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Case Report
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Brain Imaging Mitigating Evidence of Seizure Disorder in Triple Homicide

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Abstract

There is a growing body of work correlating various neuro-cognitive disorders with criminality. In this case study, the defendant murdered his wife and her two children. A history of previous childhood epilepsy, mental health disorders, and an abnormal resting F-18 FDG-PET were presented as evidence to challenge his full culpability. Using clinical neuroimaging methods and Statistical Parametric Mapping, the defendant's PET scans were analyzed for abnormal metabolism in regions of interest relative to 16 neurologically normal controls. Clinical documentation of repeated traumatic brain injury, seizure disorders, mood disorders, and abnormal PET scans resulted in the mitigation of capital punishment. Clinical neuroimaging has shown great utility in the mitigation phase of criminal law and can help us better understand the neuroanatomical correlations of brain function and behavior.

Keywords: Case report; Violent crime; Epilepsy; Emotional stress; Head trauma; FDG-PET imaging

Abbreviations: WAIS-IV: Wechsler Adult Intelligence Scale Fourth Edition; WMS-IV: Wechsler Memory Scale Fourth Edition; SPM: Statistical Parametric Mapping; VCI: Verbal Comprehension Index; PRI: Perceptual Reasoning Index; AMI: Auditory Memory Index; VMI: Visual Memory Index; PSI: Processing Speed Index; VWMI: Visual Working Memory Index; IMI: Immediate Memory Index; DMI: Delayed Memory Index

Highlights

i) We report a case of violent homicidal criminality associated with seizure spectrum disorder.

ii) FDG-PET imaging analysis and intellectual functioning tests corroborate the possibility that the patient has temporal lobe epilepsy.

iii) Seizure likely triggered by emotional stressor, followed by postictal violence and confusion.

iv) Documents the potential of neuroimaging analysis being utilized in criminal defense.

Introduction

Many studies have observed a link between seizure spectrum disorders like epilepsy, and violent behavior in both criminal and patient populations [1-3]. However, the link between epilepsy and violent crime should be examined with a critical eye; this long-held belief of a link between epilepsy and violent crime has been challenged in a longitudinal study involving the Swedish population over 36 years [4]. Brain damage that is concomitant with cause of epilepsy could complicate the narrative, as studies often fail to fully distinguish between aggression linked to seizure activity and behaviors that are related to factors such as underlying brain dysfunction, thus indirectly or less directly related to epilepsy. Structural brain injury related to trauma or encephalitis is commonly associated with the development of epilepsy, but a causal role for epilepsy in interictal violent behavior is not established [5]. Despite this muddled narrative on the association of epilepsy with violence, ictal rage and postictal psychosis are well documented phenomena often associated with violence. Ictal rage are episodes that are usually sudden in onset and brief. These can be accompanied or followed by retrograde amnesia for the incident, though aggression is generally not directed [5,6]. Postictal psychosis (PIP) on the other hand, can last days or weeks, and is associated with well-directed episodes of aggression [5,7]. This study documents a patient suffering from seizure disorder who committed a violent crime after an intense emotional trigger and aims to quantify their 18F FDG-PET imaging abnormalities.

Case Report and Background

Summary of charges

In the early hours of October 23, 2013, the defendant, Luis Toledo, 31, killed his wife after becoming enraged from discovering that she was having an affair. Toledo had suspected his wife of having an affair, which he confirmed by placing a spying device on her phone, and the couple agreed to end their marriage. That night between 1 am and 6 am, he killed his wife and her two children. He had been a loving and involved stepparent previously. He was interrogated in jail following the disappearance of his family. He admitted to killing his wife but denied that he was responsible for murdering her two children. Toledo claimed instead that his neighbor was at their house during his wife's murder and was responsible for killing her children to eliminate them as witnesses. He also claimed that his neighbor left to dispose of the bodies and demanded $10,000 from him to remain quiet about the events. Toledo attempted suicide on October 25th during a subsequent interview. He was charged with first degree murder. Toledo has refused to reveal the location of the bodies of his wife and two children, and still believes his own claim that his neighbor killed the two children and disposed of the bodies. The jury voted 10 to 2 to recommend a death sentence for Toledo, but in the State of Florida, a unanimous recommendation was required for the judge to have the option of sending Toledo to death row. Instead, he was given three consecutive life-sentences and an additional five years for evidence tampering to run consecutively.

Patient history

Toledo has an extensive history of neurological conditions. Records from the Volusia County Public School system indicate that he was in an emotionally handicapped program in school for children with mental health and behavioral conditions. Records from Lincoln Medical and Mental Health Center indicate that he was diagnosed with a seizure disorder and attention deficit disorder in July of 1993 after being hit in the forehead by a ball. According to a report from North Florida Evaluation and Treatment Center, in October of 2002, Toledo was admitted as incompetent to proceed on prior charges of armed burglary, robbery with a firearm, and kidnapping. A psychological evaluation was done, following which he was diagnosed as malingering, and deemed competent to proceed. According to records available from the Florida Department of Corrections, medical and psychiatric notes indicate that he was diagnosed with major depressive disorder, antisocial personality disorder, and borderline personality traits. It is also noted that he has a history of seizure disorder. He was treated with Remeron, Risperdal, Geodon, Zyprexa, and Seroquel, a cocktail of antidepressants and antipsychotics.

A summary of outpatient mental health care notes documents multiple suicide attempts, prosecutorial delusions, unstable mood and anger control problems. Another individual service plan review dated June 5, 2008, notes a diagnosis of bipolar disorder. He stopped taking medications due to their side effects. Additional personal history was provided by Toledo. He was raised by his biological parents and believes that both his sisters were treated for depression, and a paternal aunt possibly suffered from schizophrenia. He reports having been physically abused during his childhood by his mother, and reports that at the age of 6, he ran into a wall, and was hospitalized after suffering a concussion. He also reports a family history of amyotrophic lateral sclerosis, to which he lost his father as a teenager. In 1997, he was in a major car accident which resulted in lower back injuries. He believes that he suffered another concussion during the accident. He was in the ICU for four days, and experienced difficulties with memory and concentration following the accident, which improved over time. While incarcerated in 2008, he had a history of cutting himself, though he denies any recent thoughts of self-harm. He also denies experiencing any psychotic symptoms such as hallucinations, delusions, severe paranoia, or disorganization of thoughts, though he does report a history of symptoms consistent with mania.

Methods

Psychological evaluation

The Wechsler Adult Intelligence Scale – Fourth Edition (WAIS—IV) is used to assess intellectual ability in adults and adolescents and provides information about specific cognitive abilities across various domains. This assessment was used to summarize the defendant's overall intellectual functioning using different composite scores. The defendant was also administered 10 subtests of the adult battery of the Wechsler Memory Scale – Fourth Edition (WMS—IV). This assessment was used to evaluate the defendant's memory.

Positron emission tomography

The brain imaging scans were obtained on December 16, 2015, two years after the defendant committed the triple homicide. The 18F-FDG PET brain scan was used to assess the defendant's regional brain metabolism, and quantitatively compare his values to 16 neurologically normal controls. The patient's PET scans were then processed in MATLAB (MathWorks, Sherborn, Massachusetts, USA) using Statistical Parametric Mapping (SPM) 5 software (Functional Imaging Laboratory, Welcome Department of Cognitive Neurology, University College London, London, UK) to spatially transform the images to a template conforming to the space derived from standard brains from the Montreal Neurological Institute and convert it to the space of the stereotactic atlas of Talairach and Tournoux. The images were then smoothed with a Gaussian low-pass filter of 8mm to minimize noise and improve spatial alignment. Contrast overlay images showing regions of significantly increased or decreased metabolism were then generated in MATLAB using SPM8 software. Positive and negative contrasts were generated using the probability threshold of 0.01 and voxel threshold of 30. The normalized patient scans, contrasts, and scans of the 16 neurologically normal controls were

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then statistically analyzed using VINCI to obtain volume values in each region of interest. SPM maps show greater sensitivity to detecting abnormalities compared to visual analysis due to the quantitative properties of this method.

Results

Psychological evaluation

The defendant has a unique set of thinking and reasoning abilities that set him apart, making it difficult to assess his overall intelligence using a single score from WAIS—IV (See Table 1). The defendant's verbal reasoning abilities, measured by the Verbal Comprehension Index (VCI) is at 10th percentile (VCI = 81; 95% confidence interval = 76-87). The defendant's Working Memory Index score, which measures his ability to sustain attention, concentrate, and exert mental control, was in the 50th percentile (WMI = 100; 95% confidence interval 93-107). He displays strong nonverbal reasoning abilities. This was measured by the Perceptual Reasoning Index (PRI), in which he scored in the 73rd percentile (PRI = 109; 95% confidence interval = 102-115). The PRI measures fluid reasoning, with tasks that assess nonverbal concept formation, visual perception and organization, visual-motor coordination, learning, and visual processing of stimuli. The defendant also performs well at processing visual material quickly, indicated by his Processing Speed Index score (PSI), which was in the 70th percentile (PSI = 108; 95% confidence interval 99-116). The defendant also took the WMS—IV, from which these composite index scores were derived.

Table 1: Toledo's Wechsler Adult Intelligence Scale – Fourth Edition (WAIS—IV) and Wechsler Memory Scale – Fourth Edition (WMS—IV) scores.

	Index	Score	SEM	Percentile
Verbal Comprehension Index	VCI	81	3	10
Perceptual Reasoning Index	PRI	109	3	73
Working Memory Index	WMI	100	3.35	50
Processing Speed Index	PSI	108	5.41	70
Full Scale Intelligence Quotient	FSIQ	98	2.12	45

WAIS IV Scores and Standard Error of Measurement

Index	Sum of Scaled Scores	Index	Percentil e Rank	95% Confidence Level	Qualitative Description
Auditory Memory	31	AMI	87	19	Low Average
Visual Memory	42	VMI	103	58	Average
Visual Working Memory	18	VWMI	94	34	Average
Immediate Memory	39	IMI	98	45	Average
Delayed Memory	34	DMI	90	25	Average

The Auditory Memory Index (AMI) is a measure of Luis's ability to listen to oral information and repeat it immediately and then recall the information after a 20–30-minute delay. Compared to his peers, the defendant's auditory memory capacity is in the low average range (AMI= 87; 95% confidence interval = 81-94). On the Visual Memory Index (VMI), a measure of memory for visual details and spatial location, the defendant performed in the average range (VMI = 103; 95% confidence interval = 97-109). The defendant scored in the average range on Visual Working Memory Index (VWMI), a measure of his ability to temporarily hold and manipulate spatial locations and visual details (VWMI = 94; 95% confidence interval = 87-102). On the Immediate Memory Index (IMI), the defendant scored in the average range (IMI = 98; 95% confidence interval= 92-104). The IMI is a measure of the defendant's ability to recall verbal and visual information immediately after the stimuli is presented. On the Delayed Memory Index (DMI), a measure of the ability to recall verbal and visual information after a 20–30-minute delay, the defendant performed in the average range (DMI = 90; 95% confidence interval = 84-87).

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Positron emission tomography

PET scan analysis indicated an abnormal decrease in metabolism in the left orbitofrontal lobe, with a relative metabolic value of 1.03 in the defendant compared to 1.34 in controls, Std. Deviation = 0.13, Z-score = -2.46, P-Score = 1.4E-02. There was also an abnormal decrease in metabolism in the left superior frontal gyrus, with a relative metabolic value of 0.88 in the defendant compared to 1.33 in controls, Std. Deviation = 0.17, Z-Score = -2.65, P-Score = 8.0E-03. Furthermore, the PET scan also indicated that there was a salient abnormal decrease in metabolism in the right posterior inferior temporal gyrus, with the defendant having a relative metabolic value of 0.72 compared to 1.12 in controls, Std. Deviation = 0.10, Z-Score = -4.03, P-Score 5.5E-05. Furthermore, several regions of abnormal increases in metabolism were found. The defendant exhibited an increased metabolic value of 1.24 in the left superior temporal gyrus compared to 0.91 in controls (Std. Deviation = 0.13, Z-Score = 2.46, P-Score = 1.4E-02). There was also a region of increased metabolic value in the defendant's left thalamus, 1.13 compared to 0.86 in controls (Std. Deviation = 0.08, Z-Score = 3.23, P-Score = 1.2E-03). The PET scan also indicated that the defendant had an increased metabolic value in his right temporal pole, 1.14 compared to 0.87 in controls (Std. Deviation = 0.11, Z-Score = 2.39, P-Score = 1.7E-02).

Whole brain analysis did not show significant diffuse changes. Toledo shows a statistically insignificant increase in overall metabolic value in his neocortex (1.02 compared to 0.99 in controls, Std. Deviation = 0.02, Z-score = 1.67, P-Score = 9.4E-02) and cerebellum (1.06 compared to 0.96 in controls, Std. Deviation = 0.08, Z-score = 1.40, P-Score = 1.6E-01). The neocortex to cerebellum metabolic value ratio was found to be 0.96 in the defendant, while in controls it was 1.04 (Std. Deviation = 0.08, Z-score = -1.02, P-Score = 0.16) which was statistically non-significant. His frontal lobe and occipital lobe showed no significant difference in metabolic activity (1.14 compared to 1.11 in controls, Std. Deviation = 0.06, Z-score = 0.46, P-Score = 6.4E-01). The defendant also exhibited no significant differences in frontal to occipital lobe metabolic ratio (0.94 compared to 0.96 in controls, Std. Deviation = 0.07, Z-score = -0.32, P-Score = 7.5E-01) (See Figure 1 & Table 2).

Table 2: Quantitative analysis of metabolic values in Regions of Interest (ROI) and in whole lobes, Toledo vs controls, corresponds with Figure 1.

FDG-PET REGIONAL ROI ANALYSIS	Toled o	Average	StD	Z-Scor e	P-Score
Left Orbitofrontal Lobe, Superior Frontal Gyrus, Gray Matter, Brodmann area 11	1.03	1.34	0.13	-2.46	1.40E-02
Right Temporal Lobe, Inferior Temporal Gyrus, Gray Matter, Brodmann area 37	0.72	1.12	0.1	-4.03	5.50E-05
Left Frontal Lobe, Superior Frontal Gyrus, Gray Matter, Brodmann area 10,	0.88	1.33	0.17	-2.65	8.00E-03
Left Temporal Lobe, Superior Temporal Gyrus, Gray Matter, Brodmann area 38	1.24	0.91	0.13	2.46	1.40E-02
Left Cerebrum, Sub-lobar, Thalamus, Gray Matter	1.13	0.86	0.08	3.23	1.20E-03
Right Temporal Lobe, Superior Temporal Gyrus, Gray Matter, Brodmann area 38	1.14	0.87	0.11	2.39	1.70E-02
FDG-PET WHOLE LOBE ROI ANALYSIS	**Toled o**	**Average**	**StD**	**Z-Scor e**	**P-Score**
Neocortex	1.02	0.99	0.02	1.67	9.40E-02
Cerebellum	1.06	0.96	0.08	1.4	1.60E-01
Neocortex/Cerebellum Ratio	0.96	1.04	0.08	-1.02	3.10E-01
Frontal Lobe	1.07	1.07	0.05	0.07	9.40E-01
Occipital Lobe	1.14	1.11	0.06	0.46	6.40E-01
Frontal/Occipital Lobe Ratio	0.94	0.96	0.07	-0.32	7.50E-01

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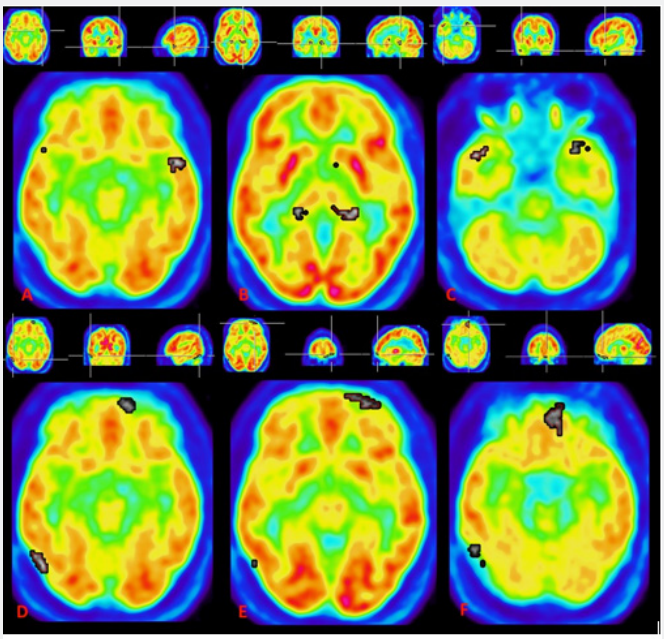

Figure 1: FEG-PET imaging study with findings of statistically significant metabolic abnormalities in Toledo in gray, (corresponds with table 2). A, B, C are regions of hypermetabolism while D, E, F are regions of hypometabolism.

a. Left Cerebrum, Temporal Lobe, Superior Temporal Gyrus, Gray Matter, Brodmann area 38, Hypermetabolism.
b. Left Cerebrum, Sub-lobar, Thalamus, Gray Matter, Hypermetabolism.
c. Right Cerebrum, Temporal Lobe, Superior Temporal Gyrus, Gray Matter, Brodmann area 38, Temporal Pole, hypermetabolism.
d. Right Cerebrum, Temporal Lobe, Inferior Temporal Gyrus, Gray Matter, Brodmann area 37, Hypometabolism.
e. Left Cerebrum, Frontal Lobe, Superior Frontal Gyrus, Gray Matter, Brodmann area 10, Hypometabolism.
f. Left Cerebrum, Orbitofrontal Lobe, Superior Frontal Gyrus, Rectal Gyrus, Gray Matter, Brodmann area 11, Hypometabolism.

Discussion

Despite existing perceptions on the link between epilepsy and violence, the tenuous relationship between epilepsy spectrum disorders and violence should be critically examined [4,5]. Documentation of Toledo and his neurological abnormalities may help us understand the neurobiological basis of violence in relation to epilepsy spectrum disorder. This case report aims to document and characterize cognitive deficits with findings in FDG-PET imaging. Despite the heinous nature of the crime and the homicide of his two stepchildren, the jury ultimately voted to give him life without parole, forgoing the death penalty. The FDG PET imaging likely played a key role in persuading the jury, demonstrating the utility of clinical brain imaging studies in criminal sentencing trials. Neuroimaging, previously utilized primarily for research and clinical practice, is being increasingly utilized in law. The link between prefrontal deficits and incidence of violent crime is growing [8]. Neurological evidence of cognitive impairments could mitigate culpability of a committed crime, and although there is strong opposition to the admissibility of neurological studies being used in sentencing trials, neuroimaging analysis can offer us the opportunity to understand the correlations between clinical findings and observed behaviors.

Conclusion

We observed bilateral hyperactivity in Toledo's temporal lobes. Though hyperactivity is generally atypical in interictal PET imaging, interictal rat models have shown bilateral hypermetabolism in the amygdala/hippocampus complex [9] and increases in focal cortical glucose metabolism has been found to occur in some epilepsy patients with malformations of cortical development [10]. Furthermore, heightened metabolic activity in the neocortex, as seen in the defendant, is often observed in patients during a sub-ictal discharge or during the early postictal phase [11]. Critically, the observed heightened metabolism in the defendant's Left Superior Temporal Gyrus provides evidence that he may have left temporal lobe epilepsy [3], which has been correlated with higher incidence of violent crime [12,13]. Toledo also displays salient metabolic asymmetries, another biomarker of epilepsy [14], with unilateral hypometabolism in his right superior temporal gyrus and left frontal regions. Toledo also displays many cognitive and behavioral characteristics associated with left temporal lobe epilepsy, such as low verbal IQ, early onset of seizures, and comorbidity with antisocial personality disorder and mood disorders [15]. This advances the narrative that Toledo may have experienced PIP, which occurs in up to 10% of epilepsy patients, and can last between under a

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day up to several weeks [17]. Symptoms may involve delusional ideation, hallucinations, thought disorder, or manic or depressive mood changes [17]. Especially worth noting is the potential for well-directed violence and increased suicidal tendencies during an episode of PIP [16]. This narrative aptly applies to Toledo's case. Moreover, the defendant's non-compliance with his medications would have lowered his seizure threshold, making it all the more likely that he experienced a seizure triggered by the emotionally charged discovery of his wife's affair [17], and then murdered her and her children while experiencing PIP. PIP is often known to be accompanied by both retrograde amnesia and suicidal tendencies [6,5], which may explain the defendant's inability to reveal the location of the bodies, and his subsequent suicide attempt. Additionally, we can also hypothesize that the defendant's violent outburst could have been further precipitated by his bipolar disorder. The decreased metabolic activity observed in the defendant's left orbitofrontal lobe coincides with observed decreased metabolic activity seen in the ventromedial prefrontal cortex of manic bipolar patients that exhibit reduced executive control [18]. The increased metabolism observed in the defendant's left thalamus is also characteristic of the manic phase in bipolar disorder [18].

Declaration of Interest

There were no direct conflicts of interests. However, Dr. Joseph Wu provides expert witness testimonials in the form of brain imaging analysis in both civil and criminal court cases.

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