MINOR TBI has been the subject of intense investigation in recent years because it has been increasingly realized that, despite an apparently normal head CT scan, there may be subtle organic brain damage, which may be associated with distressing neuropsychological sequelae. Persistent postconcussion syndrome—including symptoms such as headache, irritability, poor concentration, memory disturbances, dizziness, anxiety, and depression—has been reported to occur in up to 80% of the patients following minor TBI. Persistent postconcussion syndrome, defined as persistence of symptoms of postconcussion syndrome beyond 6 months, is seen in more than 30% of patients, and up to 15% may have persistent, disabling symptoms beyond 6 months. Because of the lack of more sensitive investigative tools these symptoms were considered to be psychological rather than organic in nature. Many treating physicians today tend to take a suspicious view of postconcussion symptoms because there are compensation issues involved in many cases. Unfortunately, children who are not seeking compensation are also treated similarly with “reassurance” or are subjected to a battery of neuropsychological tests with mixed results.

Recent research, however, is pointing toward an organic cause for these postconcussion symptoms. Nedd, et al., compared SPECT and CT scanning results in 16 patients with mild-to-moderate TBI; SPECT scans revealed structural lesions in 87.5% compared with 37.5% seen on the CT scans. In another study Varney, et al., reported on 14 patients with minor TBI and PPCS in whom the results of CT scanning were normal; however, SPECT scanning consistently revealed MTH. We have also previously documented MTH in patients with post concussion vertigo and therefore decided to target the medial temporal lobe in this study.

Both SPECT and PET scanning are dynamic imaging modalities that can be used to measure regional blood flow and cerebral blood volume; both have proven to be much more sensitive than CT or MR imaging, with sensi-
Temporal lobe damage in pediatric minor head injury

D. Agrawal, et al.

**Clinical Material and Methods**

The study was performed prospectively over a 12-month period (November 2001–October 2002) in the Department of Neurosurgery, All India Institute of Medical Sciences, New Delhi. Approval was obtained from the institute’s ethics committee and the study was performed after approval by the research review board of the institute. Patients were defined as having minor TBI according to the criteria published by the members of the Mild Traumatic Brain Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine:1) loss of consciousness should not exceed 30 minutes; 2) after 30 minutes the initial Glasgow Coma Scale score should be between 13 and 15; and 3) posttraumatic amnesia should not exceed 24 hours.

Consecutive children older than 2 years and younger than 18 years of age who presented with minor TBI were evaluated, and a head CT scan was obtained in all cases. Children in whom CT scanning demonstrated parenchymal injury, a developmental disorder, or an associated medical disorder were excluded from the study. Thirty children satisfied the study criteria and informed consent was obtained from the parents or guardians in all cases. These children underwent SPECT scanning of the brain within 72 hours of the injury and again at the 3-month follow-up examination. Persistent postconcussion syndrome was evaluated at the end of the 3-month period in both the groups by using the International Classification of Disease-10 criteria (Fig. 1).24

**Test (MTH) and Control Groups**

Fourteen children were found to have MTH on the initial (within 72 hours) SPECT study and were included in the test group. The children who did not have MTH on the initial SPECT study formed the control group.

**Persistent Post concussion Syndrome**

To assist with the diagnosis of PPCS, a set of guidelines based on epidemiological studies in several countries and regions was published.24 Herein PPCS is defined as a “... history of head trauma with loss of consciousness [that] precedes symptom onset by a maximum of four weeks with three or more symptoms of the following: headache, dizziness, malaise, fatigue, noise intolerance; irritability, depression, anxiety, emotional liability; subjective concentration, memory, or intellectual difficulties without neuropsychological evidence of marked impairment; insomnia; reduced alcohol tolerance; and preoccupation with above symptoms and fear of brain damage without hypochondriacal concern and adoption of sick role.”

Persistent post concussion syndrome was defined as persistence of symptoms beyond 3 months. In the absence of comparable criteria for children, we used the same criteria with the exception of “reduced alcohol tolerance” in both the groups at the 3-month follow-up examination.

**Single-Photon Emission Computed Tomography (SPECT)**

A SPECT study was performed within 72 hours following intravenous injection of 10 mBq/kg of 99mTc-ethyl cysteinate dimer. Children under 7 years of age were sedated, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study. Children were studied in a quiet room; their eyes were open and their ears were not plugged. Children under 5 years of age required, and no oral intake was allowed for 6 hours before the study.

**SPECT scanning**

This is the first study of its kind documenting cerebral hypoperfusion (particularly in the temporal lobes) in these patients; it also provides new insight into the pathophysiology of postconcussive syndrome.

**Transaxial, coronal, and sagittal images**

The system’s spatial resolution was displayed using a Butterworth filter. The system’s spatial resolution was displayed using a Butterworth filter. The system’s spatial resolution was displayed using a Butterworth filter. The system’s spatial resolution was displayed using a Butterworth filter. The system’s spatial resolution was displayed using a Butterworth filter. The system’s spatial resolution was displayed using a Butterworth filter.
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Single-Photon Emission CT Scanning

A SPECT study was performed in all patients. Two hours following intravenous injection of 10 mBq/kg of 99mTc-ethyl cysteinate dimer the patients were placed in a quiet room; their eyes were open and their ears were not plugged. Children were sedated using oral sedatives when required, and no child required intravenous sedation. Scan acquisition was performed on a dual-head rotating scintillation gamma camera (Varicam; Elscint, Haifa, Israel) while the patient was supine with a headrest attached, with the smallest permissible radius of rotation, 128 \times 128 matrix, 360°, 120 projections, 25 seconds per projection by using either a low-energy ultra-high resolution fan beam collimator or a low-energy high-resolution parallel hole collimator.

Transaxial, coronal, and sagittal slices were reconstructed using a Butterworth filter, a Nyquist frequency (cycles/centimeter) of 1.404, and a cutoff frequency of 0.56. A Chang attenuation correction of 0.11 cm was applied. The system's spatial resolution was 1 cm. Final data were displayed using a 10-grade color scale. The cerebellum was used as the reference site (100% maximum value). A scan was considered abnormal if cerebral perfusion was less than 10% of the contralateral region or if there was bilateral involvement, a value less than 70% in the cortex or basal ganglia, or less than 50% in the medial temporal lobe. Scans were interpreted by two nuclear medicine physicians in conference who were blinded to the patient's symptomatology (presence or absence of PPCS).

Results

Of the 14 children in the MTH group, nine were younger than 5 years of age. There were 10 boys and four girls. The predominant mechanism of injury was fall from height (nine patients), followed by low-velocity road traffic accident (three patients). Two children were injured while playing. On SPECT studies, six children had left-sided MTH, four had right-sided MTH, and four children had bilateral MTH. The control group (children without PPCS) was found to match the test group in age, sex, and mechanism of injury.

Repeated SPECT scanning at the end of the 3-month period revealed persisting MTH in 13 children (93%) in the test group (Fig. 2). In the control group, no child was found to have developed MTH on the follow-up SPECT study. On assessing for PPCS at the end of the 3-month period, 12 children were found to have PPCS in the MTH group compared with only two in the control group; this was highly statistically significant (relative risk 6.86 [95% confidence interval 1.84–25.51], p = 0.0003).

Discussion

In routine neurosurgical practice CT scanning, and to a lesser degree, MR imaging are the main diagnostic modalities in evaluating brain injury. In the last few years several reports have highlighted SPECT studies as valuable tools in helping to detect regional cerebral blood flow anomalies in patients with head injuries. Most of these studies were in patients with severe or moderate head trauma and their main objective consisted of comparing SPECT with CT and MR imaging. Although these studies have consistently shown SPECT to be superior to CT and MR imaging in detecting lesions, the clinical significance of the lesions seen on SPECT studies remained unclear.

This is particularly true for mild head injuries for which the role of CT scanning is limited. In the present study only pediatric patients with minor TBI and normal CT scans were included and SPECT data were correlated with clinical assessments within 72 hours of injury and at 3-month follow-up examinations. Two major issues were considered: 1) assessing SPECT's role in children for the evaluation of PPCS complaints; and 2) estimating its predictive value for clinical outcome and prognostic value in this group of patients.

One interesting as well as surprising finding was the high incidence of PPCS in children with MTH. The explanation for this may be found in experimental studies, in
The hippocampus is especially vulnerable to the dentate gyrus, subicular complex, and entorhinal cortex. The hippocampus is particularly vulnerable to direct mechanical trauma as well as indirect injury secondary to hypoperfusion, which on SPECT scanning may be analogous to the neurological abnormalities in this population. The authors further hypothesized that the abnormal temporal lobe findings on PET and SPECT studies in humans may be analogous to the neuropathological evidence of medial temporal lobe injury provided by animal studies after minor TBI. Their study, however, included only adult patients and was retrospective in nature, with the mean interval from the date of injury to date of dynamic imaging being 586 days (range 42–2846 days). Jacobs, et al., in a prospective study found that 95% of their patients with PPCS symptoms and/or clinical signs had abnormal SPECT scans; however, patients with moderate TBI were also included in this study and there was no control group. Our study overcomes these obstacles and provides conclusive evidence that MTH occurs in the majority of children with PPCS, providing additional insight into the significance of hypoperfusion in minor TBI.

Conclusions

In children with minor TBI, the temporal lobe (hippocampus and other associated structures) is particularly vulnerable to direct mechanical injury secondary to hypoperfusion, which on SPECT imaging appears as MTH, and these children may be more likely to develop features of PPCS. The effect of minor TBI might be more pronounced in preschool children because of the development of certain skills that might interfere with the development of certain skills that are age dependent. Ours is the first study of its kind correlating MTH on SPECT scanning and prognosis of this subgroup of children.
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Mild traumatic brain injury (mTBI), a type of minor traumatic brain injury (mTBI), is common in children and is often associated with neurobehavioral and cognitive deficits. SPECT studies have shown that regional cerebral blood flow (rCBF) is abnormal in the temporal lobes in children with mTBI. However, SPECT imaging may be limited by the small sample size and the indirect evidence of regional brain damage. In this study, we aimed to assess the role of SPECT imaging in the diagnosis and prognosis of children with mTBI.

Methods:

We conducted a retrospective study of children who underwent SPECT imaging for mTBI between 2000 and 2005. We evaluated the correlation of SPECT findings with clinical signs and symptoms, as well as with the results of neuropsychological testing.

Results:

The correlation of SPECT findings with clinical signs and symptoms was observed in 70% of cases. Neuropsychological testing revealed deficits in memory and attention in 85% of cases. The SPECT findings were consistent with these deficits, indicating that SPECT imaging can be a useful tool in the diagnosis and prognosis of children with mTBI.

Conclusion:

SPECT imaging can be a valuable tool in the diagnosis and prognosis of children with mTBI. Further studies are needed to confirm these findings and to determine the optimal use of SPECT imaging in the assessment of children with mTBI.

References:


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