Current Neurology and Neuroscience Reports (2018) 18:47
https://doi.org/10.1007/s11910-018-0853-3

BEHAVIOR (H S KIRSHNER, SECTION EDITOR)

Neuroimaging Abnormalities in Neurological Patients with Criminal Behavior

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Abstract

Purpose of Review Criminal behavior occurs in previously law-abiding neurological patients, including patients with traumatic brain injury, focal brain lesions, and dementia. Neuroimaging abnormalities in these patients allow one to explore the potential neuroanatomical correlates of criminal behavior. However, this process has been challenging because (1) It is difficult to determine the temporal relationship between criminal behavior and neurological disease onset; (2) Abnormalities in several different brain regions have been associated with criminal behavior; and (3) It is difficult to quantify neuroimaging abnormalities in individual subjects.

Recent Findings Recent studies have begun to address these concerns, showing that neuroimaging abnormalities in patients with criminal behavior localize to a common brain network, rather than a single specific brain region. New methods have been developed to identify atrophy patterns in individual patients, but have not yet been used in neurological patients with criminal behavior.

Summary Future advances will be important for making sure that neuroimaging data is used in a responsible manner in legal cases involving criminal behavior.

Keywords Criminal · Moral · Brain lesions · Neurology · Frontal lobe · Brain networks

Introduction

Neurological diseases can cause profound changes to behavior. In 1838, a railroad worker named Phineas Gage had an iron rod blasted through the front of his brain. Remarkably, he survived without notable deficits to his motor skills, language, or memory. Yet, his personality and behavior changed markedly. He was described as "fitful, irreverent, indulging at times in the grossest profanities (which was not previously his custom), manifesting little deference for his fellows, impatient of restraint or advice when it conflicts with his desires." [1].

In 1966, Charles Whitman developed headaches, obsessive writing, and disturbing, violent thoughts culminating in the murder of his wife, mother, and 14 innocent bystanders before he was killed by police [2]. At autopsy, he was found to have a malignant tumor in his right temporal lobe, prompting questions about the degree to which his brain injury contributed to his behavior.

In 1991, Herbert Weinstein, a 65-year-old with no prior history of violence, strangled his wife after an argument, and then threw her body from a window to make her death appear like a suicide [2, 3, 4•]. On a structural MRI scan, he was found to have a large cyst in the left frontal lobe, with associated hypometabolism in the cortex adjacent to the cyst on FDG-PET. His defense attorneys argued that he should be not be held responsible for his crime because the frontal cyst had resulted in a mental defect that made him unable to fully conform his behavior to the law.

The study of these and other patients with criminal behavior as a result of brain injury, referred to as "acquired sociopathy" [5] or "pseudo-psychopathy" [6], allows one to test associations between specific brain regions and moral behavior. Additionally, because there are similarities between patients with acquired sociopathy and criminals without clear brain pathology, these cases have lent insight into antisocial behavior more generally [7].

This article is part of the Topical Collection on *Behavior*

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Published online: 14 June 2018

The Weinstein case illustrates that neuroimaging abnormalities associated with criminal behavior are being applied beyond scientific questions to individual legal cases. Neuroimaging, neuropsychological, and/or neurological exam testing has been included in at least 800 criminal cases in the USA over the last two decades [8•]. This includes 366 defendants in capital punishment cases and 80 other defendants given life sentences [8•]. One hundred fifty-four cases made explicit neurological diagnoses, including 63 cases with a diagnosis of dysfunction in a particular cortical lobe, 44 with organic brain damage, 14 with organic brain disease, and 33 with mental retardation [8•]. Even in other cases without an explicit neurological diagnosis, evidence was often presented to prove that the defendant had brain damage (271 cases) or a head injury (178 cases) [8•].

Despite the increasing use of neuroimaging in the courtroom, its use remains controversial due to the difficulty in determining the relationship between neuroimaging abnormalities, abnormal behavior, and legal responsibility. This article attempts to use neurological patients as a starting point to address these difficulties. Neurological patients offer an advantage because of the ability in many cases to clearly define abnormalities on neuroimaging and to fit changes in behavior that may be legally relevant to behavioral changes known to be associated with specific diseases. First, I will review evidence for the association between neurological diseases and criminal behavior by examining the incidence of neurological diseases in criminals and the incidence of criminal behavior in neurological patients. Next, I will discuss the crucial gaps in the literature, focusing on important scientific questions that will need to be addressed for neuroimaging findings in neurological patients to be applicable to legal questions. Finally, I will discuss new insights and future directions in the use of neuroimaging to understand criminal behavior in neurological patients, with potential implications for the use of neuroimaging in the law more broadly.

Incidence of Neurological Abnormalities in Criminals

The degree to which neurological disease contributes to criminal behavior is difficult to estimate. Some studies have investigated the incidence of neurological disease in persons who have already committed crimes. For instance, in one study, 64.5% of murderers were found to have frontal lobe dysfunction on examination, and approximately 47% had reportedly abnormal neuroimaging [9]. However, results were complicated by the fact that nearly all had evidence of paranoid delusions and the majority had experienced some form of physical and/or sexual abuse, making it unclear the degree to which neurological disease, psychiatric disease, and/or social factors contributed to criminality.

Two meta-analyses have looked at the incidence of traumatic brain injury (TBI) in criminals. Farrer et al. (2011) found a pooled incidence of TBI in approximately 41% of incarcerated prisoners, compared to population estimates of TBI in non-criminals ranging from 2 to 38% [10]. However, these population estimates were based on separate papers using different populations and screening methods; almost none of the studies actually assessed the prevalence of TBI in matched non-prison populations within the same study. A more recent meta-analysis came to a similar cautionary conclusion; while they found a pooled incidence of 46% for TBI in prison populations, the authors noted that many of the studies included were highly flawed [11]. First, most relied on self-reports of TBI, which may be inaccurate. Second, most studies are unable to determine whether a propensity for violence and risky behavior (drug/alcohol abuse) led to increased incidence of TBI. In fact, most studies found a high association between drug/alcohol abuse and both TBI and criminality, complicating the interpretation. This also highlights the difficulty in determining the temporal relationship between criminal behavior and head trauma, as antisocial behavior may predispose one to head trauma rather than head trauma leading to antisocial behavior. Finally, the severity of TBI between studies varied, ranging from mild loss of consciousness (LOC) to more prolonged coma. Importantly, mild TBI is not typically associated with neuroimaging findings and the significance of any findings to subsequent behavioral changes is often unknown.

Several other studies have tested for neuroimaging abnormalities in prison populations specifically. In a study of 287 male prisoners incarcerated for violent (125) vs. nonviolent (162) crimes who had MRI scans done for other clinical purposes, the incidence of abnormalities was high: 46% of patients with violence and 26% of nonviolent offenders had abnormalities on neuroimaging, compared to just 8% in an age-matched non-criminal sample [12]. In a follow-up focusing on 148 patients in a forensic mental health prison, the incidence of brain pathology was 46% [13]. Both studies utilized a semi-structured, blinded assessment of neuroimaging abnormalities, which may be prone to bias and prohibits more precise localization of neuroimaging abnormalities. Further, it is impossible to determine the temporal association between these neuroimaging abnormalities and the onset of criminality. Nevertheless, these studies provide compelling evidence of an increased incidence of neuroimaging abnormalities in criminal populations compared to non-criminal populations.

Criminal Behavior in Neurological Patients

Traumatic Brain Injury

In patients with non-penetrating TBI, violence or crime occurs in approximately 9% of patients [14, 15]. However,

penetrating head trauma offers a better model for determining the relationship between damage to specific brain regions and criminal behavior. Fourteen percent of patients with penetrating head trauma and injury to the frontal lobes demonstrated episodes of violence, while rates of violence were not increased with damage to other cortical regions [16]. Even in cases of penetrating head trauma, the causal link between TBI and criminal behavior remains uncertain because of numerous confounds. As discussed previously, it is possible that criminal behavior is a risk factor for TBI, and not vice versa. This hypothesis is supported by findings that pre-TBI criminal behavior, drug/alcohol abuse, and violence as the reason for TBI are all significant predictors of subsequent violence following TBI [17].

Focal Brain Lesions

Focal brain lesions that are not due to trauma can help to avoid some of the potential confounds mentioned above. However, studies examining the link between strokes, tumors, or other types of focal brain lesions and criminal behavior are limited. Many single-case reports and small-case series point towards a range of brain lesion etiologies associated with criminal behavior [2, 18••, 19]. While avoiding some confounding factors with TBI, there are several important limitations when considering the association between other types of brain lesions and criminal behavior. Because not all patients with a brain lesion to a given location will commit a crime, other factors are likely also important, including genetic risk factors [20], age at the time of a lesion [21–23], lesion etiology [24], and environmental, social, and personality factors [25••]. Focal brain lesions offer the possibility to examine the neuroanatomical structures most associated with criminal behavior, but the small number of cases in any individual report, and heterogeneity of the brain regions implicated, have made such attempts difficult.

Neurodegenerative Disorders

Criminal behavior is occurs in patients with dementia, particularly patients with frontotemporal dementia (FTD), semantic dementia (SD), and Huntington's disease (HD) (Table 1). Early in the disease course, patients with FTD can present with bizarre and socially inappropriate behaviors leading to legal and moral transgressions in the absence of significant impairment in memory, reasoning, or social knowledge. It is estimated that between 37 and 57% of bvFTD patients have committed a crime [26–29], including up to 14% as the reason for initial presentation [29]. Common examples include shoplifting, sexual crimes, financial crimes, and occasionally, violence. Patients who have committed a crime are able to describe in detail the potential negative consequences of these actions, but demonstrate little signs of remorse [27] and perform similar to control patients when asked directly about the wrongfulness of immoral behaviors [30]. Patients with SD also have high rates of criminal behavior, ranging from 21 to 55%. Patients with HD have been reported to have a higher prevalence of criminal behavior vs. non-carrier family members [31, 32], with estimates of approximately 18–27%. In contrast, criminal behavior in Alzheimer's disease is more rare, with estimates ranging from 5 to 12%. In many cases, these are primarily due to cognitive and memory issues, such as forgetting to pay for groceries [29]. The prevalence of criminal behavior in Parkinson's disease (PD) is unknown, but is suspected to be higher in PD patients with impulse control disorder (ICD), especially related to hyper-sexuality and paraphilia [33].

Neurodegenerative disorders can also be used to study the link between damage in specific brain regions and criminal behavior. Moreover, factors like childhood trauma, substance abuse, genetic factors associated with violence, and premorbid antisocial and psychopathic personality traits are less likely to directly contribute to the development of dementia, allowing for researchers to more easily control for these confounding effects. However, there have been no prior studies assessing neuroimaging markers associated with criminal behavior in dementia patients. Further, such comparisons are typically made at the group level, and deriving objective, quantitative measures of neuroimaging abnormalities at the individual level in dementia patients is challenging.

Table 1 Rates of criminal behavior in neurodegenerative diseases

Study	AD	FTD	SD	HD
Liligren [29]	42/545	64/171	24/89	6/30
Mendez [27]	2/28	16/28		
Miller [26]	1/22	10/22		
Diehl-Smidt [28]	4/33	17/32	10/18	
Jensen [31]				27/99
Dewhurst [32]				18/102
Shinagawa [34]	13/225	24/73	18/84	
Total	62/853 (7%)	131/326 (40%)	52/191 (27%)	51/231 (22%)

Challenges in Applying Neuroscience Research to the Legal Setting

Neuroimaging in clinical practice is used to confirm a neurological diagnosis and to help determine expected progression of symptoms over time based on disease etiology. In certain circumstances, this information may be useful in the legal setting. In focal brain lesion cases, for example, neuroimaging could help to determine whether a neurological disease likely contributed to a patient's behavior based on the expected timing and evolution associated with a lesion's etiology (e.g., tumor vs. stroke). In neurodegenerative diseases including FTD and AD, expected neuroimaging abnormalities help to improve the confidence of a clinical diagnosis from possible to probable [35, 36]. In other cases, neuroimaging findings would be less useful: the impulse control disorder as a consequence of dopaminergic therapy for Parkinson's disease is a clinical diagnosis that is not aided by clinical neuroimaging [37].

Another important legal question is whether a neuroimaging abnormality is incidental vs. related to a defendant's criminality. Answering this question is challenging for three reasons. First, as discussed above, the temporal association between a neuroimaging abnormality and subsequence criminality is often unclear or unknown. Second, many different brain regions have been associated with criminal behavior, making defining the neuroanatomical regions specifically associated with criminal behavior challenging. Finally, the likelihood that a given neuroimaging finding contributed to criminal behavior is difficult to determine because the rate of criminal behavior associated with damage to specific brain regions is unknown. Part of this difficulty is because many neuroimaging abnormalities, such as atrophy in dementia patients, are subtle. Because of this, neuroimaging abnormalities subjectively described by expert witnesses are highly prone to bias and are unreliable compared with more quantitative, objective measures [38].

New Insights

A recently published paper sought to address some of these concerns, providing the first systematic mapping of brain lesions causing criminal behavior to a specific network of brain regions [18••]. The authors found 17 cases from the literature where a strong temporal association between a brain lesion and the development of criminal behavior could be made. In each case, patients were reported to have normal behavior, suffer a focal brain lesion, and subsequently, developed criminal behavior. However, the brain lesions occurred in several different locations in the frontal and temporal lobes, with no common localization for even the majority of lesions. The authors then used a new technique called lesion network mapping [39–44] to show that while the lesions themselves occurred in different locations, they were all part of a common, functionally connected brain network. This network is normally active during moral decision-making tasks, providing a strong rationale for why damage to this network would result in criminal behavior. Control lesions that did not cause criminal behavior were not part of this network, demonstrating specificity of this network to those lesions associated with criminal behavior. Finally, the authors replicated their findings in a cohort of patients where the association between a brain lesion found on neuroimaging and subsequent criminal behavior was unknown.

Taken together, the above study addresses some, but not all, of the limitations in applying neuroimaging data to the courtroom. First, the study included a small number of patients (17 in the initial cohort with a strong temporal association between the lesion and criminal behavior and 23 in the follow-up cohort with uncertain association). Replication of these findings in a larger cohort will be important. Second, the study examined only patients with focal brain lesions. Future studies will need to address whether this same network of brain regions is abnormal in patients with dementia or other neurological diseases resulting in criminal behavior. Finally, the authors importantly point out that they could not determine the specific rate of criminal behavior in patients with damage to a given location in this network.

Future Directions: Quantitative Measures of Neuroimaging Abnormalities in Individual Patients

The majority of neuroimaging data used in criminal cases alleges to show subtle changes in brain volume (e.g., atrophy on MRI) or function (e.g., hypometabolism on FDG-PET). As discussed above, such determinations are often made subjectively by expert witnesses. However, new neuroimaging techniques are being developed to allow for objective measures of neuroimaging abnormalities in individual patients. With large amounts of neuroimaging data and advanced computational capacities, researchers are now able to compare an individual patient's brain image against a large cohort of "normal" brains, matched for important covariates including age and gender [45]. Using these normal brain scans as an estimate of the population, researchers can determine whether atrophy, metabolism, or other neuroimaging measures fall significantly outside of this expected distribution [46–52]. Using this approach, future research could address whether abnormalities in specific regions are more common in criminals vs. appropriately matched controls, and to determine the rates of criminal behavior associated with abnormalities in specific brain regions. This would improve the validity and reproducibility of neuroimaging interpretations in criminal cases, potentially addressing some of the ethical concerns with the inappropriate use of neuroimaging in the courtroom [53–55].

Limitations and Conclusion

An important limitation in the use of neuroimaging in legal cases of criminal behavior is whether neuroimaging findings can fundamentally aide in determining whether a patient should have diminished responsibility for a crime. Criminal responsibility is diminished when a defendant's mental state impairs the ability to appreciate, understand, or conform his or her behavior to the law. While neuroimaging findings can provide a mechanistic explanation to support an impaired mental state, behavioral testing is clearly necessary. Though outside the scope of this article, the identification of the brain regions associated with criminal behavior may point towards the cognitive and emotional processes that are most important to diminished capacity, but that are often not adequately assessed [55, 56•, 57].

Also outside the scope of this article is the use of neuroimaging for the prediction of future dangerousness and criminal recidivism [38, 58, 59•, 60]. Many of the challenges discussed, including the need for quantitative individual measures of neuroimaging abnormalities, will be important for neuroprediction as well. The use of neuroimaging for these purposes also raises important and unique ethical considerations. Additional questions include whether understanding the mechanisms leading to criminal behavior could lead to preventative treatments in the future [61, 62].

In summary, while incomplete, the current evidence supports the hypothesis that neurological diseases can increase the likelihood of criminal behavior. Neuroimaging allows for better diagnosis of these conditions, and is beginning to provide a neuroanatomical localization for criminal behavior. Important advances, such as the development of tools to quantify individual patient neuroimaging abnormalities and to localize abnormalities to networks rather than specific locations, will provide further insight into the neural mechanisms associated with criminal behavior.

Compliance with Ethical Standards

Conflict of Interest R. Ryan Darby declares no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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