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Article

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Commonly available CT characteristics and prediction of outcome in traumatic brain injury patients

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Abstract: *Background*: Acute Computerized Tomography (CT) characteristics are used widely and most accepted for prediction of outcome among Traumatic Brain Injury (TBI). The commonly available and simple combinations of existing and unexplored CT parameters may be more useful in prediction of outcome. The present study explores commonly available CT characteristics by possible combinations based on anatomical basics. *Methods*: Abnormal CT sign was considered with any cranial lesion. Based on anatomical locations of cortical lobes, nine possibilities were made that include individual and combinations of mentioned lobes. The laterality was either right or left or bilateral. The outcome was favourable or unfavourable based on discharge Glasgow Outcome Scale (GOS). Binary logistic regression was used to predict outcome.

Results: 452 patients were recruited in the present study. There was significant risk of unfavourable outcome among patients with location of Sub Dural Haemorrhage (SDH) in Parietal + Temporal region (OR=10,p<0.001); Cerebral Contusion in Temporal region (OR=3,p=0.03), Frontal + Temporal region(OR=16,P=0.001), Frontal + Parietal + Temporal region (OR=18.7,p<0.001). Patients with four abnormal CT signs had worst outcome. Presence of SDH on right side (OR=4.5,p<0.001) and bilateral Cerebral Contusion (OR=4.5,p=0.003) was at the risk of unfavourable outcome. *Conclusion*: The present study based on anatomical classification has shown that location and laterality of lesion can significantly predict TBI outcome.

Key words: CT characteristics, locations, laterality, cortical regions, prediction, outcome

Introduction

Computerized Tomography (CT) examination remains the investigation of choice in the acute phase of Traumatic Brain Injury (TBI). CT characteristics not only widely accepted for descriptive purposes, but also increasingly being used as major predictor of outcome in TBI. Following TBI the pathological findings on CT scan that is represented by scoring system is oriented in predicting prognification of outcome (2, 4, 12, 13). Various studies and the international guidelines on prognosis include the CT scoring system as a major outcome predictor13. Several predicting models in terms of scoring had been developed for TBI prognostication. Few models are validated and few are not accurately validated (12). The current available CT scoring systems based on abnormal CT characteristics do not provide details that are best suited for prediction. Possibly there are other very simple combinations of CT parameters that may be more appropriate for this specific purpose that has not been investigated in detail. The aim of the present study is to examine the possible available CT characteristics with simple combinations based on anatomical location and distribution.

Methods

Inclusion and exclusion criteria

Inclusion criteria for the study were patients with history of TBI and having abnormal CT signs. Any age group and both the genders were considered, very importantly willing to participate in study. The study was approved by Institute Ethical Committee; the purpose of the study was explained in patients own language and willing patient/relative written consent was taken before enrolling into the study.

Abnormal CT signs

Patient's emergency CT scan showing any cranial abnormality was considered as abnormal CT signs. Abnormal cranial CT signs were Intra Cerebral Haemorrhage (ICH), Cerebral contusion, Sub Arachnoid Haemorrhage (SAH), Extra Dural Haemorrhage (EDH), Sub Dural Haemorrhage (SDH) and Skull Fracture (Figures 1-4).

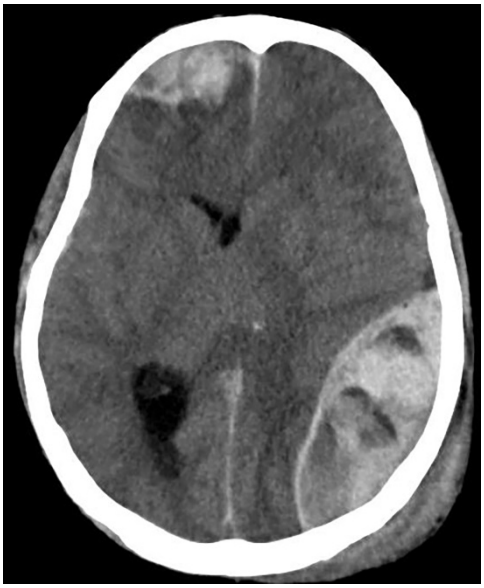

Figure 1 - CT scan brain plain showing left parieto-occiptal extradural hematoma with scalp swelling and right frontal polar contusion

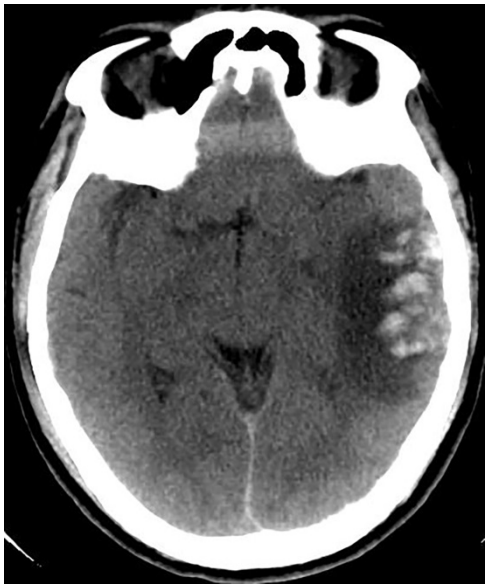

Figure 3 - CT scan brain plain showing left temporal contusion with mass effect and perilesional oedema

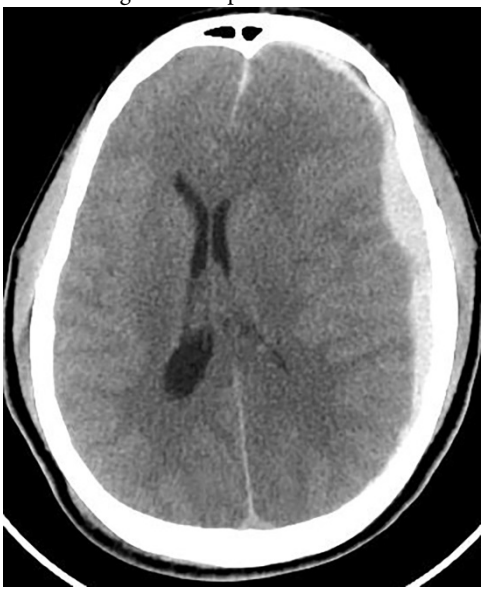

Figure 2 - CT scan brain plain showing left fronto-temporo-parietal acute subdural hematoma with mass effect and midline shift

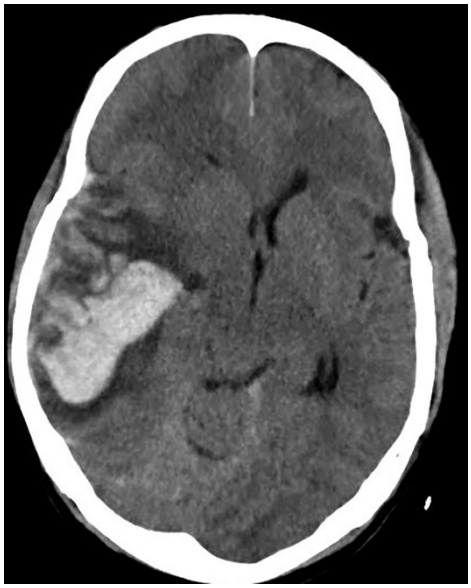

Figure 4 - CT scan brain plain showing right temporal thin acute subdural hematoma and coalescing contusion causing formation of intracerebral hematoma with peri-lesional oedema and mass effect

Location

Based on location of abnormal CT signs on different lobes of brain it was categorized into nine groups. That includes Frontal, Temporal, Parietal, Occipital, Frontal + Temporal, Frontal + Parietal, Parietal + Temporal, Temporal + Occipital, Frontal + Parietal + Temporal. Further each patient either having EDH or SDH or ICH or Cerebral Contusion or Skull Fracture, abnormal CT signs were grouped into one with either of one mentioned, two with combination of two abnormal signs, three combinations of three abnormal signs and four with combination of four abnormal signs.

Laterality

The laterality of abnormal CT signs was categorized into Left hemisphere, Right hemisphere and bilateral hemisphere.

Outcome

The discharge outcome was evaluated using Glasgow Outcome Scale (GOS). The scale was categorized into favourable that includes Good and Moderate recovery and unfavourable that includes persistent state, severe disability and death.

Statistical analysis

The collected data was analyzed using SPSS software IBM SPSS Version 22. Percentages were calculated for categorical data, and mean, standard deviation was calculated for continuous data.

Logistic regression model

Binary logistic regression was used to identify the possible risk factors responsible for discharge outcome favourable or unfavourable (dependent variables). The variables that included in logistic regression model are; EDH, SDH, Cerebral Contusion, ICH, Skull Fracture, SAH, location and laterality of abnormal CT signs. Significance level was considered with p value of ≤0.05.

Results

During study period 452 patients were explored with mean age of 39.39 ± 15.08 years. Victims from male gender were four times (79%) higher than female group (21%). Patients with favourable and unfavourable outcome were 84% and 16% respectively.

Location of abnormal CT signs

Distribution of EDH, SDH, ICH, CC and Skull Fracture at nine different location mentioned elsewhere are detailed in Table 1. Location of EDH at Temporal region is 1.2 times at the risk; Occipital region at 6 times at the risk; Frontal + Parietal region at 2 times at the risk of unfavourable outcome, however none were significant. SDH at Parietal + Temporal region was significantly ($p<0.001$) 10 times at the risk of unfavourable outcome. Presence of Cerebral Contusion was at Temporal region was 3 times at the risk ($p=0.03$); Frontal + Temporal region was 16 times ($P=0.001$) at the risk; Frontal + Parietal + Temporal region was 18.7 times ($p<0.001$) at the risk of unfavourable outcome. For details refer Table 2.

Majority of patients had one abnormal CT sign that is 271(60%), followed by two 146(32%), three 31(7%) and four (1%) abnormal findings. Patients with one, two and three abnormal CT findings were at lesser risk of unfavourable outcome with reference to four abnormal CT findings (Table 2).

Laterality of abnormal CT signs

Distribution of abnormal CT signs (EDH, SDH, Cerebral Contusion, SAH) either on left or right or bilateral hemispheres are shown in table 3. Majority of patients has abnormal CT signs (EDH, SDH, Cerebral Contusion, SAH) on right side 215 (48%), followed by left side 151 (33%) and bilateral 86 (19%). SDH on right side is significantly ($p<0.001$) 4.5 times at the risk of unfavourable outcome. Bilateral Cerebral Contusion is significantly ($p=0.003$) 4.5 times at the risk of unfavourable outcome. Presence of bilateral abnormal CT sign is significantly ($p=0.005$) 2.4 times at the risk of unfavourable outcome.

Table I

Distribution of abnormal CT findings in different anatomical lobes of brain

Location	Abnormal CT signs n (%)				
	Extra Dural Haemorrhage	Sub Dural Haemorrhage	Intra Cranial Haemorrhage	Cerebral Contusion	Skull Fracture
None	348 (77)	292 (65)	446 (98.8)	174 (38.5)	326 (72)
Frontal	27 (6)	40 (9)	2 (0.4)	113 (25)	50 (11)
Temporal	30 (7)	18 (4)	2 (0.4)	79 (17.5)	60 (13)
Parietal	16 (3.5)	7 (1.5)	0	27 (6)	3 (0.7)
Occipital	7 (1.5)	6 (1)	1 (0.2)	1 (0.2)	5 (1)
Frontal + Temporal	1 (0.2)	0	0	12 (2.7)	2 (0.4)
Frontal + Parietal	14 (3)	6 (1)	1 (0.2)	9 (2)	0
Parietal + Temporal	1 (0.2)	19 (4)	0	20 (4)	7 (0.3)
Temporal + Occipital	7 (1.5)	64 (14)	0	1 (0.2)	7 (0.3)
Frontal + Parietal + Temporal	0	0	0	16 (3.5)	0
Total	452 (100)	452 (100)	452 (100)	452 (100)	452 (100)

Table II

Outcome prediction based on location of CT characteristics

Abnormal CT sign Location	Significance	Odds ratio	95% CI	
			Lower	Upper
Extra Dural Haemorrhage*				
Temporal	0.83	1.2	0.22	6.50
Occipital	0.06	6	0.88	40.43
Frontal + Parietal	0.36	2	0.41	10.96

Sub Dural Haemorrhage*				
Frontal	0.47	1.6	0.40	6.85
Parietal	0.40	2.3	0.31	17.38
Frontal + Temporal	0.11	5.4	0.64	44.93
Parietal + Temporal	**<0.001**	10.2	4.25	23.89
Cerebral Contusion*				
Frontal	0.11	2.1	0.84	5.28
Temporal	**0.03**	3	1.10	8.58
Parietal	0.21	2.6	0.56	12.30
Frontal + Temporal	**0.001**	16.2	3.29	80.29
Frontal + Parietal	0.76	1.5	0.11	18.38
Parietal + Temporal	0.24	2.5	0.54	11.42
Frontal + Parietal + Temporal	**<0.001**	18.7	4.86	71.87
Skull Fracture*				
Frontal + Temporal	0.53	2.9	0.10	79.45
Parietal + Temporal	0.39	5	0.13	186.39
Number of abnormal CT signs$				
One	0.10	0.18	0.02	1.37
Two@	0.10	0.18	0.02	1.39
Three@	0.13	0.19	0.02	1.70

* reference is no abnormal CT sign; $reference is presence of four abnormal CT sign; @ combination of either Extra Dural Haemorrhage or Sub Dural Haemorrhage or Intra Cranial Haemorrhage or Cerebral Contusion or Skull Fracture

Table III

Distribution of abnormal CT findings based on laterality

Laterality	**Abnormal CT signs n (%)**			
	Extra Dural Haemorrhage	**Sub Dural Haemorrhage**	**Cerebral Contusion**	**Sub Arachnoid Haemorrhage**
None	350 (77.4)	272 (60)	181 (40)	404 (89.3)
Left hemisphere	47 (10.4)	68 (15)	95 (21)	16 (3.5)
Right hemisphere	51 (11.2)	104 (23)	127 (28.2)	23 (5)
Bilateral hemisphere	4 (1)	8 (2)	49 (11)	9 (2.2)
Total	452 (100)	452 (100)	452 (100)	452 (100)

Table IV

Outcome prediction based on distribution of CT characteristics

Laterality of abnormal CT signs	Significance	Odds ratio	95% CI	
			Lower	Upper
Extra Dural Haemorrhage*				
Bilateral	0.59	2.1	0.13	34.01
Sub Dural Haemorrhage*				
Left	0.32	1.5	0.64	3.66
Right	**<0.001**	4.5	2.20	9.16
Bilateral	0.85	1.2	0.14	10.55
Cerebral Contusion*				
Left	0.28	1.6	0.68	3.72
Right	0.30	1.5	0.70	3.10
Bilateral	**0.003**	4	1.60	9.31
Sub Arachnoid Haemorrhage*				
Left	0.94	1.1	0.21	5.16
Bilateral	0.37	2.1	0.39	11.83
Laterality of abnormal CT signs@				
Left	0.70	0.88	0.47	1.64
Bilateral	**0.005**	2.4	1.29	4.38

P<0.05; *reference is no abnormal CT sign; @reference is right side

Discussion

The present study summarize that there is significant risk of unfavourable outcome among patients with SDH in Parietal + Temporal region; Cerebral Contusion in Temporal, Frontal + Temporal, & Frontal + Parietal + Temporal regions and also Patients presenting SDH on right sided and bilateral Cerebral Contusion. Patients with ≤ three abnormal CT signs are having favourable outcome as compared with four abnormal CT signs. Presence of bilateral abnormal CT sign is significantly having unfavourable outcome as compared with right side.

Among brain injury patients, early diagnosis and aggressive management is very crucial to prevent further complications of ongoing injury process. Identification of anatomical site of injury is essential for taking appropriate measures to reduce morbidity and mortality (1). In acute settings imaging helps in accurate localization of any cerebral damage. During first 24 hours of injury conventional CT scan is considered to be imaging modality of choice because of its availability, lesser imaging time, able to perform on disturbed patients and cost effective (2). CT scan is superior in detecting any bony damage and bleeding in brain parenchymal or meninges or spaces (3). CT characteristics not only provide details of devastating site but also provide base for

interpreting outcome (4).

Brain injury is affected by multiple factors and heterogeneous in manifestation because of which identifying variables specific for outcome prediction is challenging. In present armamentarium individual or combination of CT characteristics scoring system has remained vital entity in prognostication of TBI patients. The scoring systems have incorporated CT characteristics like cisterns, midline shift, volume of mass lesions, blood in brain spaces, and density of lesion (5, 6). Many studies have detailed and verified these scoring systems in predicting outcome. The scoring systems are not without limitations. Prediction of TBI outcome may be better with individual or combination of location and/or laterality of abnormal CT signs (4, 8, 9, 10).

The locations of abnormal imaging characteristic either focal or diffuse are also important in predicting outcome (10). But localization of imaging characteristic in specific brain lobes (either single or combination) may also be useful in outcome prediction, because brain lesions in different anatomical areas are heterogeneous in manifestation (10). A study on paediatric TBI predicted outcome based on location of brain lesions. In the study the brain were distinguished into three zones: zone A (cortical structures); zone B (basal ganglia, corpus callosum, internal capsule, and thalamus); and zone C (brainstem). The Magnetic Resonance Imaging (MRI) Fluid-attenuated inversion recovery (FLAIR) hyperintense lesions in mentioned zones were correlated with GOS. The study reported that Patients with lesion in all three zones were 4.4 times at the risk of unfavourable as compared to lesions only in zone A or both in zone A & B (10). In the present study only cortical areas are evaluated based on standard anatomical demarcation that is frontal, parietal, temporal and occipital lobes. Our study reports that the patients with abnormal CT signs in one or two or three lobes were having favourable outcome with reference to abnormal CT signs in four brain lobes. The injury to brain in multiple areas predicts worst outcome as reported from our study and literature.

The type of CT characteristics that include SDH, EDH, SAH, ICH and Intra Ventricular Haemorrhage (IVH) plays a significant role in prediction of outcome (7, 8). The anatomical locations of mentioned CT characteristic also have significance in outcome prediction (8, 9). A study from China correlated daily living activities (as assessed by Barthel index) with location of brain lesions among TBI patients. The study reveals that cerebral contusion in temporal, parietal, frontal and occipital lobes among moderate to severe TBI patients were showing significant difference with outcome. The current study reports that cerebral contusion in temporal, frontal + temporal, & frontal + parietal + temporal region and SDH in parietal + temporal region are at the risk of unfavourable outcome.

Laterality of brain injury has significant role in prediction of outcome (11). A study evaluated occupational profile of unilateral TBI patients. The study reported that patients with left hemispheric TBI manifest with poorer functional independence, ability, participation and the quality of performance of everyday activities. The study suggested

that patients with left hemispheric brain lesion need intensive treatment for better improvement (11). The current study reported that patients with bilateral abnormal CT signs have unfavourable outcome as compared with right sided lesions. The abnormal CT characteristics like SDH on right sided and cerebral contusion on bilateral distribution were having worst outcome.

Limitation; Posterior fossa abnormality is not incorporated in the present study, as posterior fossa has significant effect on outcome (10). Our study is restricted only to cortical areas, but sub cortical and brain stem regions are also affected in brain injury as evidenced in literature (10). In the study unfavourable outcome number is lesser than one forth of favourable outcome. The present study had not grouped severity of injury, grouping was important because mild injury may not have significance with location of brain lesions and outcome (8). ICH and cerebral contusion is taken as two different entities. In spite of these limitations our study provides clue that very commonly available CT findings provide higher prediction value for TBI outcome.

Conclusion

The study endow that anatomical distributions of CT findings have potential inference in predicting of TBI outcome. Further studies should include these variables with appropriate anatomical distribution into existing scoring system and look for any higher predictive values in interpreting TBI outcome.

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