

THE ADMISSIBILITY OF SPECT SCANNING

Judith F. Tartaglia, J.D.

I. Medical Studies

From an attorney's perspective, nothing is more important than the admissibility of evidence, and the ability to survive a *Daubert* or *Shreck* challenge. There can be no question that SPECT scanning is highly sensitive and may provide functional information that is not available from neuroimaging techniques such as CT and MRI. (Report of Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology, hereafter "TTASANN.") However, SPECT is not without limitations and several medical studies provide fertile ground for *Daubert* and *Shreck* challenges in the areas of causation and clinical significance, including correlation of findings with function and ability to prognosticate, all crucial aspects of the proof in a closed head injury case.

In the area of causation, it has been shown for instance, that depressed and anxious people demonstrate abnormal findings on SPECT.¹ In 1994, Masdeau *et al.* reported that damage was detected on SPECT in both the HIV encephalopathy and MTBI populations, but SPECT readers could not differentiate between which patient population was being reviewed or what damage was caused by head injury.² A significant limitation of SPECT therefore is the inability to determine abnormalities that may have pre-existed the head injury. In a 2001 study, Campayo, *et al.* found that in 11 research subjects with somatization disorder, 7 patients showed hypoperfusion on SPECT imaging. The authors controlled this study for patients with known depression and anxiety disorders, and concluded that because of the small sample further research was needed using sequential exams associated with neuropsychological assessments. It is important that the American Academy of Neurology considers the research in SPECT scanning in head trauma to be "investigational." Similarly, research that attempted to identify certain SPECT abnormalities with HIV encephalopathy, seizures, diagnosis of TIA and various progressive neurological diseases such as Huntington's chorea is considered to be investigational.³ The concerns of TTASANN were reflected by Dr. Francis Kittredge in his presidential address, Challenges for Neurological Care, 2001-2030,⁴ given at the 2001 annual meeting of the American Academy of Neurology ("AAN"). While Dr. Kittredge acknowledged that functional imaging "is informing our diagnosis and treatment, and demonstrating changes in response to therapy," he also emphasized the need for increased "outcomes research" in the area of brain imaging and other areas.

Davalos and Bennet followed the recommendations of TTASANN and continued to research the efficacy of SPECT with mild head injuries. They reviewed the literature from 1966 to 2000 and concluded that SPECT might be a useful tool in the detection of MTBI but because of the lack of consensus regarding SPECT's sensitivity in this area, they recommended that future researchers consider the possibility of multiple subtypes of MTBI, hemodynamically different types of contusions and the need for complementary

diagnostic tools such as neuropsychological testing. In the latter area however, research has shown weak correlations between neuropsychological testing and SPECT results.^{5, 6, 7} In a study by Kessler *et al.*, SPECT was compared with MR imaging, and QMR imaging. Each neuroimaging modality detected brain abnormalities that the other two did not. Neuropsychological and psychological testing indicated significant memory impairments and subjective emotional distress even several years post injury, but SPECT abnormalities alone were not correlated with intellectual and memory outcome. An earlier study by Kant, *et al.* revealed significant differences between subjects with normal and abnormal SPECT scans on various neuropsychological tests, including part B of the Trail Making Test, number of errors on the Wisconsin Card Sorting Test, percentile rank for delayed recall of the Logical Memory Subtest of the Wechsler Memory Scale, and revised or percentile rank for delayed recall on the Visual Reproduction Sublist of the Wechsler Memory Scale-Revised. It is also important to note that in this study the raw scores for the Beck Depression Index did not differ significantly between the group with SPECT abnormalities and those without SPECT abnormalities, indicating that self-reported depressive symptomatology was not related to the abnormalities seen on SPECT scans.

It has been hoped that results of SPECT scanning might provide valid data to predict outcome after traumatic brain injury. To date research in this area has not provided a basis for predicting outcome or ultimately to assist in an early evaluation of damages.⁸ In a study by Jacobs, *et al.*, SPECT scans were done on 136 patients who had experienced head injury at 3 months, 6 months and 12 months post injury. The researchers concluded that when the SPECT scan was normal, it was a reliable tool in the exclusion of clinical sequelae of closed head injury. However, at 3 and 6 months, SPECT studies had negative predictive value. Clinical normalization occurred earlier than changes on the scan. At 12 months post injury, a positive SPECT study is a more reliable predictor for clinical outcome.

Similarly in a study by Hofman, *et al.*, the authors concluded that brain lesions are common after mild traumatic brain injury and up to 77% of patients may have abnormal findings either on MR images or SPECT scans, and these lesions may lead to brain atrophy. The association between hypoperfusion seen on acute SPECT and brain atrophy after six months suggested the possibility of secondary ischemic brain damage. There was only a weak correlation between neuroimaging findings and neurocognitive outcome.⁹

These studies suggest that SPECT remains an investigational tool in the diagnosis of brain injury. In order to present proof of causation, function and outcome, SPECT results must be presented in conjunction with other imaging studies, neuropsychological testing and reports of objective clinical observation. In addition, attorneys must remain cognizant of the methodology used in performing the scan and the timing of the scan.

BIBLIOGRAPHY

SPECT AND PET ADMISSABILITY REPORTED CASES

SPECT

1. *Guilbeau v. W.W. Henry Co.*, 85 F.3d 1149 (5th Cir. 1996). The plaintiff in that case allegedly suffered from chronic toxic encephalopathy resulting from a short-term exposure to chemicals contained in a carpet adhesive. Plaintiff offered the testimony of Dr. Thomas Callender, who testified as an expert in internal medicine, neurotoxicology and occupational medicine. Dr. Callender's testimony was based in large part on the results of a 1990 SPECT scan which purported to show abnormal areas of decreased circulation. Despite a rigorous cross-examination regarding the lack of foundation for his testimony and the issue of whether SPECT was reliable scan evidence, the jury returned a verdict of \$2.9 million. The verdict subsequently was overturned on the ground that the product was not defective. Nevertheless, it is worth noting that Judge Reynado Garzo, in his dissenting opinion, expressed his belief that the plaintiff had carried his burden in proving causation through the use of SPECT scan evidence.

2. In *Rhilinger v. Jancics, et al.*, 1998 WL 1182058 (Mass. Super. 1998), a Massachusetts trial court allowed a plaintiff's expert to testify as to the results of a SPECT test to prove injuries consistent with toxic encephalopathy. Ms. Rhilinger alleged that she developed toxic solvent encephalopathy from exposure to chemicals stored illegally in the basement of her apartment building. She asserted that the chemicals leaked and caused a migration of fumes into her residence which ultimately caused brain damage. After she experienced various physical and cognitive symptoms including fatigue, dizziness, memory loss, hoarseness and stuttering in her speech, she was seen by a Dr. Howard Hu at the Center for Occupational and Environmental Medicine at the Massachusetts Respiratory Hospital. Dr. Hu diagnosed Ms. Rhilinger with toxic encephalopathy.

The defendants brought a *Daubert* challenge to the admissibility of the SPECT scan evidence on three grounds, namely, that the use of SPECT scan imaging to diagnose brain injury due to chemical exposure (1) is not supported by valid scientific evidence; (2) has not been subjected to empirical testing or otherwise properly tested or studied; and (3) has not been generally accepted as a diagnostic tool for toxic encephalopathy in the relevant scientific and medical communities.

The court included a thorough discussion of SPECT scans, and noted that the medical community had used SPECT technology for at least 15 years. The court acknowledged that, as of that time, there was inadequate evidence to support the use of SPECT scans to establish the existence of a cause and effect relationship in toxic exposure cases. Indeed, the plaintiff's own doctor testified that a SPECT scan could not be relied upon as definitive evidence to rule in or to rule out a diagnosis of TSE. Nevertheless, the court relied on Dr. Hu's testimony that: (1) "individuals who have a history of exposure to chemicals are at a higher risk of having abnormal SPECT scan results"; (2) Ms. Rhilinger's SPECT scan results were consistent with the results of those individuals; (3) Ms. Rhilinger had no other identifiable disease process or diagnosis to

account for her abnormal SPECT scan results; and, (4) her MRI was normal, thus ruling out other possible origins of her cognitive difficulties.

In holding that the SPECT evidence was admissible, the court stated that:

There is no dispute that SPECT scans show abnormalities in brain function. Neither is there a dispute that SPECT scans cannot conclusively establish the existence or non-existence of TSE in a patient. Plaintiff's experts do not opine that the SPECT scan does, in fact, establish the diagnosis. They merely assert that is one of a constellation of diagnostic tools which they used and considered consistent with their conclusion that Rhilinger suffers from TSE.

There also is no dispute that SPECT scanning is relevant to prove or disprove the other possible explanations for plaintiff's condition. The scientific evidence submitted by both parties approves of the use of SPECT scans to identify other brain disorders such as epilepsy, stroke and dementia. Plaintiff's proffered expert testimony does not go beyond what is considered scientifically defensible use of SPECT scan technology.

The judge held that SPECT evidence is "scientifically reliable" in such a toxic tort case. Thus, the plaintiff got in her SPECT evidence by using it to show a diagnosis "consistent with" toxic exposure.

3. *In re Air Crash at Little Rock Arkansas*, 291 F.3d 503 (8th Cir. 2002) involved a dispute over whether post-traumatic stress disorder is in itself a "physical injury" for which recovery under the Warsaw Convention was allowed. The Eighth Circuit rejected as speculative the testimony of plaintiff's expert to the effect that "people with chronic PTSD may have brain dysfunction, meaning that PTSD is both biological and physical." *Id.* at 511. While this case did not deal with the admissibility of PET or SPECT evidence, it bears mentioning because the Eighth Circuit noted in its opinion that the plaintiff failed to have one of these tests performed to confirm the existence of a physical injury. Thus, the Eighth Circuit seemed to indicate that a PET or SPECT just might have proved the requisite physical injury from PTSD.

4. In a FELA action alleging multiple chemical sensitivity syndrome, however, a trial court excluded an expert's testimony which relied heavily on SPECT images. *Summers v. Missouri Pacific Railroad System*, 897 F. Supp. 533 (E.D. Okla. 1995). The court in that case noted the lack of reliable scientific and medical data to support the use of SPECT technology to diagnose neurotoxic exposure.

PET

5. *Hose v. Chicago Northwestern Transportation Co.*, 70 F.3d 968 (8th Cir. 1995), the trial court allowed PET scan evidence for the limited use of eliminating alternative theories of injury. Mr. Hose allegedly suffered toxic encephalopathy resulting from occupational exposure to manganese fumes. In his FELA action against his employer, the court permitted Mr. Hose's expert to testify on the basis of a PET scan. Specifically,

his expert testified that the PET scan did not match the typical patterns for Alzheimer's, alcoholism or stroke, but, rather, showed a pattern consistent with dementia and an "overall picture. . . very consistent with manganese encephalopathy and toxicity as the cause of this dementia." The judge allowed this testimony despite his admission that the scientific literature did not explain how manganese toxicity would appear on a PET scan. The jury returned a \$1.33 million verdict. On appeal, the Eighth Circuit upheld the verdict and held that the trial court did not abuse its discretion in allowing the PET scan evidence. The Eighth Circuit's opinion relied to a great extent on the fact that the expert's testimony was limited to showing consistency with, as opposed to diagnostic proof of, manganese encephalopathy.

6. *Penney v. Praxair*, 116 F.3d 330 (8th Cir. 1997) involved a claim of brain injuries following an automobile accident. The 62-year-old plaintiff allegedly suffered a whiplash-type injury and claimed symptoms including headaches, dizziness, vertigo, ringing ears, a sore neck and various other maladies. He underwent both an MRI and a CT scan, neither of which showed any brain injury. The plaintiff then had a PET scan which, according to his expert, revealed "abnormalities which were consistent with a traumatic brain injury." 116 F.3d at 332. The district court refused to admit the PET scan evidence, reasoning that it would "not be helpful to the jury in deciding the issues when compared with the likelihood that the jury would misapply the evidence." *Id.* On appeal, the Eighth Circuit upheld the district court ruling. The appellate court sustained the trial court's holding that the Plaintiff failed to establish a foundation sufficient to justify admission into evidence of Plaintiff's PET scan results. The court's primary concerns were Plaintiff's advanced age and ingestion of regular doses of heart medication throughout the testing period. Those factors were not present in the control group against which Plaintiff's PET scan results were measured. The court stated that it was not clear whether the factors had any impact on the results, but that Plaintiff had failed to carry his burden of establishing a reliable foundation for his PET scan readings. According to the court, the risk that the jury would misapply the PET scan results outweighed the evidence's potential to help the jury decide issues regarding Plaintiff's injury. The court acknowledged *Penney's* apparent inconsistency with *Hose*, stating that admissibility of PET scan results must be decided on a case-by-case basis.

CRIMINAL CONTEXT

7. The only pre-*Daubert* decision is the 1992 New York case of *People v. Weinstein*, 156 Misc. 2d 34, 591 N.Y.S.2d 715, a criminal case in which the court held PET scan results to be admissible evidence. The court reasoned that the *Frye* standard should be inapplicable in a criminal trial where the Defendant raises an insanity defense. According to the court, any evidence relevant to the insanity defense should be admitted if it meets a reasonableness standard. Relying upon expert testimony and published studies, including one from the *Journal of Nuclear Medicine*, the court stated in dicta that PET is a generally accepted means of imaging brain function, but the formulae used to analyze PET results are not generally accepted within the scientific community as a whole. While the formulae used to quantify PET data are not generally accepted, they are routinely used by PET experts who rely upon the results produced by the formulae in making

diagnoses. Therefore, experts can reasonably use the formulae and results derived from the formulae in developing opinions. Clearly, the reasoning of the Weinstein court supports the admission of PET scans under the Daubert rule.

8. *United States v. Mezvinsky*, 206 F.Supp.2d 661 (E.D.Pa. 2002) (rejecting defendant's attempt to prove "insanity" defense through PET scan evidence).

9. In *United States v. Gigante*, 982 F.Supp. 140 (S.D.N.Y. 1997), the court refused to admit the testimony of Dr. Monte Buchsbaum of New York's Mount Sinai Medical School. Dr. Buchsbaum opined that a PET scan would allow him to "measure where and how much brain activity occurred," and further opined that Mr. Gigante's PET scan revealed "organic brain dysfunction, possibly due to Alzheimer's disease or multi-infarct dementia." *Id.* at 147. The district court rejected this testimony.

See also United States v. Gigante, 996 F.Supp. 194 (S.D.N.Y. 1998) (rejecting Mr. Gigante's second attempt to introduce PET scan evidence). The shortcomings on which the trial court focused are essentially some of the same that arise in the toxic tort context.

10. Jackson v. Calderon, Warden of California State Prison at San Quentin, 1997 WL 855516 (D.D.Cal.), held PET scan results inadmissible for the limited purpose of diagnosing chronic use of the drug PCP. There had been only one study on PET scans of persons with a history of abusing PCP, and that study involved only seven patients. The court found insufficient evidence to substantiate the reliability of PET scan technology to determine PCP abuse. The court found that the study of PET scans of individuals with a history of PCP abuse was an unpublished study not subjected to peer review. The court stated that its finding justified the exclusion of the evidence under Daubert.

OTHER CASES

11. The United States Court of Federal Claims addressed the admissibility of PET scans for the first time in Barnes v. Secretary, Department of Health and Human Services, 1997 WL 620115(Fed.Cl.). This case was a special multi-district proceeding brought by plaintiffs claiming injury from the disease Tuberosus Sclerosis ("TS") in actions authorized by the National Childhood Vaccine Injury Act, 42 U.S.C. 300aa-1 et seq. In Barnes, as in Timothy McCollum and Lee Ann McCollum as Parents and Natural Guardians of Grant E. McCollum, 1998 WL 338237 (Fed.Cl.), also an action under the National Childhood Vaccine Injury Act, the Federal Claims Court considered expert testimony regarding brain injury based upon PET scan evidence without any mention of Daubert. The Barnes decision made no observations as to the methodology of or theory behind PET scans, but merely referred to the PET scan evidence. The McCollum decision simply cited the doctor's testimony that, "PET scanning is a method by which metabolic activity in cells can be assessed," before discussing the PET scan results. The implication of the treatment of PET scan evidence by the Barnes and McCollum cases is that PET scans constitute "scientific knowledge" of brain injury and are therefore presumptively admissible under Daubert so long as they are relevant to a material issue in the case.

II. Case Law

In addition to the handout in your materials entitled "SPECT and PET Admissibility Reported Cases" prepared by Brain Matters, Inc., the following case law is applicable:

A. Tenth Circuit

1. *Kent v. Apfel*, 75 F. Supp. 2d 1170 (1999).

In this case, the claimant's application for Social Security Disability was denied. The claimant utilized a PET imaging study to support his claim that he had sustained a head injury. Among many other somatic complaints, the claimant complained of forgetfulness and visual difficulty, and his expert witness opined that it appeared that the functional metabolic deficits shown on the PET scan involving the left temporal lobe and the left posterior occipital cortex as well as the left orbital frontal cortex could be related to the subtle deficits in cognitive and integrative functioning as well as deficits in visual motor coordination and angular discrimination which were reported in the psychological assessment report. The court noted the report of the PET scan in conjunction with other testing that had been done and concluded that the order of the Commissioner of Social Security should be reversed and the case remanded because the Commissioner's finding of credibility of claimant's testimony on pain, symptoms and residual functional capacity was not supported by substantial evidence.

2. *Bryan v. Mullin*, 235 F.3d 1207 (2003).

In this case, Mr. Bryan was convicted of first-degree murder and sentenced to death. This was a *habeas corpus* action in which the issue was whether Mr. Bryan's counsel's strategic decision not to present at the penalty stage of his trial evidence of his mental illness constituted ineffective assistance of counsel. The court of appeals held that it was not. However, the dissent noted that a SPECT scan done on Mr. Bryan that was consistent with irreversible brain pathology, chronic paranoid schizophrenia and organic delusional disorder like all the evidence proving organic brain damage, was never presented to the jury. The dissenting judges opined that the SPECT scan was significant in proving organic brain damage and this combined with a failure of counsel to present the other evidence that was available of organic brain damage should have entitled Mr. Bryan to a reversal of the

judgment and a remand so that a jury could consider evidence of his diseased mental state.

3. *Hando v. Shalala*, 13 F.3d 405 (10th Cir. Wyo. 1993).

This is an unpublished opinion in which in a Social Security disability action. Ms. Hando claimed that she became disabled due to chemical allergies in 1984. Ms. Hando received an antibody blood test and PET scan in 1991, and her physician testified that he believed that the results of the PET scan and the antibody blood test were compatible with chemical sensitivity, which he believed stemmed from her exposure to paint in the early 1980's. The court of appeals however gave greater weight to the psychologist's testimony that if Ms. Hando such a problem, her behavior would have been more and more socially restrictive and that her activities were inconsistent with a fear of chemical exposure. The court did not find that the results of the PET scan were conclusive for a finding of chemical sensitivity or disability as a result of that sensitivity.

4. *Summers v. Missouri Pacific Railroad System*, 132 F.3d 599 (1997).

In this case, railroad employees brought an action against the Missouri Pacific Railroad under the Federal Employers Liability Act ("FELA") and the Boyle Inspection Act ("BIA") alleging injuries resulting from exposure to diesel exhaust fumes. The United States District Court for the Eastern District of Oklahoma granted the railroad's motion to exclude expert testimony and this appeal followed. The employees' expert relied in part on the results of the SPECT test to confirm whether or not the employees were suffering from chemical sensitivity. The district court found that the SPECT test and others that the proffered expert used "have been the subject of much criticism by the scientific community as not having met acceptable scientific levels of methodology and criteria, and are not designed to test for the recognized medical condition of chemical sensitivity." The employee's proffered expert testimony was inadmissible.

B. Michigan

1. *SPECT Imaging Inc. v. Allstate Ins. Co.*, 633 N.W.2d 461 (2001).

In this case, a healthcare provider brought an action against automobile insurers to recover personal protection insurance benefits for brain imaging by single-photon emission computer tomography ("SPECT"). The circuit court granted Allstate's

motion for summary judgment and the court of appeals reversed and remanded. In its opinion, the court of appeals noted that Allstate moved the trial court for an evidentiary hearing seeking to determine whether evidence of SPECT imaging which defendants claimed was a "novel scientific procedure" was admissible pursuant to M.R.E. 702 and M.C.L. 600.2955. The trial court declined to hold an evidentiary hearing and instead ordered the parties to bring cross motions for summary judgment. After a hearing on motions for summary judgment, the trial court observed that "implicitly Section 3107 would seem to require a showing that any medical technology used for any medical expense incurred is at least somewhat reliable." The trial court appeared to favor an approach that was grounded in public policy and it also appeared reluctant to render a decision that would inhibit physicians in their use of new, novel technology to treat patients. However, the defendants' argument on appeal was that the trial court erred in determining as a matter of law that brain SPECT scans constitute "reasonably necessary" expenses under the No Fault Act where actual disputes existed with regard to whether the scans were reasonable and necessary in relation to the defendants' insureds. The court of appeals agreed. The court ordered that on remand, the trial court was to conduct an evidentiary hearing to determine whether expert testimony and evidence relating to SPECT imaging are admissible under M.R.E. 702 and *Davis Frye*, and further ordered that the party proffering the evidence bears the burden of demonstrating its acceptance in the medical community. The trial court was also ordered to undertake the threshold determination of whether under *Davis Frye* "it has been demonstrated that the evidence relating to SPECT imaging in the treatment of mild traumatic brain injury has gained general acceptance in the medical community." Finally, the court ordered that if the trial court determined that the expert testimony with regard to SPECT imaging met the standards of M.R.E. 702 and *Davis Frye* and were admissible, that the issue of the reasonableness and necessity of the SPECT imaging was a question to be reserved for the trier of fact.

2. *Fini v. General Motors Corp.*, 2003 WL 1861025 (Mich. Appeal).

This is an unpublished opinion of a case in which plaintiff was involved in an automobile accident from which she alleged that she sustained a brain injury. The plaintiff relied on SPECT scanning at trial to prove her claim, and the defendants appealed the admissibility of the SPECT evidence. The defendants claimed that SPECT scans were not considered reliable evidence within the scientific community to diagnose closed head injuries, and they contended that plaintiff failed to establish a proper foundation for admitting this evidence. The court of appeals held that the *Davis*

Frye analysis was appropriate for purposes of determining the admissibility of SPECT evidence. Under *Davis Frye*, the party offering novel scientific evidence must demonstrate that it has gained general acceptance within the scientific community. The court noted that the use of SPECT may have important implications for classification and management of patients with mild head trauma. The court further concluded that the evidence demonstrated that SPECT scans were generally accepted within the scientific community as having an ability to show abnormalities in brain functioning and that they are used in the same fashion that a CT scan might be used by an expert to evaluate a patient and reach a diagnosis. The plaintiffs also presented evidence from a board certified neuropsychologist who testified that he used CT scan and SPECT scan as part of a process of "clinical correlation." The court held that this neuropsychologist was an appropriate expert to testify regarding whether his neurological testing could be correlated with plaintiff's SPECT scan.

III. Summary

The law regarding the admissibility of SPECT scanning is limited and no majority rule has emerged. Certain trends, however, can be identified. First, some jurisdictions admit SPECT evidence to support claims of brain injury, but they generally require corroborative evidence such as neuropsychological testing and other neuroimaging studies. Second, in brain injury cases courts give considerable weight to objective clinical evidence of a person's ability to function and may exclude SPECT evidence on the basis that the findings are not consistent with a plaintiff's functioning. Third, SPECT and PET scans are not generally admissible to prove toxic exposures and chemical sensitivities. Courts note the lack of scientific and medical data to support the use of SPECT and PET technology in these instances. Fourth, in the criminal context, most courts have rejected SPECT scans as support for an insanity defense.

In summary, courts in the jurisdictions that have considered the admissibility of SPECT scan evidence are split on whether there is adequate medical and scientific data to support its validity to show the existence of a brain injury and more importantly, to show causation of the alleged injury or predict outcome. In 1996 TTASANN considered SPECT technology in the area of diagnosing brain injury "investigative" and the American Academy of Neurology has emphasized the need for "outcomes research." The mandate to those who advocate the use of SPECT scanning to diagnose brain injury is therefore clear in terms of the need for continued research. Absent this research, the admissibility of SPECT will undoubtedly continue to be challenged.

¹ Davalos, D. and Bennett, T. (2002), "A Review of the Use of Single-Photon Emission Computerized Tomography as a Diagnostic Tool and in Mild Traumatic Brain Injury." Applied Neuropsychology, 9:92-105.

² Masdeau, J.C., Van Heertum, R.L., Kleiman, A., Anselmi, G., Kissane, K., Horng, J., *et al.* (1994). "Early Single-Photon Emission Computed Tomography in Mild Head Trauma: A Controlled Study." Journal of Neuroimaging, 4:177-181.

³ Report of Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology, Neurology (1996), 46:278-28.

⁴ Kittredge, F. (2001), Presidential Address, American Academy of Neurology, "Challenges for Neurological Care, 2001-2030." Neurology, 57:3.

⁵ Kessler, S.R., Adams, H.F., Bigler, E.D. (2000), "SPECT, MR and Quantitative MR Imaging: Correlates and Neuropsychological and Psychological Outcome in Traumatic Brain Injury." Brain Injury, 14:851-7.

⁶ Kant, R., Smith-Seemiller, L., Isaac, G., Duffy, J. (1997), "TcHMPAO SPECT in Persistent Post-Concussion Syndrome After Mild Head Injury: Comparison with MRI/CT." Brain Injury, 11:115-124.

⁷ Van Heertum RL, Drocea C, Ichise M, Lobotesis K, Fawwaz R (2001), "Single Photon Emission CT and Positron Emission Tomography in the Evaluation of Neurologic Disease." Radiologic Clinics of North America, 39:5.

⁸ Jacobs, E.P., Put, E., Ingels, M. Put, T., Bossuyt, A. (1995), "One Year Follow-Up of Technetium-99m-HMPHO SPECT in Mild Head Injury." Journal of Nuclear Medicine, 37:1605-1609.

⁹ Hofman PA, Stapert SZ, van Kroonenburgh MJ, Jolles J., de Kruijk J and Wilmink JT (2001), "MR Imaging, Single-Photon Emission CT and Neurocognitive Performance After Mild Traumatic Brain Injury." American Journal of Neuroradiology, 22:441-9.