structural abnormality or injury to a specific

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[150] Institute of Medicine of the National Academies Frequently Asked Questions, http://www.iom.edu/CMS/6008.aspx (last visited June 28, 2007).

[151] The President's Commission for the Study of Ethical Problems in Medicine and Biomedicine and Behavioral Research, 48 Fed. Reg. 34,408, 34,408 (July 28, 1983) (referring to the Public Health Service Act (P.L. 94-622), which was amended in 1978).

[152] Exec. Order No. 13237, 66 Fed. Reg. 59,851 (Nov. 28, 2001).

[153] *Id.*

[154] *Id.*

[155] *Id.*

[156] Staff Working Paper, *supra* note 99.

deficit, and then to be used only as a tool for interpretation by the expert witness to assess its clinical significance. Furthermore, we have recommended that functional brain images not be used for the purpose of linking a particular functional change in a modular fashion in the brain to assess motivation, propensity, or responsibility for a complex behavior or an inability to inhibit it (very similar to the inadequacies of polygraphs currently used for lie-detection). Given the current state of medical and scientific knowledge about brain science, once functional brain images are admitted as evidence for these purposes, the adversarial system is an inadequate forum for determining the evidentiary validity of such evidence. Guidance is needed for judges who must make evidentiary determinations from the medical profession, in conjunction with relevant scientific societies, concerning the proper use of the images and of the accompanying testimony in the courtroom. Further, national oversight bodies are needed to guide research on, and the use of, these technologies in the field of medicine and in fields outside of medicine, and to provide an educational forum for professionals and the public on the current status of the science. The image itself is only a tool; at the end of the day, the expert is everything—only a human brain can evaluate another human brain. We would like to emphasize that the image alone used as evidence of behavior is at this time and for many years to come at best wishful thinking and material for science fiction, and at worst, pseudoscience. "fMRIology" in this context rings of "Phrenology," replacing bone with blood to explain human behavior.