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TRAUMA RADIOLOGY: IMPORTANCE OF COMPUTED TOMOGRAPHY SCANS IN ACUTE TRAUMATIC BRAIN INJURY

Aiman Mohammed Imtiaz

Secunderabad Research and Diagnostic Center, Sec'bad, India
aiman_mohammed@ymail.com

Abstract

We are all increasingly aware of traumatic brain injury (TBI), whether through the news, media or personal experience, but what exactly is TBI? TBI is a physical injury to the brain, which has many causes including road traffic accidents (RTA), falls, assaults, and sports. Because the brain supervises and controls almost all aspects of normal human function, physical, psychological, hormonal or otherwise, injury to the brain may result in wide array of medical, psychological and behavioral problems. Neuroimaging has become an important part of the diagnostic work up of such patients. This review will discuss the role of Computed tomography (CT) as the primary modality of choice in the initial assessment of head injury patients as it is widely available, faster and highly accurate in detecting skull fractures and brain parenchymal lesions.

Keywords: CT scan, head injury, trauma radiology, TBI

1. Introduction

Trauma is one of the most common cause of death and lifelong disability in early decades of life of which majority of cases are neurological trauma [1]. TBI is becoming the most common and devastating problem due to exponential growth in population and increased vehicle use. Head injuries due to road traffic accidents (RTA) are the second most common cause of death, only next to cancer [2]. Head injury remains an important cause of death and disability in young adults, with over 50% of patients experiencing unfavorable outcomes [3]. Studies have shown that nearly 1.6 million head injuries occur in the United States each year, resulting in over 50,000 deaths and over 70,000 patients with permanent neurological deficits [2,3]. TBI accounts for up to 10% of the health care budget and an estimated annual cost to society of $30 billion [4]. Prompt and proper management of TBI can significantly alter their course especially within 48 hrs of injury. Neuroimaging, especially CT can determine the presence and extent of injury and guide surgical planning and minimally invasive interventions [4]. The following review will discuss the indications for imaging patients with TBI and role of CT.

2. Methodology

100 cases of acute TBI with positive CT scan findings were selected randomly during a period of 6 months from 25/9/15 to 25/3/16 and studied retrospectively. In each case, the age, and sex of the patient, type of trauma, associated injuries and CT findings with their percentages are documented.

3. Results

- Out of 100 cases included in the study 72 % are males while females constituted only 28% showing male preponderance in acute TBI.

- 68% cases were associated with fracture of the vault. The distribution of different etiologies is shown in the following diagram-

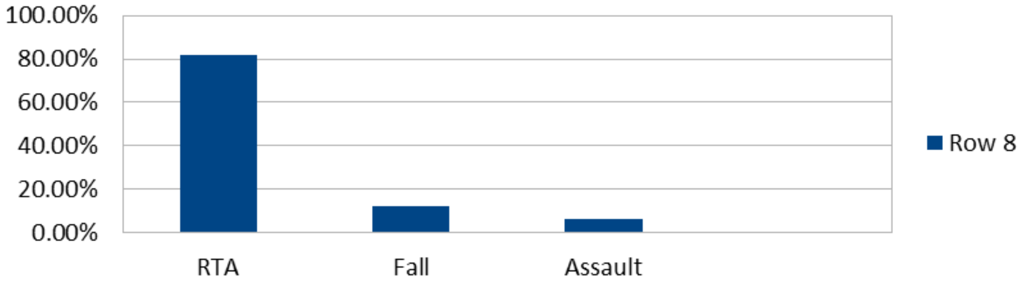

Figure 1: Distribution of etiologies in acute TBI

- Incidence of different sequelae of Acute Traumatic brain injury is shown in Figure 2; where 43% of the cases had brain contusion. Most of the patients with brain contusions had anisocoria, or >60 years or with GCS scores <13. 21% of the patients had subdural hematoma, 13% with subarachnoid hemorrhage (patients were mostly in extremes of age). Most of the cases of SAH were associated with contusions also. 4% had epidural hematoma. 100% of the cases with epidural hematoma were associated with fracture of cranial bones. 12% of the patients had intracerebral hematoma. Whereas Intraventricular hemorrhage and pneumocephalus was found to be least common, 3% and 4% respectively.

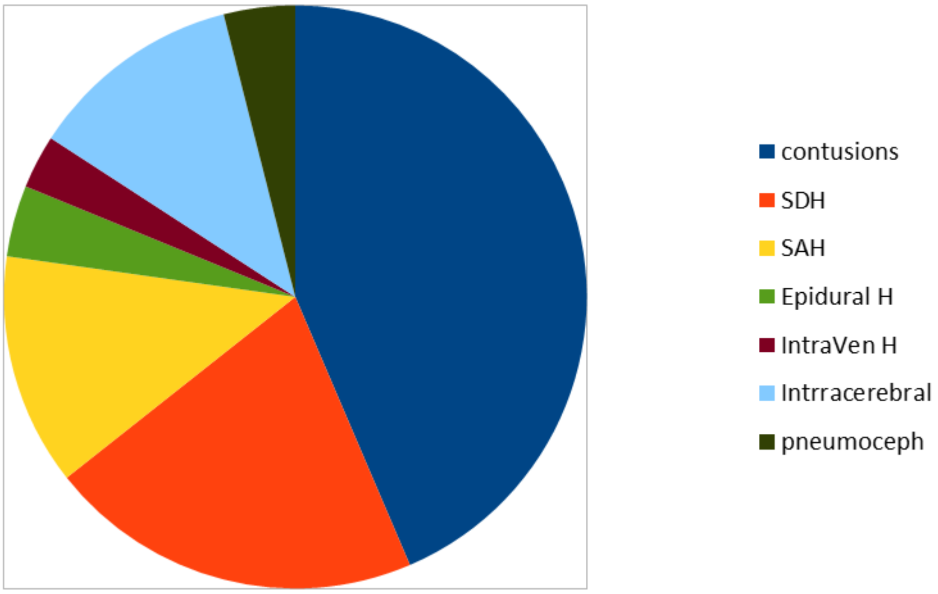

Figure 2: Various intracranial sequelae seen on CT scan after Traumatic brain injury

- Of the 100 patients, 68 had positive CT scans. All patients with positive CT scan had one or more of 7 findings: headache, vomiting, age over 60 years, drug or alcohol intoxication, deficits in short term memory, physical evidence of trauma and seizures.

- Study revealed that performing CT in acute TBI, decreased morbidity and mortality and could lead to cost savings. Performing CT in all head injury patients was cost effective.

- Of 100 patients having cranial CT, neurological examination was positive in 33 cases with positive CT scans.

- In patients requiring craniotomy, the sensitivity of the CT scan was found to be 100% and specificity of 56%.

- MRI scans were more sensitive in detecting non hemorrhagic lesions. There were 2 cases of child abuse and both had injuries of varying ages identified by MRI but not CT. MRI showed evidence of Diffuse axonal injury (DAI)

- Differences in outcome measures, physician acceptance, practice and medico legal environments and judgment affect scanning decision making.

4. Discussion

RTA is the most common etiological factor in TBI cases. Third and fourth decade of life is the commonest age group with male gender because they are involved in economic and social life [5-8]. It is found that children and young adults are most commonly involved in trauma [5,9]. In our study there is increase in the incidence of TBI from pediatric age group to young adults followed by a plateau which constitutes the age group of 40-60 years which is followed by decline in incidence constituting the age group of above 70 years.
According to our study, RTA is the cause of injury in 84% of the cases, while falls constitute 9% of the etiology and 7% assault injuries. In this study 60% of the cases are associated with fracture of the bony vault, while, the non-fractured cases constitute 40% only. However, the lacks of visualization of a fracture doesn't exclude a significant injury to the underlying brain; therefore a skull fracture may or may not indicate a brain parenchymal injury [10].

4.1 Indications for imaging

Not all head trauma patients require neuroimaging [11]. Studies have found that less than 10% of patients that are considered to have minor head injuries have positive CT findings and less than 1% require neurosurgical intervention [12]. But this implies that there are still a small number of low risk patients that would benefit from neuroimaging. Numerous criteria have been developed to categorize the cases into low risk and high risk, including the New Orleans Criteria [13] and the Canadian Head CT rules, [14,15], none have been found to be foolproof. Most practitioners have focused on several criteria:

- **Glasgow coma scale:** Rates a patient's level of consciousness from 3 (worst) to 15 (no impairment) based on patient's ability to open his or her eyes, level of communication. Any score below 13 warrants imaging [16].
- **Vomiting and headache:** Based on New Orleans criteria, all TBI patients with headache or vomiting should be imaged. In our study, presence of vomiting or headache was predictive of intracranial hemorrhage in 45% of the cases.
- **Amnesia:** Longer and more severe amnesic episodes imply a greater chance of hemorrhage.
-**Age (>60 years and infants):** According to New Orleans criteria, all head injury patients over 60 years of age should undergo imaging [17] and according to Canadian CT rules, anyone over age of 65 years is at high risk for needing neurosurgical intervention [18,19]. Studies have also shown a high incidence of intracranial injuries among infants who had no signs or symptoms, suggesting that imaging should be pursued more aggressively in younger children [20].
-**Anticoagulation or coagulopathies:** Although one study showed that patients with abnormal clotting profile were more likely to have delayed brain injury on CT, it has not been clearly established if anticoagulation or coagulopathies should affect the decision to image [21].

4.2 CT v/s MRI in acute TBI

In the acute setting, early diagnosis and management helps in prevention of sequelae due to primary brain injury hence improving mortality and morbidity while reducing hospital stay and costs. Radiology helps in identifying parenchymal and cranial problems and helps in determining their severity and operability. Imaging findings also can provide important prognostic indicators, which may help decide the aggressiveness of management.

In the period immediately after injury, CT scans are most commonly used to diagnose acute problems which may be life threatening. Anatomical imaging with MRI is very sensitive and accurate in diagnosing cerebral pathology in TBI patients. However, conventional CT is the initial imaging modality of choice during first 24hr after injury [22,23,24]. CT is easily available and cost effective, requires shorter imaging time and is easier to perform on patients who are on ventilator support, in traction or agitated. The advent of fast multi-detector CT has dramatically reduced scanning time. Imaging data can be visualized using brain or bone contrast windows and reconstructed into three-dimensional CT in order to demonstrate bone injury. Acute CT is useful in identifying those individuals in whom deterioration is a result of a mass lesion and demonstrate extradural, subdural or intracranial hemorrhage and midline shift.

Forty-eight to 72 h after injury, MRI is generally considered superior to CT. Although CT is better at detecting bony pathology and certain types of early bleeds, the ability of MRI to detect hematomas improves over time as the composition of blood changes. The overwhelming majority of patients with brain injury don't show any abnormality on MRI. MRI is more sensitive in detecting white matter abnormalities than CT [25]. In addition, Gradient echo and fluid attenuation inversion recovery (FLAIR) MR sequences demonstrate high sensitivity for DAI and may help predict outcome [26].Despite the obvious advantages of MRI in terms of delineating the extent and severity of brain injury, MRI is not immediately accessible, and CT remains the modality of choice in acute phase.

DIAGNOSIS	CONCLUSION	SENSITIVITY	
		CT	MRI
DAI	MRI> CT	20%	97%
Fracture	CT> MRI	94%	36%
Hemorrhagic contusion	CT> MRI	94%	24%
Non hemorrhagic contusion	MRI> CT	36%	97%
SDH	CT> MRI	90%	42%
SAH	CT> MRI	94%	32%
Epidural hemorrhage	CT> MRI	96%	72%
Intraventricular hemorrhage	MRI> CT	71%	93%

4.3 Pathologies of TBI seen on imaging

Currently, the advantages of cost and convenience for CT have limited the use of MRI in the acute management of TBI [27]. Additionally investigators are using MRI to better understand the mechanism of secondary brain injury in trauma.

Hemorrhage and edema

Hemorrhage or edema can cause mass effect which can directly compress vascular structures resulting in ischemia and infarct, directly impinging upon other vital structures, or herniate different parts of the brain. Therefore, hemorrhage or edema that is either worsening or already large enough to produce mass effect should be urgently evacuated.
In this study, *brain contusion*s are relatively common, occurring in up to 44% of the patients with blunt trauma and frequently as coup or counter-coup injuries. Contusions associated with a fall, aniscoria, low GCS scores or older patients are likely to benefit from prompt neurosurgical intervention [28]. On non-contrast CT, contusions appear as low attenuation if hemorrhage is absent and mixed or high attenuation if hemorrhage is present. In the acute stage, CT is more sensitive than MRI, as the clot signal can be indistinguishable from brain parenchyma on MRI. After the first few hours, the hemoglobin in the contusion loses its oxygen to become deoxyhemoglobin, which is still not visualized on T1-weighted MRI, but the concentration of red blood cells and fibrin can cause low signals on T2-weighted images. Over the next several days, as the contusion liquefies and deoxyhemoglobin oxidizes to methemoglobin that is strongly paramagnetic, the contusion becomes more easily visualized on MRI.

Subdural hematomas are the second most common pathology after TBI. They are potentially associated with high mortality [28]. Subdural hematomas cause midline shift which is easily visible on CT. They appear as extra-axial concavo-convex hyper dense area with a concave inner margin and convex outer margin equal in density to CSF and blood fluid levels are occasionally seen. It is difficult to distinguish it from chronic SDH on CT scanning [29].

Subarachnoid hemorrhages are more common in children and occur in 13% of patients in this study. It is often seen adjacent to a contusion. CT is superior to MRI in detecting acute SAH. However, FLAIR sequences may find small acute or sub-acute SAH missed by CT and conventional MRI [30].

Epidural hematomas are relatively uncommon and are associated with fracture of cranium in 90-100% of the cases. They appear as an extra-cerebral biconvex and hyper dense elliptical collection with a sharply defined edge and arises within the potential space between the skull and dura.

Intraventricular hemorrhages are also uncommon (less than 4%) and are associated with high morbidity and mortality. On non-contrast CT, blood is of higher attenuation than the low attenuation CSF. On MRI, CSF pulsation artifacts may be misinterpreted as Intraventricular hemorrhage, thus confounding interpretation on conventional MRI sequences. However, FLAIR MRI may be superior to noncontract CT [31]

Increased intracranial pressure

An increased intracranial pressure (ICP) may require ICP monitoring and treatment by osmotic agents, drainage or hyperventilation. Presence of loss of gray-white junction due to cerebral edema, midline shift, a hematoma mass, subdural hematoma, herniation, or change in ventricular shape and size on CT should raise suspicion of intracranial hypertension. According to Miller and colleagues there is a linear association between ICP and CT findings [32]. Further, CT guided percutaneous placement of ICP can be done.

Cerebral herniation

Cerebral herniation is associated with high mortality and morbidity because of compression of vital structures like blood vessels and cranial nerves. Herniation most commonly occurs with diffuse brain swelling as the background. It can also occur with normal ICP when a small volume of clot involves the border of two intracranial components [33]

CT and MRI can effectively diagnose cerebral herniation. The better soft tissue definition of MRI and its multiplanar imaging ability are particularly important in descending transtentorial herniation (caudal descent of brain through the tentorial incisura) [33, 34]

Fractures

Although plain x ray film of skull may detect fracture but CT is the imaging modality of choice in detecting cranial fractures and based on the CT findings prompt intervention can be done to prevent CSF leak, infections and hemorrhage. High definition CT is adequate in detecting small fractures that are the sites of CSF leaks. Open skull fractures depressed more than the full thickness of the skull should be surgically elevated [35]. Several imaging modalities have been used to identify CSF leaks: radionuclide with 111-indium or 99m-Tc DTPA, CT cisternography and MRI using a 3D constructive interference sequence. Radionuclide studies are sensitive in detecting CSF leaks but poor at providing information about exact anatomic location, which is important in to guide surgical repair. CT cisternography has been used traditionally for this purpose.

Pneumocephalus

Fractures involving the Para nasal sinuses, mastoid air cells, or the entire thickness of the cranium can allow air to enter the intracranial space. Air appears as an area of low attenuation on CT and signal void on MRI [36] Patients with basilar skull fractures should receive a follow-up CT scan to exclude pneumocephalus.

Foreign bodies

With rising prevalence of firearm injuries, it is increasingly common to find foreign bodies in the head. Non contrast CT remains the imaging modality of choice. Studies on the use of MRI have been limited and have not found MRI have been limited and have not found MRI to add information to affect acute management.

Vascular Injury

Trauma can damage walls of the blood vessels leading to dissections, aneurysms and fistulae. Imaging is used to identify the presence of vascular lesions, inform the decision to repair by determining the size and location of the lesion, collaterals, and guide the type and approach of the intervention. Contrast angiography is the gold standard investigation for diagnosis of vascular injury. However, MRI, MRA and CTA are growing in use and capability. Conventional angiography provides information about the lumen of the blood vessels, MRA and CTA can provide information about the arterial walls and MRA about adjacent parenchymal lesions [37]. CTA offers better resolution and fewer flow related artifacts than MRA. [38, 39]

Cerebral ischemia

All the complication of head trauma eventually leads to cerebral ischemia which if untreated is associated with high morbidity and mortality. Cerebral ischemia can occur in the absence of CT findings or before CT findings evolve. Because conventional CT is poor at detecting cerebral ischemia, practitioners have explored the use of other modalities to detect altered cerebral perfusion.

In such patients perfusion-CT is the modality of choice. In perfusion CT, nonionic iodinated contrast material is administered intravenously and multiple sequential CT images of the head track the flow of contrast material through the brain. Comparison with Xenon CT and PET have found that perfusion CT accurately assesses brain perfusion [40]. Perfusion CT is more sensitive (87.5%) than conventional non contrast CT (39.6%) in detecting cerebral ischemia [41].

5. Conclusion

Imaging is an important clinical tool used in the management of patients with TBI. Abnormal neurological examination is the most important criterion available to select patients for emergency CT. CT scanning is the *primary modality of choice* in the diagnostic work up of patients with acute *traumatic brain injury* for identification of various intracranial consequences, especially with in 48 h, which helps in the initial assessment, treatment planning, and follow-up and long-term management of patients. CT allows rapid assessment of the extent and type of brain pathology which ensures patients who require urgent surgical intervention at the earliest opportunity. CT perfusion can be implemented easily which provides quantitative perfusion data in addition to structural images.

CT scan is essential in the management of patients with minor head injuries and if neurological examination is normal and the scan is negative the patient can be safely discharged from the emergency room. Although MRI identifies lesions not evident on CT, MRI does not alter management plans and is of limited value in the acute management of TBI. MRI may be of medico legal benefit in cases of child abuse.

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