

Review Article

CT Scan importance in the first eight hours of head injury

Mohammed Alfageeh^{1*}, Moneerah Bahran², Sultan Albargi³, Ibrahim Althomali⁴, Adnan Alzahrani⁴, Amal Al-Buqaisi⁵, Mahdi Al-Ramadhan⁶, Abdullah Hussain⁷, Abdullah Alghamdi⁸, Khalid Alsuhaibani⁹

¹Faculty of Surgery, Umm Al-Qura University, Al Qunfudhah, Saudi Arabia

²Department of Radiology, Maternity and Children Hospital, Mecca, Saudi Arabia

³Department of Radiology, Security Forces Hospital, Mecca, Saudi Arabia

⁴College of Medicine, Taif University, Taif, Saudi Arabia

⁵College of Medicine, University of Hail, Hail, Saudi Arabia

⁶College of Medicine, Imam Abdulrahman Bin Faisal university, Dammam, Saudi Arabia

⁷College of Medicine, King Abdulaziz University, Jeddah, Saudi Arabia

⁸College of Medicine, King Saud bin Abdulaziz University for Health Sciences, Jeddah, Saudi Arabia

⁹College of Medicine, Arabian Gulf University, Manama, Bahrain

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*Correspondence:

Dr. Mohammed Alfageeh,

E-mail: alfageeh2015@gmail.com

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ABSTRACT

Traumatic brain injury following head injury is a major public health problem that can result in significant long-term morbidity and mortality among adults and children worldwide. Emergency brain imaging is necessary for individuals subjected to traumatic brain injury to early detect treatable conditions. Prompt neurosurgical management of treatable conditions can prevent further damage and secondary neurological deficits. This will subsequently improve the outcome and reduce long-term disability. Computed Tomography (CT) of the brain is the investigation of choice for assessment of patients with head injury due to its availability, advantages, and sensitivity for multiple lesions following head trauma. This article will review and discuss the importance of CT imaging in evaluating patients with traumatic brain injury, its advantages, limitations, and prognostic values.

Keywords: CT brain, Early, Head injury, Traumatic brain injury

INTRODUCTION

Traumatic brain injury following head injury is a major public health problem that can result in significant long-term morbidity and mortality among adults and children worldwide. In the United States, it is estimated that approximately 1.7 million individuals sustain traumatic brain injury annually.

Though most of those injuries are mild, up to 70,000 permanent disability and 50,000 deaths result.^{1,2} Emergency brain imaging is necessary for individuals subjected to traumatic brain injury to early detect

treatable conditions.³ Prompt neurosurgical management of treatable conditions can prevent further damage and secondary neurological deficits. This will subsequently improve the outcome and reduce long-term disability.^{4,5} Computed Tomography (CT) of the brain is the investigation of choice for assessment of patients with head injury due to its availability, advantages, and sensitivity for multiple neurological conditions following head trauma.^{6,7}

This article will review and discuss the importance of CT imaging in evaluating patients with traumatic brain injury, its advantages, limitations, and prognostic values.

EPIDEMIOLOGY AND IMPACTS OF TRAUMATIC BRAIN INJURY

Traumatic brain injury is one of the leading causes of morbidity and mortality worldwide. Head injury can affect multiple structures inside the skull and can involve various brain areas either primarily after injury or secondarily with delayed effects. The incidence of traumatic brain injury in the United States is estimated to be 538/100,000 individual during the past decade.⁸ Head injuries are twice as common in men in comparison to women, and the most common mechanisms of injuries are falls, motor vehicle accidents, and sport injuries or assaults representing 32%, 19%, and 18% of the causes of injuries, respectively.⁸ The vast majority of these cases (78%) are mild who do not need hospitalization, 20% are indicated for hospitalization, and death occur in 3% of these cases. In 2000, traumatic brain injuries required 9.2 billion dollars for medical management costs and resulted in 51.2 billion dollars loss in productivity.^{9,10} The main cause of head injury in adults is motor vehicle accidents, whilst falls are the main cause of injury in extremes of age (children below the age of 5 years and elderly above the age of 75 years).^{11,12}

GRADES OF TRAUMATIC BRAIN INJURY

Many classifications have been developed for evaluating the severity of traumatic brain injuries. Basically, traumatic brain injuries are classified into mild, moderate, and severe injuries according to the initial Glasgow Coma Scale, duration of loss of consciousness, and duration of posttraumatic amnesia.^{13,14}

Mild traumatic brain injury includes patients who have an initial Glasgow Coma Scale of 13 or more, loss of consciousness for less than 30 minutes, and posttraumatic amnesia for less than 1 hour. Patients with moderate traumatic brain injury have an initial Glasgow Coma Scale between 8 and 12, loss of consciousness between 30 minutes and 6 hours, and posttraumatic amnesia ranging from 1 to 24 hours. Initial Glasgow Coma scale below 8, loss of consciousness for 6 hours or more, or posttraumatic amnesia for more than 24 hours are considered severe cases of traumatic brain injury. Though this classification represents the severity of injury and extent of cerebral damage, mild cases are not devoid of long term complications.^{1,15}

Many other factors play a role in predicting the outcome after traumatic brain injury, yet not included in the severity scales. The most common of them are age of patients at time of head injury and alcohol consumption. Advanced age is associated with poor outcome, and some studies report that only 6% of patients above the age of 60 years may have a good functional recovery, even with mild traumatic brain injuries.^{16,17} Furthermore, patients aged 65 years or more who sustain Glasgow Coma Scale below 8 for more than few days have a very low chance to have a good functional outcome.¹⁸ Persistent

vegetative state often develops in these patients. Chronic alcohol consumption occurs in at least 50% of patients with traumatic brain injury and it has a poor prognostic value.¹⁹

TYPES OF TRAUMATIC BRAIN INJURIES

Injuries resulting from head trauma are classified into primary and secondary injuries. Primary injuries refer to the lesions that result due to the direct effect of trauma on the head, and they exist at the time of presentation to the emergency department. These lesions include subdural hemorrhage, subarachnoid hemorrhage, epidural hemorrhage, cortical contusions, intracerebral hematomas, diffuse axonal injury, intraventricular hemorrhages, and vascular injuries. Secondary injuries, on the other hand, refer to lesions that appear as complications of primary injuries and they are preventable. Examples of secondary lesions include cerebral edema, cerebral herniation, brain ischemia, encephalomalacic changes, hydrocephalus, leptomeningeal cysts, and CSF leakage.²⁰

CT BRAIN IN TRAUMATIC BRAIN INJURY

Early brain imaging is essential after traumatic brain injury for evaluating treatable cerebral lesions that might have evolved. Early imaging should be performed within 8 hours of onset of head trauma to visualize acute lesions as will be detailed in the next section.²¹ Follow-up brain imaging is also indicated in some instances at 24-48 hours when intracranial hemorrhage is detected at initial settings or when further deterioration of the level of consciousness occurs.¹⁵ Computer tomography (CT) of the brain is the first line and of choice imaging modality for traumatic brain injury evaluation.²² This section will discuss the advantages, limitations, indications, roles and findings of CT brain in early evaluation traumatic brain injury.

Advantages and Limitations

In the emergency state of traumatic brain injuries, CT brain represents a quick, available, safe, and invasive imaging modality for early evaluation of the cerebral condition following head trauma. Additionally, most of the monitoring instruments and life-support equipment can be accommodated and are not contraindication for entry into the CT scanner suite. One of the main advantages of CT brain in these situations is its high sensitivity for demonstration of intracranial hemorrhage either intra-axial or extra-axial. It can also visualize bone fractures, ventricular size, and mass effect. In comparison to Magnetic resonance imaging (MRI), CT is superior in visualizing bone fractures and radiopaque foreign bodies.

CT imaging is a rapid modality whereby serial sections from the vertex to the skull base can be accurately obtained at 3.75 to 5 mm cuts in less than ten minutes. In suspected orbital, skull base, or maxillofacial fractures,

modern CT scanners provide thinner cuts (1-2.5 mm) for evaluation of these tiny fractures. Multi-slice CT scans also provide high-quality three-dimensional images which improve the diagnostic yield. In acute conditions of traumatic brain injury, CT images are reviewed in multiple levels and windows, and the interpretation is carried out in the workstations. Intravenous contrast injection is not used in these acute conditions not to mimic or mask underlying hemorrhage. These measures allow quick and accurate performance and interpretation of the CT findings. However, several limitations exist when physicians use the CT brain as the sole imaging modality in evaluating patients with traumatic brain injury. The main limitation is the poor sensitivity of the CT scans in visualizing many head injury-associated lesions small cortical contusions, hypoxic insults, and diffuse axonal injury. CT scans are not sensitive to detect these non-hemorrhagic lesions.²³

Other imaging techniques that were or are still being used in traumatic brain injury include plain X rays and MRI scans. In the past, plain skull X rays were used to evaluate adults with head trauma.²⁴ However, plain films were proved to be poor predictors for demonstrating intracranial pathologies. It can visualize significant pathologies in rare occasions. MRI scan is performed only in cases where neurological deficits cannot be explained by the CT findings. Whilst CT scan is the modality of choice in patients with acute traumatic brain injury, MRI is referred in subacute or chronic cases of traumatic brain injury.^{25,26}

MRI has the advantage of being more sensitive than CT to non-hemorrhagic lesions, small extra-axial collections, subarachnoid hemorrhage, and brainstem lesions²³. Furthermore, it enhances the visualization of cortical contusions, diffuse axonal shear or injury, and white matter lesions²⁷. However, neither regular MRI scans nor CT imaging are not sensitive to small micro-hemorrhagic foci. The imaging modality in this case is the gradient echo T2*-heightened images that are sensitive to the altered local magnetic field due to hemosiderin deposition.²⁸

Indications

In the setting of acute head injury, CT brain is indicated in all cases of severe traumatic brain injury, in patients with depressed or compound skull fractures, in patients with penetrating injury, in cases of persistent focal neurological deficits, those with asymmetrical pupillary light reflexes, bleeding diathesis, or anticoagulation therapy.^{22,29}

In general, all patients should have CT scan of their brain following head injury except for those with low risk defined as normal neurological examination, no concussion, Glasgow coma scale of 15, no suspicion of skull fracture, and no history of drug or alcohol intake.

Minor traumatic brain injury, though debatable, often requires CT imaging.³⁰

Role of CT imaging in traumatic brain injuries

CT imaging play a vital role in acute traumatic brain injuries. It is sensitive to bone fractures and multiple primary lesion as follows:

Scalp injury

Scalp injuries can indicate the site of impact of head injury. They include soft tissue lacerations, cephalohematoma, subgaleal hematoma, or foreign bodies. CT brain can demonstrate these injuries early after head trauma.²¹ It can visualize subgaleal hematoma which is the commonest scalp injury after head trauma. It can also visualize radio-opaque foreign bodies and can reveal soft tissue injury as focal edema at the site of impact.²⁹

Skull Fracture

CT scans are highly sensitive to most of the types of skull fractures with the exception of linear non-displaced fractures.³¹ However, this doesn't decrease the value of CT brain in acute evaluation of traumatic brain injury because nonlinear fractures do not often require any treatment except when associated with an underlying epidural hematoma. Depressed and compound skull fractures, which are urgent indications for surgical interventions, can be easily detected with plain CT scans. Furthermore, any underlying parenchymatous contusion can be detected.

Orbital fractures, skull base fractures, and maxillofacial fractures require meticulous radiological evaluation on thin-cuts CT scans (1 mm).³² CT scans can also predict the presence of temporal bone fractures. In this condition, opacification of mastoid air cells, and the presence of pneumatocephals or the presence of fluid in the middle ear cavity occur. Thin-cuts may be necessary for accurate demonstration of the temporal lobe fracture itself.³³

Epidural hematoma

CT scans can visualize different types of hemorrhagic lesions. Epidural hematoma appears between the skull and cerebrum as a well-defined ovoid biconvex extra-axial hyper-density exerting a mass effect on adjacent brain tissue. Epidural hematoma often results from adjacent bone fracture most commonly at the temporal fossa leading to injury to the middle meningeal artery.²⁹

Less common sites of epidural hematoma include the posterior fossa, the middle cranial fossa, and the skull vertex due to disruption of the venous system such as the transverse sinus, sphenoparietal sinus, or superior sagittal sinus, respectively.²⁹ One of the ominous signs of epidural hematoma on CT scans is the 'swirl sign' where

hypointense signal exists within the hyperdense hematoma.³⁴ This sign indicates rapid expansion of the epidural hematoma and necessitates close follow-up.

Subdural hematoma

The second type of hematomas that can be visualized on CT imaging is the subdural hematoma. Subdural hematoma appears as crescent-shaped extra-axial homogenous hyperdensity that layers the hemispheric skull convexity and are limited by dural attachments.³⁵ Unlike epidural hematomas, subdural hematomas are often venous in origin resulting from disruption of the bridging cortical veins. They are commonly seen among elderly due to involitional cerebral atrophy and secondary stretching of the bridging veins making them very vulnerable to injury. Subdural hematomas are often associated with parenchymatous injury.³⁶

Subarachnoid hemorrhage

After head trauma, subarachnoid hemorrhage results due to small pial vessels disruption, extension from an adjacent hematoma, or spread from intraventricular hemorrhage. On CT scans, subarachnoid hemorrhages appear as serpentine hyperdense areas conforming the shape of the cerebral sulci.²³ They occur most commonly contralateral to the site of impact of head injury (contrecoup). They commonly occur at the Sylvian fissure or interpeduncular cisterns. Basilar, Sylvian, and circle of Willis subarachnoid hemorrhages indicate rupture of an adjacent aneurysm. Though CT brain can visualize many cases of traumatic subarachnoid hemorrhage MRI FLAIR films are considered the diagnostic modality of choice for detecting this type of haemorrhage.²⁷

Intraventricular hemorrhage

Early detection of intraventricular hemorrhage is critical because it is associated with grave complications, high morbidity, and mortality rates. Intraventricular hemorrhage can lead to obstructive hydrocephalus and epididymitis.³⁷ It often results from extension from a parenchymatous hematoma adjacent to the ventricular system, retrograde flow of subarachnoid hemorrhage via the fourth ventricles foramina to the ventricles or tearing of subependymal veins due to rotational shearing forces. Intraventricular hemorrhage appears on CT films as CSF hyperdense fluid inside the ventricles with air-fluid level.³⁸ Small amount of intraventricular hemorrhage may appear as hyperdense layers inside the occipital horns of the lateral ventricles.

Cortical contusion

Cortical contusions may be hemorrhagic or non-hemorrhagic. Non-hemorrhagic contusions are difficult to be visualized on CT brain scans and they require MRI brain for better detection. Hemorrhagic contusions appear early on CT brain films as focal hyperdense lesions

affecting the gray matter and sparing the underlying white matter.²¹ They are usually surrounded by vasogenic edema. They are commonly detected at the temporal lobes and orbitofrontal lobes. This is attributed to the fact that these lobes are in contact with rough inner skull tables. They are also common underlying depressed skull fractures. "salt and pepper" appearance occur when the contusions evolve, this comprises mixed areas of hyperdensity and hypodensity.²⁹

Brain edema and herniation

CT scans are also important to detect secondary lesions such as diffuse cerebral edema and brain herniation. Edema may be vasogenic, cerebral, or cytotoxic edema. On CT films, diffuse cerebral edema appears as effacement of sulci, cisterns, and ventricular system.²⁹ Brain herniation, secondary to diffuse brain edema, can also be detected on CT coronal films. Subfalcine herniation appears as displacement of the cingulate gyrus across midline beneath the falx cerebri. Displacement of the temporal lobe over the tentorium is the key finding in uncal herniation. Transtentorial herniation involves displacement of the brain upward with large posterior fossa hematomas, or downwards across foramen magnum with increased intracranial tension.³⁹

CONCLUSION

Early CT brain is essential in almost all cases of head injury except those classified as low risk (normal neurological examination, no concussion, no evidence of skull fracture, Glasgow coma scale of 15, and no history of drug or alcohol intake). CT is the imaging modality of choice in acute evaluation of head injury. It has the advantages of being quick, safe, available, convenient in emergency cases, and sensitive to most of the acute post traumatic lesions. CT scans can detect various types of skull fractures such as depressed and compound fractures, various types of hemorrhage such as epidural, subdural, subarachnoid, parenchymatous, and intraventricular hemorrhages, and many secondary complications such as brain edema and herniation. The main limitations of CT scans are their insensitivity to non-hemorrhagic lesions, hypoxic insults, and diffuse axonal injury. However, it remains the diagnostic investigation of choice in patients with acute head injury.

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