Discordance Between FDG Uptake and Technetium-99m-HMPAO Brain Perfusion in Acute Traumatic Brain Injury

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A 28-yr-old woman who sustained a mild traumatic brain injury had an ^{18}F-fluorodeoxyglucose (FDG) PET brain study using coincidence imaging performed on a dual-head gamma camera (MCD version; ADAC, Milpitas, CA) followed 24 hr later by ^{99m}Tc-hexamethyl propyleneamine oxime SPECT brain perfusion imaging using a triple-head gamma camera (TRIONIX, Twinsburg, OH). The results of the SPECT brain perfusion study demonstrated decreased frontoparietal cortical brain perfusion, whereas ^{18}F-FDG cerebral uptake was normal. Neuropsychological evaluation suggested frontal lobe involvement. This case demonstrates the possibility of discordance between brain perfusion and glucose uptake in acute mild traumatic brain injury.

Key Words: fluorine-18-fluorodeoxyglucose; technetium-99m-hexamethyl propyleneamine oxime; traumatic brain injury; coincidence imaging; SPECT brain perfusion

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Literature review revealed several studies comparing SPECT brain perfusion imaging with ^{18}F-fluorodeoxyglucose (FDG) PET imaging in various neurological diseases, including Alzheimer's disease (*1–3*), Huntington's chorea (*4*), cerebral microangiopathy (*5*) and traumatic brain injury (*6,7*). In most instances, the changes seen on SPECT brain perfusion are associated with the corresponding abnormalities on FDG PET. Other studies have reported discordance in acute cerebrovascular accident (*8*), where ischemic areas on SPECT brain perfusion have normal glucose uptake on FDG PET studies. The studies also demonstrated that if blood flow to the ischemic area was restored before irreversible damage had occurred, then the tissue may likely recover and resume normal function (*8*). In traumatic brain injury there are few comparisons between the findings of SPECT brain perfusion changes and FDG PET. On the other hand, there is enough literature (*9–12*) to show that morphological changes detected by CT or MRI are not as sensitive as either SPECT or PET studies. Functional abnormalities may extend beyond anatomic abnormalities on CT or MRI and are often present in regions adjacent to or remote from the focal damage.

The aim of this article is to describe cerebral perfusion and glucose uptake changes in a patient with acute mild head injury. Although the cerebral blood flow was reduced, the cerebral uptake of glucose remained intact.

CASE REPORT

A 28-yr-old woman with no history of medical problems was struck by a car and lost consciousness for a brief period of time (1–2 min). On arrival at the emergency room, she complained of headaches and pain in the posterior head, left arm, right ankle and neck. The physical examination revealed a young woman in moderate distress with a Glascow Coma Scale (GCS) score of 15 and normal vital signs. She had swelling and tenderness in the right occipital region.

A CT scan was performed, which was normal (Fig. 1). In terms of severity, the head injury was classified as mild according to criteria outlined by the American Congress of Rehabilitation Medicine, which requires loss of consciousness of approximately 30 min or less, an initial GCS score of 13–15 and post-traumatic amnesia (PTA) not greater than 24 hr (*13*). The patient suffered a loss of consciousness for 1–2 min with an initial GCS of 15 and PTA for approximately less than 1 hr.

The CT scan, which was performed on the day of the accident, was normal. At the time, the patient was interviewed by a neurologist as well as a research investigator, and she agreed to participate in a mild head trauma study that was being conducted at our hospital and is approved by the institution's institutional review board. A neuropsychological evaluation was completed within 1 wk from the day of the injury. A battery of selected tests, known to be sensitive to the effects of head injury, consisted of the following: (a) Trails A and B from the Halstead-Reitan Battery, to estimate psychomotor speed and set-shifting ability; (b) Finger Tapping test, to obtain a measure of manual speed; (c) Digit Symbol subtest (WAIS-R), which is sensitive to deficits in graphomotor ability; (d) Mattis-Kovner Selective Reminding Test, to assess memory; and (e) Brown-Peterson Consonant Trigram Test under an interference condition, which is sensitive to attention deficits. In addition, the Shipley Institute for Living Scale, which consists of vocabulary and abstract reasoning subscales, was used to determine the level of premorbid intellectual functioning.

The patient's premorbid intellectual functioning was estimated to be in the average range. In terms of neuropsychological findings, the patient's performance was well within normal limits on the Mattis-Kovner (verbal memory) and on Trail Making A and B (psychomotor speed and cognitive flexibility). A relative slowness, although within the normal range, was noted on the Digit Symbol subtest. On the Finger Tapping test of motor speed, the patient's performance with the dominant side (right side) was significantly slower than expected. Attention problems were evident on the Brown-Peterson test. The Brown-Peterson Consonant Trigram test, under an interference condition, was found to be sensitive to the effects of mild head injury (*14,15*). Impaired performance on this test was interpreted as being consistent with frontal lobe or frontal/brain stem system deficit (*16*). There is also abundant evidence that deficits in motor speed implicate a deficiency in the frontal/subcortical circuitry. Thus, this patient's pattern of test results, with compromised performance on the Finger Tapping and Brown-Peterson tests, is suggestive of frontal lobe involvement.

On the same day and 1 hr after the injection of 3.2 mCi (118 MBq) FDG, images of the brain (Fig. 2) were acquired using a

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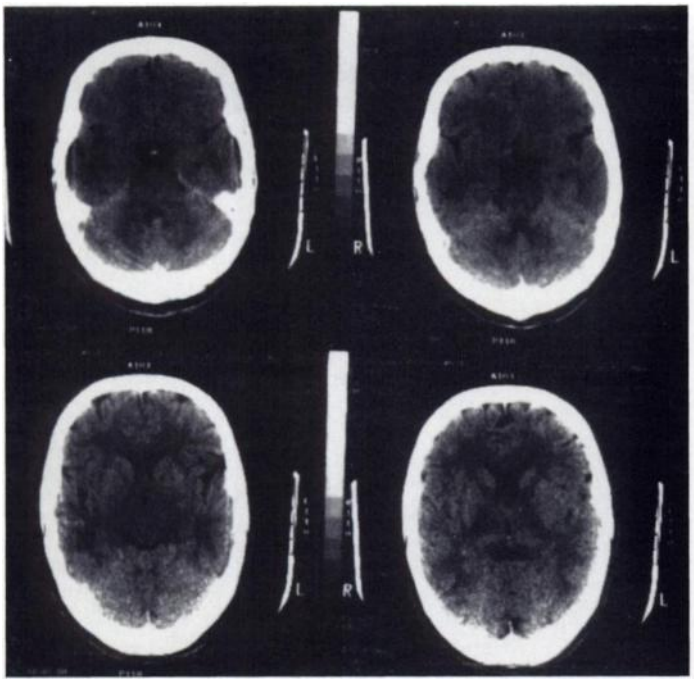

FIGURE 1. CT on the day of admission shows normal findings.

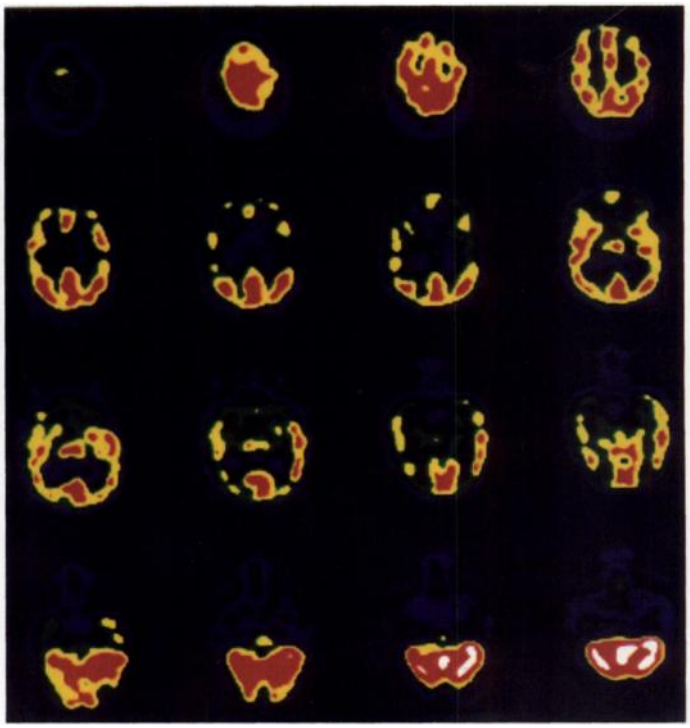

FIGURE 3. Technetium-99m-HMPAO brain perfusion SPECT study on third day after the patient's accident shows hypoperfusion of frontoparietal lobes bilaterally.

VERTEX dual-head gamma camera (MCD version, ADAC, Milpitas, CA) equipped with electronic circuits for coincidence detection. A total of 64 projections (32 per head) with an acquisition time of 80 sec per projection were obtained. Projection data were reconstructed with Butterworth and ramp filters with backprojection including scatter and attenuation correction. The images were displayed in 2 pixels (3.8 mm thick) in transverse sections, 8 color and gray scales and read by an expert nuclear medicine physician using the guidelines of Loessner et al. (*17*). The study (Fig. 2) showed normal glucose uptake of cortical and basal structures. The following day, a SPECT brain perfusion study (Fig. 3) was performed 2 hr after the intravenous injection of 22 mCi (814 MBq) ^{99m}Tc-hexamethyl propyleneamine oxime (HMPAO). After a waiting a period of 2 hr, the patient was scanned using the triple-head gamma camera (TRIONIX, Twinsburg, OH) with low-energy, ultra-high-resolution and parallel-hole collimators. The data were collected as 64 × 64 matrix, 3.56 mm/pixel, a total of 120 projections at 40 sec/view, with a radius of rotation not to exceed 14 cm, and as close to the head as possible. The raw data were smoothed using a Butterworth filter and uniform attenuation correction was applied. Images were then reoriented in the axial, coronal and sagittal planes. The final data were displayed on 2 pixels (7.4 mm thick) on 10 graded color scales. The cerebellum was used as the reference site for 100% maximum value. Any decrease in cerebral perfusion in the cortex under 70% or under 50% in the medial temporal region was considered abnormal. The study revealed decreased cortical brain perfusion especially involving the frontal and parietal lobes bilaterally. The patient made a good recovery and had no complaints at discharge.

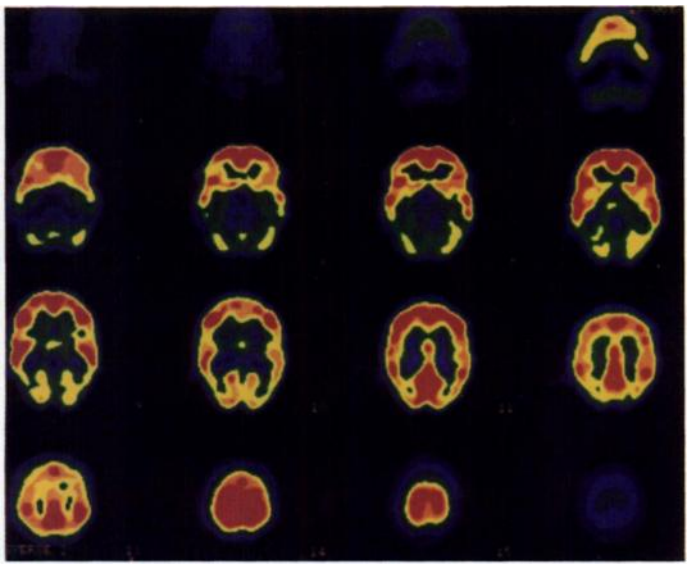

FIGURE 2. Fluorine-18-FDG study on second day of admission shows normal patterns. Frontal lobe glucose uptake is higher than that in parietal and occipital lobes.

DISCUSSION

Ischemic cell injury occurs in over 90% of patients who suffered head injury and is usually secondary to diffuse axonal injury that occurs as a result of stretching and tearing of axons in the white matter of the cerebral hemispheres and the brain stem (*18,19*). Diffuse axonal injury (DAI) has been found to cause widespread cortical hypometabolism (*11,20*). Previous studies by Alavi et al. (*11,20,21*) have shown that whole-brain hypometabolism shown by FDG PET studies correlate well with the severity of head trauma, GCS and neuropsychological testing (*11,20–24*). DAI-induced hypometabolism has shown improvement as early as 3 wk on serial PET scans, and severely injured areas show persistent hypometabolism (*20*). Global and regional metabolic rates have been found to improve as patients recover from head trauma (*11,22*). Gross et al. (*6*) reported 20 patients with chronic behavioral deficits after mild traumatic brain injury and concluded that (a) even mild traumatic brain injury may result in continuing brain behavioral disorders; (b) PET can help elucidate dysfunctional brain circuitry in neurobehavioral disorders; and (c) specific brain areas may correlate with deficits in daily neurobehavioral functioning and neuropsychological test findings. Abdel-Dayem et al. (*12*)

studied a series of patients who had sustained severe head injury. All of the patients were in a state of diminished consciousness. They found brain perfusion SPECT using ^{99m}Tc-HMPAO to be more sensitive than CT. It identified lesions at an earlier time; the lesions were greater in size than corresponding ones seen on CT.

In most instances, the abnormalities seen on SPECT brain perfusion studies are concordant with the same abnormalities on FDG PET (*1–7*). Discordance has been associated with good prognosis particularly in acute cerebrovascular accident (*8*). Recently Yamaki et al. (*7*) described cerebral hemodynamics and metabolic changes in 3 patients with severe diffuse brain injury, who had GCSs of 4, 5 and 4 at admission. All were imaged within 10 days. Although cerebral blood flow was reduced in all 3 patients, the cerebral metabolic rate for glucose for 1 patient was significantly elevated (discordant to blood flow), whereas the remaining 2 patients had matching decreased cerebral blood flow and glucose metabolism. The first patient with uncoupling died as a result of his injury, whereas the other 2 patients made good recoveries. This implied that the discordance in acute severe traumatic brain injury is a sign of poor prognosis. Although the literature on traumatic brain injury is not abundant, the case report by Yamaki et al. (*7*) has shown that discordance in acute severe traumatic brain injury is associated with unfavorable outcome. Although the regional cerebral metabolic rate for glucose and the regional cerebral blood flow (rCBF) for the patient reported by Yamaki et al. (*7*) were discordant, the metabolic ratio (cerebral metabolic rate for oxygen/cerebral metabolic rate for glucose) was relatively low. Yamaki et al. speculated that a long-lasting rate of anaerobic glycolysis is an important factor in the poor outcome of severe diffuse brain injury patients. In our patient, the discordance was not associated with bad prognosis. The normal glucose uptake indicates that the tissue of concern is alive with good metabolism rather than nonviable tissue, as suggested by the SPECT brain perfusion study. It has been suggested that changes in rCBF in mild traumatic injury reflects vascular compromise, which is probably secondary to the associated vasospasm and edema of the brain after the trauma, which could explain the SPECT brain perfusion findings in mild traumatic brain injury (*25*).

CONCLUSION

It is possible that the edema and the vasospasm secondary to traumatic brain injury causes decreased perfusion that can be seen by SPECT brain perfusion imaging but is not severe enough to impair glucose uptake. The patient might have symptoms related to the decreased brain perfusion that can be demonstrated by various neuropsychological tests.

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