

**Case Report**
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## Emerging Role of Prefrontal Lobe Involving Visual Function in a Case with Whiplash-Associated Disorders

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**ABSTRACT**

Whiplash, often resulting from vehicle accidents, can cause bony or soft tissue injuries leading to clinical symptoms related to the cervical spine or brain. However, diagnosing whiplash objectively is challenging, as acute phase abnormalities in the cervical spine or brain are difficult to detect through anatomic/structural imaging. We present a case of a 54-year-old woman suffering from Whiplash-Associated Disorder (WAD) without abnormal structural abnormalities. Using brain perfusion single-photon emission computed tomography (SPECT) to measure regional cerebral blood flow, hypoperfusion was observed in the bilateral prefrontal regions and parietal/occipital lobes, which was associated with her visual impairment. We support the nociceptive-vascular hypothesis and propose an additional role for the prefrontal lobe in contributing to WAD in patients following whiplash injury. Further investigation is needed to monitor the effects of brain perfusion after treatment using SPECT.

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**Introduction**

Whiplash often results from vehicle accidents, causing bony or soft tissue injury and leading to clinical symptoms related to the cervical spine or brain. With an annual global incidence ranging from 16 to 200 cases per 100,000 individuals, whiplash injury is one of the most impactful car crash-related injuries, placing a significant burden on the healthcare system. Although the majority of Whiplash-Associated Disorders (WAD) symptoms recover within the first three months after the accident, they can persist beyond three months, with symptoms lasting for over a year in up to 50% of patients. WAD commonly presents with headache and neck pain, and approximately 40% of whiplash patients will develop chronic symptoms of both. Other symptoms including dizziness, neck stiffness and paresthesia sensation in the arms and hands were also seen. However, visual disturbance is not common [1-4].

Whiplash is difficult to objectively diagnose, and any abnormalities of brain or cervical spine in the acute phase are difficult in detecting through Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) [5]. Although CT/MRI cannot give us more detail

about CNS defects, the PET or single-photon emission computed tomography (SPECT), a noninvasive imaging tool, has been often used to visualize the brain's perfusion, helping us identify regional brain perfusion abnormalities [6-8].

Recent study in WAD has found that there are higher blood flow in the precuneus and posterior cingulate regions, and lower in the parahippocampal, upper temporal, and inferior gyri, as well as in the thalamus and insular cortex through brain mapping [9]. Herein, we reported a case of a woman suffering from WAD without abnormal CT and MRI findings; instead, revealing perfusion deficit in other sites observed from the SPECT.

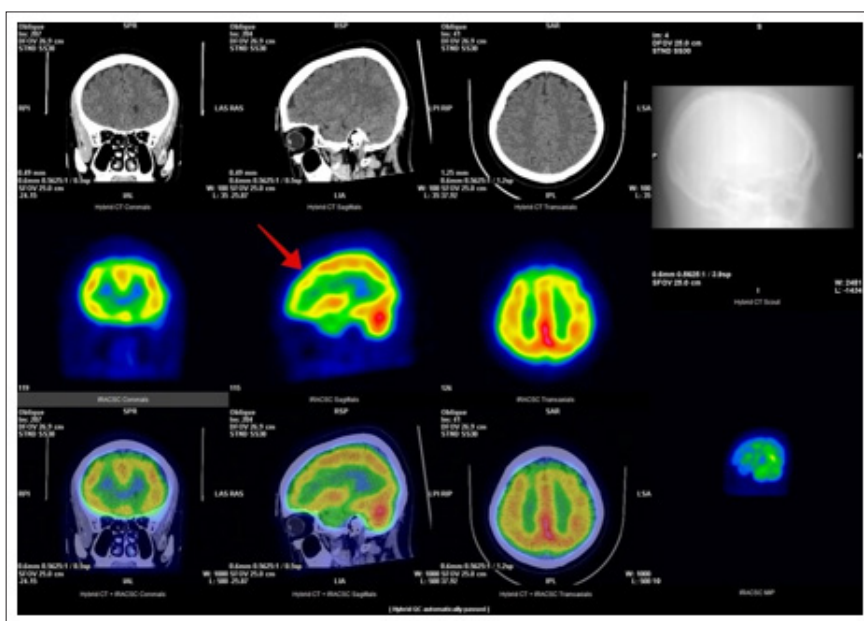
**Case Presentation**

The patient is a 54-year-old woman with no underlying disease. On the evening of September 18, 2022, she was rear-ended by a small car when driving on the road, causing her neck to suddenly jerk forward and backward (whiplash). Before the ambulance arrived, she was still able to answer the police's questions, but her gait was unsteady. Twenty minutes later, when she was transported to the hospital by ambulance, her speech became blurred. High-dose steroid treatment was prescribed for the first three days of hospitalization. CT and chest X-ray showed no destructive damage. By the morning of the third day, she reported no pain, allowing her to be discharged that afternoon.

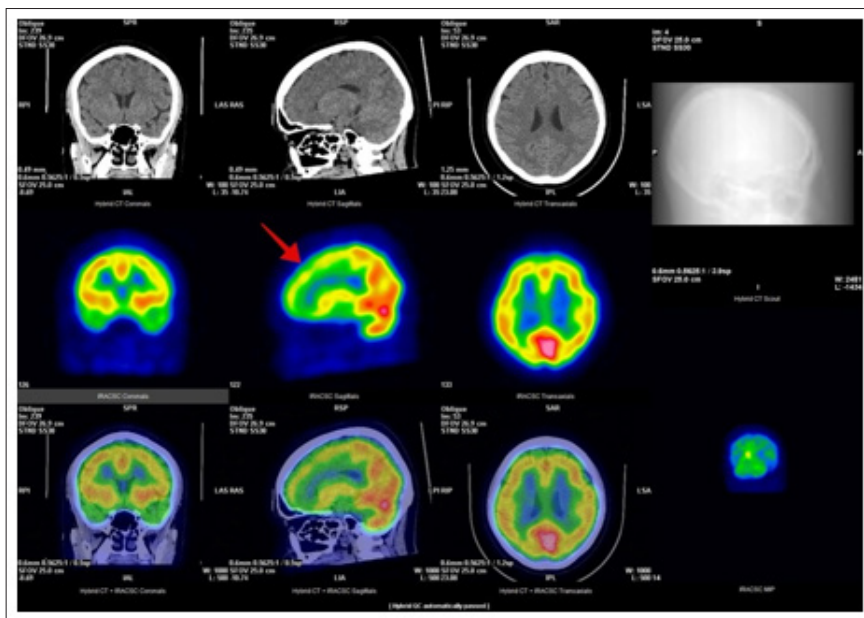
After being discharged, however, the patient reported numbness and pain in her head, face, and both shoulders down to her fingers, with the left side being more severe. She experienced difficulty standing for extended periods and instability while showering. Visual disturbances were also noted, with blurred vision, swollen eyes and face. Only when she was lying with her neck hanging off the bed can her vision improve. An ophthalmological examination in October 2022 revealed no structural eye damage or swelling due to eye pressure. An MRI ruled out the possibility of brain damage and a tumor affecting her vision. Subsequently, the patient regularly underwent physical therapy, electrotherapy, and acupuncture. After physical therapy on October 11, 2022, the patient's vision brightened and cleared significantly. Similar improvements were observed in the summer of 2023 and on December 15, 2023, though vision clarity fluctuated with weather changes and usually became blurry before thunderstorms until recently. The patient's right eye vision has stabilized with no numbness feeling of her right except upper right side of her face,

while left eye vision remains unstable and the left side of her face remains numb and mildly swollen. Besides, after extracorporeal shock wave therapy, the numbness and pain improved in the first to fourth fingers of her left hand, but the little finger of her left hand remained tight, with the tension extending to her shoulder.

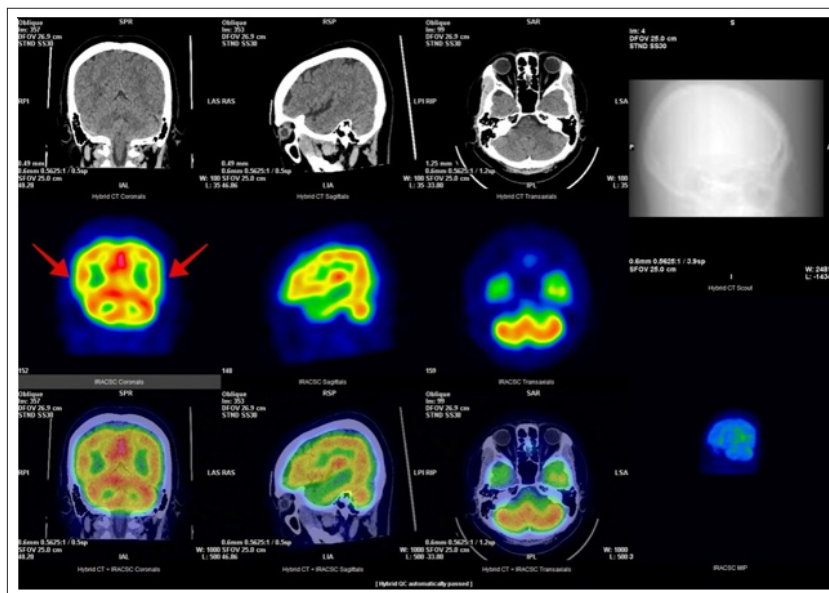
On June 6, 2024, this woman was admitted to our hospital for further examination and rehabilitation. MRI revealed no significant finding. However, no definite abnormal signal intensity mass lesion in the brain noted including supratentorial cerebral hemisphere and infratentorial cerebellum and brain stem region were found. In order to determine the potential cerebral blood flow abnormalities, the Tc-99m ethyl cysteinate dimer (Tc-99m ECD) SPECT was arranged and showed decreased regional cerebral blood flow (rCBF) in bilateral prefrontal regions and parietal/occipital lobe (Figure 1A-1C), which is statistically analyzed through easy Z-score imaging system (Figure 2).



(A)

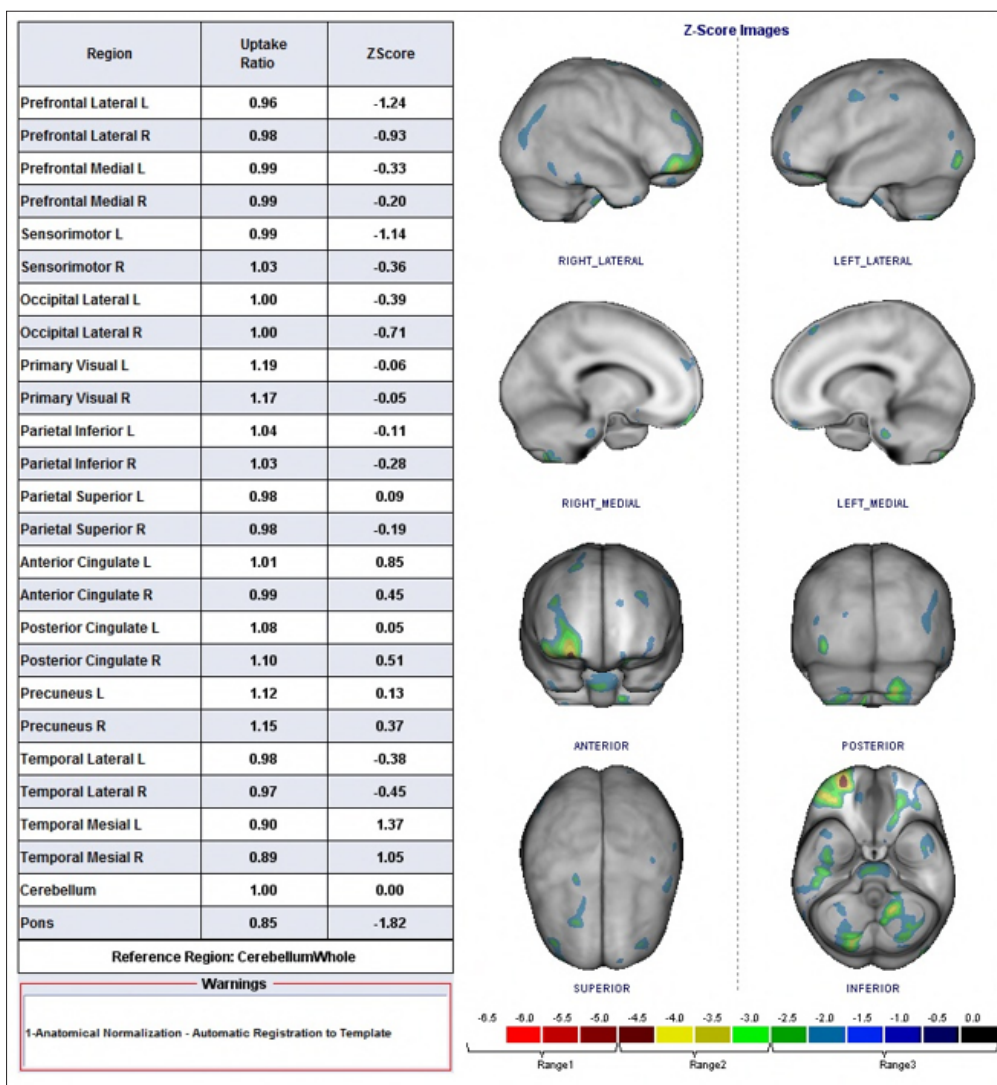


(B)



(C)

**Figure 1:** Brain SPECT-CT images. Cerebral Hypoperfusion (arrow) are Demonstrated in Right (A) and (B) left Prefrontal Regions and (C) Parietal/Occipital lobe



**Figure 2:** The easy Z-Score imaging System (eZIS). The Degree of Decrease in Regional Cerebral Blood flow is Analyzed by eZIS



We scheduled daily rehabilitation sessions including physical, occupational and speech therapies for this patient during her hospital stay. The patient reported significant improvement in vision. The initial numbness and pain are now limited to the left cheek and left forehead.

## Discussion

This is a case of vehicle accident-induced WAD including visual impairment, no significant finding can be seen in CT/MRI image. However, the result of SPECT showed decreased rCBF in bilateral prefrontal regions and bilateral parietal/occipital lobe. To our knowledge, this is the first report to disclose the connection between brain perfusion images and the WAD including visual impairment. This case presents with visual deficits. In addition to the previously noted parietal/occipital lobe hypoperfusion, there is now evidence of prefrontal hypoperfusion.

The medical term “Whiplash” was first introduced in 1928 by Dr. Harold E. Crowe, an orthopedic surgeon of the Western Orthopedic Association, to describe a sudden acceleration-deceleration phenomena on the neck. Since then this term Whiplash Injury has been used till now. WAD is defined as a bony or connective tissue injury of the head and neck causing by an acceleration-deceleration mechanism, and resulting in a group of neck and CNS-related symptoms [10]. Over the past few decades, the incidence of whiplash injury has been rising, with the incidence rate of emergency department visits ranging from 235 to 300 per 100,000 people around the world. However, detail and diagnosis have not been established well [11-14].

Recently, a case-control study conducted by Vallez Garca et al. Presented functional neuroimaging studies on whiplash injury through H215O positron emission tomography in 12 female patients. Compare to healthy control groups, patients with WADs showed higher blood flow in the precuneus and posterior cingulate regions, and lower in the parahippocampal, upper temporal, and inferior gyri, as well as in the thalamus and insular cortex through statistical parametric mapping, but not mention of prefrontal lobe(s).

In this patient, she suffered from blurred vision after serious traffic. The Tc-99m ECD-SPECT scan revealed an obviously decreased cerebral flow in bilateral prefrontal regions and bilateral anterior temporal poles. While the occipital lobe is the main cortex which processes vision, the prefrontal area may contribute to conscious vision as well [15]. Besides, the frontal eye field (FEF), which is located in the dorsolateral prefrontal cortex, controls the voluntary scanning eyes movement (saccades). Non-human primates studies have proved that damage to the FEF produces visual defects, other symptoms including difficulty in initiating saccades and gaze fixation were also found [16,17]. Therefore, the patient reported blurred vision, and the SPECT image revealed reduction of rCBF in bilateral prefrontal regions and parietal/occipital lobe might be contributing to the patient’s vision decline.

Since the poor correlation between MRI and clinical manifestation of whiplash injury was reported by Karlsborg et al, in a prospective study, and the prognosis of whiplash is also not always associated with post-injury MRI [18,19]. Brain SPECT-CT is an imaging technique in scintigraphic rehabilitation that merges SPECT and CT imaging to deliver detailed significance regarding combination of the function and structure of the brain [20-33]. It is a great clinical tool to detect cerebral blood flow impairment and differentiate an ischemic event after stroke onset [34,35]. In same way, in

those with dementia with Lewy bodies, significant decreased perfusion can be found through ECD-SPECT in frontal, parietal, temporal, and thalamus regions compared to the control group [36]. ECD-SPECT can be a helpful tool to help us understand the underlying mechanisms of WAD by providing functional insights into physiological processes and biological pathways. However, it is essential to be aware that in different studies of WAD, the areas showing decreased blood flow on SPECT may vary. Otte et al, proposed a nociceptive-vascular hypothesis based on the facts that most WAD patients exhibit decreased blood flow in the posterior parietal and occipital gyri, when compared to healthy individuals. In contrast, Lorberboym et al, and Sundstrom et al, reported localized reduced perfusion in the temporal lobe using SPECT [37-40].

Our findings, however, revealed hypoperfusion in the bilateral prefrontal regions and bilateral anterior temporal poles, which might be contributing to the patient’s symptoms. The association between WAD and abnormalities in brain perfusion can be explained by the nociceptive-vascular hypothesis, from Otte et al, the chronically injured upper cervical spine painfully triggered continuous production of some kind vasoactive peptides, leading to constriction of blood vessels in the posterior parietal and occipital gyri, and resulting in hypoperfusion. We have the same opinion of the nociceptive-vascular hypothesis, and more, we put forward another role of prefrontal lobe in the development of WAD in patients after whiplash injury.

## Conclusion

This is a pioneering research regarding emerging role of prefrontal lobe, showing that visual impairment in WAD is associated with hypoperfusion in bilateral prefrontal regions as well as parietal/occipital lobes. Brain SPECT image is a useful technique that can help us achieve what MRI/CT cannot in the diagnosis of whiplash injury. Additionally, it can serve as a baseline for tracking treatment effectiveness. The following effects of brain perfusion after treatment monitored by SPECT needs further investigation. Brain SPECT scintigraphy acts an incredible imaging tool in clinical practice in varying disorders for assessment of correlation between phenomenon and localized brain lesion(s) and observation of outcome/progression after intervention(s). Brain ECD-SPECT study is very useful in the field of scintigraphic rehabilitation.

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