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Indications and need for neuroimaging and newer developments in brain imaging in mild head injury.

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Abstract: Mild head injury (MHI) accounts for over 80% of hospital attendance due to head injury. However, there is no consensus in the evaluation and management of patients with MHI. The aim of this article is to provide an overview of the indications and need for neuroimaging in MHI as well as the evolving role of newer imaging modalities in the evaluation and management of MHI. The current evidence in the literature does not support the routine use of plain radiography of the skull in the evaluation of patients with MHI. The prevalence of intracranial lesions in MHI varies from 5% in GCS 15 to 40% in GCS 13. Several groups have proposed various guidelines for the evaluation and management of MHI patients. These include: NICE guidelines, New Orleans CT head rule, Canadian CT Head rule, Italian Guidelines, Scandinavian Guidelines, EFNS (European Federation of Neurosurgical Societies) guidelines, and WHO guidelines. Most of these guidelines are applicable only to adult patients. Separate guidelines have been provided by the American Academy of Pediatrics for children less than 2 years of age and for those between 2 and 20 years of age. However, recent studies have shown that none of these guidelines have 100% sensitivity. Therefore, physicians who use these guidelines should be aware of the small risk of missing intracranial lesions in patients with MHI. Newer imaging modalities like newer MR sequences, MR spectroscopy, Magnetic Source Imaging (MSI), PET, and SPECT have provided objective evidence of structural and functional alterations in patients with MHI even when CT and routine MR sequences do not reveal abnormalities. Thus, these imaging techniques have been shown to have a role in the evaluation of patients with persistent post-concussive symptoms and they have provided proof of organic basis for these symptoms.

Keywords: Computed tomography, Glasgow Coma Scale, Magnetic resonance imaging, mild head injury, minor head injury, PET, SPECT.

INTRODUCTION

Head injury is one of the most common injuries and can be considered a silent epidemic. It is rapidly becoming one of the leading causes of death and disability, especially in the young population. The incidence of traumatic brain injury varies between 229 and 1967 per 100,000, with the highest incidence occurring in men aged 15–24 years[1,2]. Traumatic brain injury is the leading cause of death among people younger than 45 years[1,2]. Most patients (about 80%) sustain a MHI and do not need complex health care. This however, does not mean that MHI is a totally benign condition. A recent meta-analysis of the literature showed that of 1000 patients arriving at hospital with mild head injury, one will die, nine will require surgery or other intervention, and about 80 will show pathological findings on CT. At least these 8% of patients will probably need in-hospital care[3]. Patients with MHI who have a low risk of dying are those with the greatest risk of inadequate diagnosis and treatment[4].

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Definition of MHI

Mild head injury generally refers to patients with admission Glasgow Coma Score (GCS) of 13 – 15[5-9]. However, in recent years some authorities have questioned the validity of including patients with GCS 13 under the rubric of MHI as these patients have a prognosis that is similar to those with moderate head injury[10,11]. In this review, MHI refers to patients with admission GCS scores of 13–15.

Is there a role for Plain skull radiography in MHI?

The diagnostic value of plain skull radiography is debated. Because earlier studies showed that radiographic evidence of a skull fracture increases the risk of intracranial haemorrhage, skull radiography was used as the principal triage tool on which management decisions were made[12-15]. However, recently available evidence in the literature point to the low sensitivity and specificity of skull fracture visualized on plain radiographs for intracranial hemorrhage[16,17]. To judge the usefulness of the diagnosis of skull fracture, it is important to evaluate the sensitivity and specificity of this finding as a test for the presence or absence of intracranial lesions. Hoffman et al performed a meta-analysis of the literature and concluded that positive skull radiograph does not predict the occurrence of intracranial lesions with certainty[17]. Only one-third of intracranial lesions were predicted by positive skull radiographs. Therefore, they concluded that skull radiographs are ineffective as a screening tool for MHI. Thiruppathy and Muthukumar showed that even though positive skull radiographs were predictors of intracranial lesions in CT, they were inferior to CT in detection of skull fractures[18]. Another study by Thillainayagam et al showed that up to 10% of skull fractures are missed by less experience physicians, who usually see most patients with MHI in many institutions[19]. This reduces the usefulness of the skull radiograph even further. Recently issued guidelines by the European Federation of Neurosurgical Societies (EFNS guidelines) and the WHO guidelines do not recommend the use of skull radiograph as a screening tool for MHI[10,20].

CT Prevalence of intracranial abnormalities in MHI

The prevalence of intracranial lesions in MHI detected by CT varies among different studies mainly because of the differences in study design, inclusion/exclusion criteria, and study setting[10]. Several studies have shown that in patients with MHI with GCS score of 15, the prevalence of intracranial abnormalities may vary from 5% to 8%[8,9,21-25]. A comprehensive study of 3121 patients admitted to Canadian hospitals reported a CT prevalence of intracranial lesions of 4.8% in GCS 15, 17.2% in patients presenting with GCS 14, and 40.9% in patients presenting with GCS score of 13[9]. Thus, the prevalence of intracranial lesions is inversely proportional to the GCS score. The incidence of CT abnormalities is higher in patients older than 60 years when compared to those between 14 and 60 years[25].

Clinical Predictors of Positive Cranial CT in MHI

In common clinical practice, physicians encounter patients with apparently mild head injury. The injury might appear mild, but the physician cannot be absolutely sure that the patient does not have an occult intracranial lesion[26-28]. Traditionally, a physician who was in doubt about whether a patient had an intracranial injury would admit the patient to the hospital for observation. However, hospitalization is labor-intensive and expensive[29]. Livingston et al reported that 31% to 50% of patients admitted to the hospital for observation had no evidence of repeated neurological examinations[30]. The reliability of observation at home is also questionable. Saunders et al have reported that less than half of all the persons responsible for observation accurately followed discharge instruction and 19% of them even denied having ever been given instructions[31]. In view of this, CT is being increasingly used to triage patients with MHI[32]. However, CT scans are expensive. Hence, guidelines have been developed by several groups to safely triage patients with MHI. Some of the popular guidelines are:

1. NICE (National Institute of Clinical Excellence, U.K.) (2003)[33].
2. New Orleans CT Head Rule (2000)[8].
3. Canadian CT Head Rule (2001)[9].
4. Guidelines of the Italian Society for Neurosurgery (1996)[11].
5. Scandinavian Guidelines (2000)[34].
6. European Federation of Neurosurgical Societies Guidelines (EFNS guidelines)(2002)[20].
7. WHO guidelines (2004)[10].

Canadian CT Head Rule

The Canadian CT head rule is based on a study by Stiell et al[9]. The study yielded a set of five high-risk factors and two medium risk factors. *This study was restricted to patients over 15 years and those with GCS 13 – 15.*

High risk factors

- GCS score of less than 15 at 2 hours after injury
- Suspected open or depressed skull fracture
- Any sign of basal fracture
- Vomiting 2 or more times
- Age over 65 years

Medium risk factors

- Anterograde amnesia of more than 30 minutes
- Dangerous mechanism of injury (pedestrian struck by vehicle, occupant of vehicle thrown out of the vehicle, fall from height of more than 5 feet).

However, this study has many limitations. In this study, the following CT findings were not considered important in neurologically intact patients: solitary contusion of less than 5 mm diameter, localized subarachnoid blood less than 1 mm thick, hematoma less than 4 mm thick, isolated pneumocephalus and closed depressed fracture not through the inner table of the skull. The other limitation of this study is that about one-third of patients did not undergo

CT and were only followed by telephonic interviews. Despite these limitations, the authors of this study claimed 100% sensitivity in the detection of intracranial lesions.

New Orleans CT Head Rule

This rule was developed and validated by Haydel and colleagues[8]. This study was conducted in two phases: a derivation phase and a validation phase. The main inclusion criteria for this study were patients with history of loss of consciousness following trauma with admission GCS score of 15 and a normal neurological examination. Minimum age for entry into the study was 3 years. Thus, unlike Canadian CT head rule study, this study also included pediatric patients. This study identified seven criteria for positive CT:

1. Age > 60 years
2. Headache
3. Vomiting
4. Seizure
5. Deficits in short term memory
6. Drug or alcohol intoxication
7. Physical evidence of trauma above the clavicles.

Subjecting patients to CT when any one of these criteria was present yielded 100% sensitivity and when all the criteria were absent there was no case with a positive CT i.e. there was a negative predictive value of 100%.

The limitations of this study are: *this study did not include patients with GCS 15 without loss of consciousness* after the injury and therefore, the findings of this study should not be extrapolated to those patients with admission GCS of 15 and without loss of consciousness. This latter group of patients constitutes a significant percentage of patients attending the emergency departments. Furthermore, several studies have shown that loss of consciousness is not an accurate predictor of positive CT[18,24,28].

Italian Guidelines

These guidelines for the management of MHI were developed by the Italian Society for Neurosurgery[11]. *This guideline included only patients with a GCS score of 14 or 15.* Patients with GCS score of 13 and those with GCS scores 14 or 15 but with focal neurological deficits, suspected depressed skull fracture of the cranial vault or clinical signs of basilar skull fracture were considered to have moderate head injury and were excluded. Moreover, these guidelines are applicable only to adults. MHI is divided into 3 groups according to different level of risk.

Group 0

- GCS 15
- No loss of consciousness
- No amnesia
- No headache or vomiting but have pain limited to the impact zone

This group of patients can be discharged with an information sheet mentioning the precautions to be taken at home. CT is not required.

Group 0-R

Same as Group 0 but with added risk factors which include: alcoholism, coagulopathies, anticoagulation therapy, drug use, epilepsy, previous neurosurgery, and old age.

In this group of patients CT should be considered.

Group 1

- GCS 15 with one of the following
- Loss of consciousness
- Post-traumatic amnesia
- Worsening headache or vomiting

An early CT scan is warranted. If CT is normal, patient should be kept under observation for at least 6 hours. If CT shows a skull fracture without any other intracranial lesions, observation for 24 hours is indicated.

Group I patients affected by coagulopathies or undergoing treatment with anticoagulants should undergo repeat CT before being discharged.

Group 2

- GCS 14 but no focal neurological deficits.

Patients in this group should undergo an early CT scan, be admitted, kept under continuous observation and discharged only when proved to be neurologically intact.

The limitations of this study are: *it is not applicable to children and this study has not been validated independently in centers outside Italy.*

Scandinavian Guidelines

These guidelines were proposed by the Scandinavian Neurotrauma committee of the Scandinavian Neurosurgical Society[34]. These guidelines were based on the Head Injury Severity Scale developed by Stein and Spetttell[35]. Like the Italian guidelines, the Scandinavian guidelines also included GCS 13 under moderate head injury. The Scandinavian guidelines divided MHI into minimal, mild and moderate head injuries.

Minimal Head Injury

- GCS 15 and
- No Loss of consciousness

These patients can be discharged home with instructions.

Mild Head Injury

- GCS 14 –15 and/or
- Loss of consciousness £ 5 min and
- No focal neurological deficit

In these patients CT is recommended. If CT is normal, patient can be discharged home. However, if CT is unavailable, then the patient should be admitted for observation for a minimum period of 12 hours and then discharged home if found fit.

Moderate Head Injury

- GCS 9 – 13 or
- Loss of consciousness ³ 5 min or
- Focal neurological deficit.

In these patients CT is mandatory.

Patients with risk factors

When any one of the following risk factors were present, both CT scanning and hospital admission for observation is recommended, even when the injury is minimal or mild. The risk factors are as follows: thereapeutic anticoagulation or hemophilia, radiographically demonstrated skull fracture, clinical signs of basal fracture or depressed fracture, post-traumatic seizures, shunt-treated hydrocephalus, multiple injuries.

European Federation of Neurosurgical Societies (EFNS) Guidelines

The EFNS guidelines classify MHI into four categories, each with its own management paradigm[20].

MHI Category 0

- GCS 15
- No Loss of consciousness
- No post-traumatic amnesia
- No risk factors

Risk factors : unclear or ambiguous accident history, continued PTA, retrograde amnesia more than 30 minutes, trauma above the clavicles including clinical signs depressed or basal fracture, severe headache, vomiting, focal neurological deficit, seizure, age less than 2years, age more than 60 years, coagulation disorders, high energy accident.

Patients in this category can be discharged home.

MHI Category 1

- GCS 15
- Loss of consciousness < 30 min
- Post-traumatic amnesia < 60 min
- No risk factors

For patients in this category CT is recommended and if CT is normal, may be discharged home with instructions for observation.

MHI Category 2

- GCS 15 with risk factors

For patients in this category CT is mandatory

MHI Category 3

- GCS 13/14 with or without risk factors.

For patients in this category CT is mandatory.

WHO Guidelines

These guidelines were proposed by the WHO collaborating task force on mild traumatic brain injury in the year 2004[10]. They proposed a set of six historical and four clinical criteria as follows:

HISTORY

1. Age ³ 60 years
2. Dangerous mechanism of injury
3. Any vomiting
4. Headache
5. Any seizure
6. Anterograde amnesia

Examination

1. GCS < 15
2. Drug or alcohol intoxication
3. Skull Fracture
   a. Suspected open or depressed fracture skull
   b. Signs of skull base fracture

4. Evidence of trauma above the clavicles Patients with GCS 15 without any of the above risk factors can be discharged home without CT examination. Patients with GCS score of 15 and one or more of the risk factors should undergo CT scan and if the scan is normal, the patient can be discharged for home observation. Patients with GCS score of 13 or 14 should be admitted to the hospital and undergo CT.

Limitations of Clinical Guidelines for CT scanning in MHI

Many of these guidelines like the Canadian CT head rule and the New Orleans CT head rule claimed 100% sensitivity in detecting intracranial lesions in patients with MHI. However, this has not been validated by independent studies. Unpublished data from a study conducted at the Head Injury unit of our institution showed that even though both Canadian and New Orleans CT head rules had more than 95% sensitivity, they did miss some patients with intracranial lesions (Rajbaskar R and Muthukumar N –unpublished data). Another recent study conducted in Spain by Ibanez and colleagues showed that none of these guidelines have 100% sensitivity[36]. Thus, none of the presently available guidelines can achieve 100% sensitivity in detecting patients with intracranial lesions following MHI. This is a point to consider as presently most physicians have to face not only clinical but also legal responsibilities. *Thus, while using these guidelines physicians should be aware of the small risk of missing intracranial lesions in patients with MHI.*

American Academy of Pediatrics and American of Family Physicians Joint Guidelines for CT in Children with MHI[37]

Guidelines for patients in the age group of 2 – 20 years: According to this parameter, MHI is defined as those children with head injury who have normal mental status at the initial examination, and who have no abnormal or focal findings on neurological examination, and who have no physical evidence of skull fracture. This includes children who might have sustained brief loss of consciousness (less than one minute), vomiting, seizure and might be experiencing headache at the time of presentation.

Children with no loss of consciousness: Observation in hospital or home under a reliable caregiver .

Children with brief loss of consciousness (less than one minute): Cranial CT is recommended. The use of skull radiograph in children with MHI is not recommended. The clinician should weigh the benefits of subjecting young children to CT against the risk of anesthesia or sedation for CT in such children.

Guidelines for patients less than 2 years of age(38)

Children less than two years of age are considered separately because in them, clinical assessment is more difficult, asymptomatic or occult intracranial injury occurs commonly, the risk for nonaccidental injury (child abuse) is higher, the incidence of skull fractures from minor trauma is greater, and leptomeningeal cysts (growing fractures) may develop. American Academy of Pediatrics sub-classified children, less than 2 years with MHI as follows:

High risk group

- Depressed mental status
- Focal neurological findings
- Signs of depressed or basal fracture
- Acute skull fracture by clinical examination or plain radiography
- Irritability
- Bulging fontanelle
- Loss of consciousness more than 1 minute
- Seizures
- Progressively worsening vomiting

In this group CT is mandatory.

Intermediate Risk Group: This group is further subdivided into two subgroups:

1. Children with clinical indicators of possible brain injury:
    - Three or more episodes of vomiting
    - Transient Loss of consciousness (less than 1 minute)
    - History of lethargy or irritability which has resolved by the time of examination
    - Behavior not as in pre-injury status
    - Non acute skull fracture (more than 24 hours)

CT should be considered if more than one of the above factors are present.

2. Children with a concerning or unknown mechanism of injury or who have findings on physical examination that may indicate an underlying skull fracture:
    - A higher force mechanism (motor vehicle collision or child ejection, falls more than 3-4 feet)

- Falls on to hard surfaces
- Scalp hematomas particularly if large and boggy and located in the temporo-parietal area
- Unwitnessed trauma
- Vague or absent history of trauma in the setting of signs or symptoms of head injury

If CT available –CT; otherwise skull radiography and observation.

Low risk group

- Children with low energy mechanisms (falls from height of less than three feet)
- No signs or symptoms at least two hours after the injury

Observation, if feasible, at home.

Newer Developments in Brain Imaging in Mild Head Injury

CT remains the most important imaging modality in the evaluation of patients with mild head injury. While MR imaging is increasingly being used to evaluate patients with MHI, it has not gained widespread acceptance because of the costs, limited availability, and limited practical usefulness in the acute trauma setting. However, recent reports in the literature point to an increasing role of MRI, MSI (magnetic source imaging), PET and SPECT in the evaluation of patients with "post-concussion symptoms" which are very common after MHI. It is well known that MHI can have long lasting effects and after 6 months about 15 % to 30% of patients may have appreciable complaints often termed as "post-concussional syndrome"[39]. Apart from post-concussional syndrome, there is also evidence that MHI patients might have neurocognitive impairment. While MR conventional MR imaging provides evidence of structural damage, other techniques like SPECT and PET provide evidence of abnormalities of brain function. This section provides a brief overview of the importance of these newer neuroimaging techniques in MHI.

Hoffman and colleagues studied 21 patients with MHI (GCS 14 and 15) with MRI, SPECT and neurocognitive examination within 5 days after head injury and again after 2 and 6 months[39]. They found 57% of patients have abnormalities on MRI and 61% had abnormalities on SPECT and these patients showed evidence of brain atrophy during follow-up. Thus, they postulated that the post concussion symptoms that are known to occur in patients with MHI may have an organic rather than functional basis. More recently, Chen and colleagues performed PET study in a small group of patients with MHI[40]. They showed that even though patients with MHI may have normal metabolism during the resting state, when they were exposed to a cognitive challenge, there was evidence of hypometabolism, especially, in the frontal and temporal lobes[40]. Thus, they postulated that such changes might account for the persistent symptoms like impaired concentration, disturbed memory and altered behaviour in patients who have suffered MHI. Similar results were reached by Audenaert and colleagues with their SPECT study[41]. Levine and colleagues studied patients with MHI with and without post-concussive symptoms as well as control subjects with MR, MSI and EEG[42]. They showed that MSI was more sensitive than any other technique in detecting abnormalities in patients with persistent post-concussive symptoms and as much as 65% of such patients have abnormalities on MSI. Moreover, these abnormalities closely correlated with the neurocognitive deficits the patients had.

New MR techniques, such as magnetization transfer imaging, diffusion-weighted imaging, and MR spectroscopy may increase the sensitivity of MR imaging for traumatic lesions and increase correlation to neurocognitive deficits and eventually to long-term outcome[43-47].

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