Advanced Neuroimaging and Mild Traumatic Brain Injury Litigation, Revisited

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Over a decade has now passed since publishing our brief series addressing advanced neuroimaging in the context of mild TBI litigation.[1,2] That being the case, it seems like an appropriate interval to revisit these matters and consider the present landscape, to include appropriate uses and ethical reporting of advanced neuroimaging, as well as the ongoing potential for idiosyncratic applications, if not abuses. Much has changed in the intervening decade in terms of various publications, guidelines, and position statements on the subject of neuroimaging in TBI, including its clinical and forensic applications. At the same time, implementation of these publications, guidelines, and position statements is lagging, and misapplications and misinterpretations continue to feature regularly in medicolegal matters involving claims of highly atypical, and medically improbable, negative outcomes after mild TBI. I offer here an update on advanced neuroimaging and the best evidence for its use as informed by findings from the fields of neuroradiology, brain injury medicine, and neuropsychiatry. I also explore the increasingly apparent need for greater involvement of forensically-trained physicians (i.e., forensic neuropsychiatrists) to serve as experts in such matters.

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In our initial 2008 publication on the subject of advanced neuroimaging in mild TBI litigation,[1] we explored the evidence pertaining to cerebral single photon emission computed tomography (SPECT) imaging and TBI, anchored that analysis to *Daubert* criteria, and identified a rather modest role for this technology; in short, this analysis concluded that SPECT offers at best secondary and often superfluous evidence in support of a diagnosis of mild TBI, and only when primary forms of evidence (e.g., clinical history, standard structural imaging results, and neuropsychological test results) already do so. We then similarly addressed the subject of diffusion tensor imaging (DTI) in mild TBI litigation, once again identifying a rather modest role based upon the best evidence.[2] We also noted the potential for powerfully misleading testimony based on DTI interpretations, when they are left misused and the foundations for their misuse go unchallenged. At the time of these publications, there was relatively little guidance regarding these advanced neuroimaging techniques and their diagnostic characteristics, the extent to which their use informs functional capacity or prognosis after mTBI, or the manner in which ethical expert testimony applies findings from advanced neuroimaging to cases before triers of fact. Absent such clear guidance, it seemed inevitable that there would be transgressions, meaning instances involving testimony suggesting that advanced neuroimaging confirms a diagnosis of mild TBI, or attributes persistent symptoms to such an injury despite the absence of a full and necessary consideration of the differential diagnosis for the injury event and presenting symptoms, particularly when the clinical history is incompatible with the natural history of mild TBI or in the setting of unequivocal neuropsychiatric comorbidity.

Fortunately, positions and guidance more influential than my own have offered clarity on the usefulness of various advanced neuroimaging techniques in the setting of TBI, as well as more clear guidance regarding what constitutes ethical reporting and testimony in mTBI litigation. A publication entitled "Guidelines for the Ethical Use of Neuroimages in Medical Testimony: Report of a Multi-Disciplinary Consensus Conference"[3] addresses many of these topics. I direct readers' attention to the fact that brain trauma is specifically identified in this guideline as an area for further exposition and as an area "exemplary of use and abuse of neuroradiologic data in the courtroom" (Ref. 3, p 634). Also of note are explicit statements regarding the "few clinical settings in which sufficient literature and/or clinical evidence has demonstrated sensitivity and specificity" (Ref. 3, p 633). Recognizing the potential value of appropriately framed testimony based upon advanced neuroimaging, the guidelines propose standards to facilitate offering scientifically sound opinions while mitigating the risk for abuse of advanced neuroimaging in legal proceedings:

> Experts should present all relevant facts available in their testimony, ensure truthfulness and balance, and consider opposing points of view.
>
> Experts should specify known deviations from standard practice.
>
> Experts should have substantive knowledge and experience in the area in which they are testifying.
>
> Experts should use standard terminology and describe standardization methods and the cohort characteristic from which claims are determined, when applicable.
>
> Nonvalidated findings that are used to inform clinical pathology should be approached with great caution.
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> Recognized appropriateness guidelines should be used to assess whether the imaging technique used is appropriate for the particular question.
>
> Experts should avoid drawing conclusions about specific behaviors based on the imaging data alone.
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> Experts should be willing to submit their testimony for peer review.
>
> Experts should be prepared to provide a description of the nature of the neuroimages (e.g., representational/statistical maps when derived from computational postprocessing of several images) and how they were acquired.
>
> Raw images and raw data should be made available for replication if requested.
>
> Experts should be able to explain the reasoning behind their conclusions.
>
> False-positive rates should be known and considered if the expert's testimony includes quantitative imaging.
>
> Experts should be prepared to discuss limitations of the technology and provide both confirming research and disconfirming studies (Ref. 3, p 635).

Given the principle-based nature of most of these points, their durability seems self-evident and not tied to the evidence basis in support of any given imaging modality or its application to any neuropsychiatric condition. When I first wrote about these guidelines,[4] I did so with optimism about its effect on our field:

> The importance of these standards is difficult to overstate . . . The imminent publication of the new guidelines (representing consensus from truly multidisciplinary proceedings) represents a renewed opportunity for medical and legal professionals to meaningfully adopt and maintain such guiding principles. The standards serve to protect the integrity of both medical science and legal proceedings, and thus ought to be embraced by all who aspire towards virtuous medicolegal practice (Ref. 4, p 22).

Unfortunately, the opportunity for widespread adoption of these proposed standards may be lost, as they clearly have not been spontaneously adopted by many who routinely offer testimony based upon advanced neuroimaging and it would seem that courts have been reluctant to enforce them.

The American College of Radiology (ACR) usefully comments on these concerns. The ACR publishes and updates appropriateness criteria, including a set of appropriateness criteria specific to head trauma. The criteria address the appropriateness of various neuroimaging modalities across different clinical scenarios via different variants, such as acute head trauma versus subacute or chronic head trauma. For the version that was active in 2012,[5] variant four (see Table 1) was typically most applicable to medicolegal matters, addressing subacute or chronic closed head injury with cognitive or neurological deficits. At that time, SPECT and positron emission tomography (PET) were doing relatively well, with appropriateness of their use in neuroimaging of persons with subacute or chronic closed head injury with cognitive or neurological deficits, rated 4 of 9 (i.e., at the lowest end of "may be appropriate"). The appropriateness of fMRI use in this

Table 1. ACR Appropriateness Criteria, 2012, 2015, and 2021 Versions

Radiologic Procedure	ACR Rating 2012*	ACR Rating 2015*	ACR Rating 2021
MRI without contrast	8	9	Usually appropriate
CT head without contrast	6	7	Usually appropriate
Tc-99m HMPAO SPECT	4	1	Usually not appropriate
FDG-PET	4	2	Usually not appropriate
fMRI	2	2	Usually not appropriate
DTI	Not featured	1	Usually not appropriate
MRS	Not featured	2	Usually not appropriate

*Rating Scale: 1-3, usually not appropriate; 4-6, may be appropriate; 7-9, usually appropriate.

context was rated 2 of 9 ("usually not appropriate"). Magnetic resonance spectroscopy (MRS), DTI, and volumetric analysis were not given an appropriateness rating at all.

The ACR appropriateness criteria were then updated in 2015 (see Table 1).[6] Additional time and research did not benefit the appropriateness ratings given to SPECT or PET, both of which, in all variants considered, were downgraded to "usually not appropriate," including for the neuroimaging evaluation of persons with subacute or chronic closed head injury with cognitive or neurological deficits. In this iteration of the ACR appropriateness criteria, DTI and MRS appear and are rated as "usually not appropriate" (1 of 9 and 2 of 9, respectively), and volumetric analysis remained off this list of neuroimaging types whose appropriateness was considered.

The ACR very recently offered another update in 2021,[7] and all advanced techniques are rated as "usually not appropriate" across all scenarios involving head trauma (volumetric analysis was again off the list). Variant 7 is typically most applicable in the 2021 update, addressing "subacute or chronic head trauma with unexplained cognitive or neurological deficits" (Ref. 8, pp 20-23).

Especially compelling is the publication entitled "Imaging Evidence and Recommendations for Traumatic Brain Injury: Advanced Neuro- and Neurovascular Imaging Techniques."[9] This is a white paper, essentially a position statement, endorsed by the American College of Radiology Head Injury Institute, the American Society of Neuroradiology, the American Society of Functional Neuroradiology, and the American Society of Pediatric Neuroradiology. Various advanced neuroimaging techniques are addressed, including DTI, fMRI, MRS, PET, SPECT, and magnetoencephalography (MEG). The abstract from the publication states:

> These advanced neuroimaging techniques are currently under investigation in an attempt to optimize them and substantiate their clinical relevance in individual patients. The data currently available, however, confine their use to the research arena for group comparisons, and there remains insufficient evidence at the time of this writing to conclude that these advanced techniques can be used for routine clinical use at the individual patient level (Ref. 9, p 1).

The Radiological Society of North America (RSNA) echoed this appraisal in a similar statement on traumatic brain injury imaging in 2021:

> Advanced neuroimaging techniques, including MRI diffusion tensor imaging, functional MRI, MR spectroscopy, perfusion imaging, PET/SPECT and magnetoencephalography, are of particular interest in identifying further injury in TBI patients when conventional non-contrast head CT and MRI are normal, as well as for prognostication in patients with persistent symptoms. *At present, there is insufficient evidence supporting the routine clinical use of these advanced neuroimaging techniques for diagnosis and/or prognostication at the individual patient level*. This is the focus of ongoing research (emphasis in original) (Ref. 10, p 1).

Analogous perspectives feature in the literature pertaining to the neuropsychiatric approach to TBI. The American Psychiatric Association Publishing *Textbook of Traumatic Brain Injury, Third Edition*,[11] offers a chapter dedicated to clinical imaging,[12] and in that context notes the above referenced ACR appropriateness criteria. The chapter addresses various advanced imaging modalities, specifically noting DTI, MRS, SPECT, PET, MEG, and fMRI. Those imaging techniques are all noted to be "increasingly applied in research but are not yet part of standard clinical practice" (Ref. 12, p 110). Various challenges and limitations pertaining to specific techniques are noted. For example, in relation to DTI:

> . . . limitations and challenges associated with diffusion imaging have precluded widespread clinical use. . . The first relates to absence of normative data, because differences in both scanner hardware and software, parameters used at acquisition, and post processing techniques affect quantitative values derived from diffusion imaging. The second challenge is that the methods used in most group-based studies rely on standard population analyses, which assumes a common spatial pattern of pathology that is often not necessarily present in TBI. . . The third

> limitation of DTI is its lack of specificity in distinguishing different forms of pathology underlying alteration in diffusion metrics and the need for additional radiological-histological validation (Ref. 12, p 110-11).

The textbook, *Brain Injury Medicine: Principles and Practice, Third Edition*,[13] also includes a chapter dedicated to structural neuroimaging and addresses various imaging techniques and their clinical appropriateness.[14] Advanced neuroimaging techniques also are addressed, with the caveat that these represent "imaging modalities that are not yet included in standard clinical practice but are increasingly utilized in research" (Ref. 14, p 206). In this context, DTI, MRS, SPECT, PET, MEG, and fMRI are discussed. A separate chapter addressing neuroimaging correlates of functional outcome specifically offers some cautionary statements in relation to forensic applications:

> At this point, to use advanced neuroimaging findings forensically, careful clinical correlation is needed that takes into account all aspects of the history of injury and clinical course, premorbid factors, and acute and chronic conventional neuroimaging findings, as well as the potential limitations of the quantitative technique to be used. As normative data bases for advanced neuroimaging improve, including automated methods uniformly and reliably applied to the patient with TBI, these types of analyses will likely become routinely performed in research and clinical settings (Ref. 15, p 293).

The appropriate use of advanced neuroimaging in the setting of brain injury litigation remains a subject that generates controversy inside and outside the courtroom. That said, the prevailing position statements and guidelines from professional societies and the expert opinions offered in the current referenced textbooks in the field of brain injury medicine note that advanced neuroimaging techniques are powerful research tools that are nonetheless of marginal usefulness, at best, at the single-subject or individual patient levels.

This does not necessarily mean that medicolegal applications are entirely inappropriate, provided that results are presented in a manner consistent with the best evidence and in accord with the guidelines for the ethical use of neuroimages in medical testimony (i.e., at a minimum, prominent limitations are readily acknowledged and appropriate deference paid toward the nonspecificity of abnormalities identified via these techniques). Unfortunately, it is not uncommon to encounter expert opinions and testimony on advanced neuroimaging techniques in legal proceedings that fall short of these basic and ethically necessary acknowledgments.

For example, such opinions and testimony are not infrequently offered in circumstances involving the occurrence of a possible mild concussive injury after which follows a course of illness that defies the known natural history of concussion. In such a context, co-occurring neuropsychiatric, neurological, orthopedic, musculoskeletal, substance use, developmental, or psychosocial conditions not infrequently are left unaddressed in interpretative reports as potential contributors to or explanations for such atypical postinjury courses. I routinely encounter medical opinions or expert testimony about DTI or SPECT imaging studies that interpret them as essentially diagnostic of mild TBI and explanatory of associated neuropsychiatric impairment, despite a course of illness incompatible with the natural history of concussion and without regard for comorbid conditions like preexisting depression, chronic pain, sleep apnea, substance use or abuse, hypertension, and diabetes (to name but a few examples). In these cases, the problem is not so much the presentation of advanced neuroimaging findings in the medical opinions or expert testimony but instead that the opinions offered, and associated testimony, claim that the neuroimaging findings are diagnostic, validate subjective complaints, fully explain persistent symptoms after an increasingly remote concussion, or explain away clearly documented signs of symptom invalidity. It is important that consideration regarding the appropriateness of testimony based upon advanced neuroimaging reflects upon both the state of the science more generally, as well as the particulars pertaining to any given intended presentation. Stated differently, any given misapplication might run contrary to the science more generally (i.e., claiming a pattern specific or unique to mild TBI), while also failing to attend to specifics of the case at hand (i.e., overlooking co-occurring conditions, a course of illness incompatible with mild TBI, or prominent validity concerns).

Complicating matters is the fact that medical professionals engaging in mild TBI litigation as experts seldom have forensic training, let alone the training in neuropsychiatry needed to integrate clinical histories and presentations with complex combinations of cognitive, emotional, behavioral, sensory, motor, and other physical symptoms and signs with results from neuroimaging. While these physicians routinely hail from disciplines like neurology and physiatry, and bring considerable expertise in these areas, these are disciplines that do not afford opportunities for

formal fellowship training or certification in forensic assessment and practice, including the rules of evidence and the role of the medical expert.

These disciplines also are not subject to ethics guidelines applicable to forensic psychiatry (such as those published by AAPL),[16] which preclude mixing clinical and medicolegal roles. The implications of the absence of such guidelines and prohibitions makes it commonplace for a neurologist or physiatrist offering clinical services and treating entirely subjective complaints to simultaneously offer medicolegal opinions regarding their causation, and often to do so under conditions that fall short of accepted practices in forensic psychiatry. For example, it is not uncommon to encounter a clinician endorsing claimed cognitive impairment and headaches as a consequence of mild TBI, absent recognition or awareness of medical records more contemporaneous to the injury event which reveal an evolution in both illness and the narrative (e.g., late emerging claims of loss of consciousness or amnesia), and with modest ability to interpret or appreciate the salience of various signals and formal assessments of symptom invalidity.

Such circumstances are problematic, as they interfere with the efforts of all parties involved in such cases to adhere to guidelines governing forensic assessment and testimony by physicians. The *AMA Guide to the Evaluation of Disease and Injury Causation, Second Edition*,[17] is instructive in this regard. The AMA Guide speaks to the need to scrutinize the validity of evidence, as well as the prominence of malingering and the "pervasive avoidance of these evaluation components" (Ref. 17, p 509), which has been found in evaluations where malingering is not properly considered. The text reports that "approximately 50 percent of clinical presentations within a legal claim produce objective evidence of malingering" and that "to even minimally comply with the requirements of step 5 from a causation protocol, the analysis needs to include" coherent methods for approaching this subject (Ref. 17, p 509). The Guide goes on to state that "there is no credibility for a legal claim of mental illness unless this portion of the diagnostic system has been thoroughly considered and found to have no relevance to the case" (Ref. 17, p 509).

The point is that assessment for and consideration of malingering is a requisite component of sound methodology in any competent and objective medicolegal evaluation. Accomplishing that requisite component is problematic in the context of clinical care and establishing or maintaining therapeutic relationships and is all but impossible absent specific training in forensic assessment.

Of course, the above-described problems could be obviated by more formalized medicolegal training being made available to various medical specialties and subspecialties, and by adopting more broadly applicable guidance on the separation of clinical and medicolegal roles. Given the domains of impairment so common after TBI, including cognition, emotion, and behavior, this work itself suggests, or very strongly calls for, a role for the forensic psychiatrist in such cases. Unfortunately, psychiatry's historical disregard of TBI as a condition of interest and a contributor to psychiatric morbidity has been rather inauspicious, a circumstance which in turn has resulted in a modest role for forensic psychiatry in TBI litigation. But that era should be drawing to an end with the increasing appreciation of the psychiatric and neuropsychiatric aspects of TBI, with the thoughtful treatment of TBI and its sequelae in the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5)[18,19] and its upcoming text revision, and the widely available continuing medical education opportunities on TBI for psychiatrists. All of these developments should facilitate psychiatrists' effective engagement in the evaluation and management of persons with history of brain injury and further the efforts of forensic experts in our fields to offer well-informed and ethical testimony on such cases.

The DSM-5,[18] released in 2013, represents a major advancement over prior versions of the manual, and one which should serve to dramatically improve the evaluation of persons with history of TBI by various mental health professionals. This manual features well-accepted criteria for identifying and characterizing TBI across the spectrum of severity, thereby facilitating important clinical distinctions between mild TBI and moderate to severe injuries. The manual also offers cogent information regarding the natural history for mild TBI, and recommendations applicable to cases wherein atypical courses of illness manifest:

> Neurobehavioral symptoms tend to be most severe in the immediate aftermath of the TBI. Except in the case of severe TBI, the typical course is that of complete or substantial improvement in associated neurocognitive, neurological, and psychiatric symptoms and signs. Neurocognitive symptoms associated with mild TBI tend to resolve within days to weeks after the injury with complete resolution typical by 3 months. Other symptoms

> that may potentially co-occur with the neurological symptoms (e.g., depression, irritability, fatigue, headache, photosensitivity, sleep disturbance) also tend to resolve in the weeks following mild TBI. Substantial subsequent deterioration in these areas should trigger consideration of additional diagnoses (Ref. 18, p 626).

The applicable differential in such instances is broad but involves many common conditions which psychiatrists (and forensic psychiatrists) are especially adept at identifying, such as depression, anxiety, PTSD, medication effects, substance abuse, disrupted sleep, chronic pain, and a spectrum involving somatization, factitious symptoms, and malingering.

With additional time and practice, mental health professionals will gain the requisite experience in this clinical context to allow for the sort of expertise which should in turn facilitate medicolegal assessment in matters involving TBI. The forensic psychiatrist should then be able to meld the applicable clinical expertise in brain injury neuropsychiatry with the training and ethics requirements applicable to forensic practice, enabling a relatively unique ability to offer optimal medicolegal assessment. The need for provision of such services by forensic psychiatrists in brain injury litigation is long overdue.

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