Correlation of Initial Computed Tomography Findings with Outcomes of Patients with Acute Subdural Hematoma: A Prospective Study

Ajay Choudhary[1] Kaviraj Kaushik[1] Surya Narayanan Bhaskar[1] Laxmi Narayan Gupta[1] Rajesh Sharma[1] Rahul Varshney[1]

[1]Department of Neurosurgery, Atal Bihari Vajpayee Institute of Medical Sciences, Ram Manohar Lohia Hospital, New Delhi, India

Address for correspondence Kaviraj Kaushik, MCh, Department of Neurosurgery, Atal Bihari Vajpayee Institute of Medical Sciences, Ram Manohar Lohia Hospital, Baba Kharak Singh Road, Near Gurudwara Bangla Sahib, Connaught Place, New Delhi 110001, India (e-mail: kabirapgims@gmail.com).

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Abstract

Introduction In modern emergency service systems, patients are often treated with sedation, intubation, and ventilation at the accident site. But neurosurgical assessment before all these emergency services is important. Thus, this study was designed to investigate the relationships between various parameters of initial CT scan findings and the outcomes of the patients.

Methodology A total of 56 adult patients of traumatic acute subdural hematoma (SDH) whose computed tomography (CT) scan was performed within 8 hours of injury were recruited. The patients with prolonged hypotension, open head injury or depressed skull fracture, bilateral side acute SDH, or contusions/hematoma/extradural hematoma on the contralateral side were excluded. Six separate CT findings were analyzed and recorded, including hematoma, midline shift, subarachnoid hemorrhage (SAH), presence of basal cistern obliteration (BCO), intraparenchymal hematoma/contusion in the same hemisphere, and presence of effacement of the sulcal spaces, and were followed up for three months for outcome analysis.

Results The overall mortality and functional recovery rate were 27 and 50%, respectively. The patients with obliterated basal cisterns and the presence of underlying SAH in patients with acute SDH had statistically significant poorer outcomes as compared with others. However, the extent of midline shift, SDH thickness, and the presence of underlying contusions and sulcal effacement on initial CT scan showed no statistically significant correlation with patients' outcomes.

Conclusions *BCO* and *presence of subarchnoid hemorrhage* underlying acute SDH on the earliest scan in head injury patients signify the severity of brain parenchymal injury. Along with the initial Glasgow Coma Scale score after resuscitation, these two factors should be considered as the most significant ones for predicting the outcomes in traumatic acute SDH patients.

Keywords
- traumatic brain injury
- subarachnoid hemorrhage
- SDH
- CT findings
- basal cistern obliteration

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Introduction

In view of the growing population and increased vehicle use, traumatic brain injury (TBI) is becoming the most common and devastating problem, especially in young healthy people. Trauma is one of the most common cause of death and lifelong disability in the early decades of life, of which majority of cases are neurological trauma.[1] The total volume of TBI in India is unknown, but estimates suggest that there are more than a million trauma-related deaths in India per year, of which 50% are related to TBI.[2] The mortality is high in cases of traumatic acute subdural hematoma (ASDH), with reported rates ranging from 50 to 90%.[3-6] Several factors that influence the outcomes in these cases have been studied extensively, including patient age, initial Glasgow Coma Scale (GCS) score, timing of surgical intervention, and initial computed tomography (CT) findings.[3-10]

In modern emergency service systems, patients are often treated with sedation, intubation, and ventilation at the accident site before a neurosurgical assessment is performed. These treatments make it impossible to assess neurological status accurately on arrival at the hospital. In such cases, surgical decisions and prognosis prediction are largely based on initial CT findings.[8,9]

Methodology

A total of 56 adult patients of traumatic acute SDH, whose CT scan was performed within 8 hours of injury were recruited. The patients with prolonged hypotension due to other major systemic injury, those with open head injury or depressed skull fracture, and those with bilateral side acute SDH or contusions/hematoma/extradural hematoma on the contralateral side were excluded. The severity of head injury was based on the GCS score system. Patients were treated as per the management plan based on clinical and radiological findings. The following six separate CT findings were analyzed and recorded:

- Subdural hematoma thickness.
- Extent of midline shift.
- Presence of subarachnoid hemorrhage (SAH).
- Presence of basal cistern obliteration (BCO).
- Presence of intraparenchymal hematoma/contusion (IPH/C) in the same hemisphere.
- Presence of effacement of the sulcal spaces.

Patients were followed up for a minimum of 3 months, and their outcomes were assessed using the Glasgow Outcome Scale (GOS). GOS I, II, & III were accepted as poor outcomes and GOS IV and V as good outcomes. Mortality rates were calculated in relation to the parameters listed previously.

Statistical analysis was performed using chi-square and Fisher's exact tests. A *p*-value of <0.05 was considered to indicate a statistically significant difference.

Results

A total of 56 patients were enrolled in the study. The mortality and survival rates were 27% (15/56 patients died) and 73% (41/56 patients achieved functional recovery), respectively. The results analysis was performed on the basis of the following parameters:

- Severity of head injury (►**Table 1**).
- CT scan findings (►**Table 2**):
  - SDH thickness.
  - Extent midline shift.
  - SAH.
  - BCO.
  - IPH/C in the same hemisphere.
  - Effacement of the sulcal spaces.

Table 1 Patient outcome correlation with GCS score on presentation

GCS on presentation	Poor outcome	Good outcome	*p*-Value
Severe head injury (*n* = 31)	24	7	<0.0001
Moderate head injury (*n* = 17)	9	8	
Mild head injury (*n* = 8)	0	8	

Abbreviation: GCS, Glasgow Coma Scale.

Table 2 Patient outcome correlation with various CT parameters

SDH thickness	Poor outcome	Good outcome	*p*-Value
<5 mm (*n* = 17)	13	4	0.26
5–10 mm (*n* = 27)	14	13	
>10 mm (*n* = 12)	7	5	
Midline shift	Poor outcome	Good outcome	0.077
< 5 mm (*n* = 15)	7	8	
5–10 mm (*n* = 35)	21	14	
>10 mm (*n* = 6)	6	0	
Basal cisterns	Poor outcome	Good outcome	0.001
Obliterated (*n* = 28)	23	5	
Patent (*n* = 28)	11	17	
Underlying contusion	Poor outcome	Good outcome	0.299
Present (*n* = 16)	8	8	
Absent (*n* = 40)	26	14	
Underlying SAH	Poor outcome	Good outcome	0.001
No SAH (*n* = 23)	8	15	
SAH present (*n* = 33)	26	7	
Sulcal effacement	Poor outcome	Good outcome	0.067
No sulcus effaced (*n* = 8)	2	6	
Sulcal effacement present (*n* = 48)	31	17	

Abbreviations: CT, computed tomography; SAH, subarachnoid hemorrhage; SDH, subdural hematoma.

Severity of Head Injury

There were 31 (51.35%) patients with severe head injury (GCS score: 3–8), 17 patients with moderate head injury (GCS score: 9–12), and 8 with mild head injury (GCS score: 13–15).

In the severe head injury group, 24 (77.5%) patients had poor outcomes and 7 patients(22.5%) had good outcomes. In moderate head injury group (n = 17), 8 (47%) patients had good outcomess and 9 (53%) patients had poor outcomes. In the mild head injury, all patients had good outcomes.

Subdural Hematoma Thickness

The SDH thickness was divided into the following three groups:

- <5 mm.
- 5–10 mm.
- >10 mm.

In our study, the hematoma thickness was not significantly correlated with either the initial GCS score of patients or the outcomes of patients.

Midline Shift

The midline shift was present in 49 (87.5%) of 56 cases. In 15 (26.78%) patients, the midline shift was less than 5 mm. In our study, the extent of midline shift on the first CT scan was not found to be significantly correlated with poor outcomes.

Basal Cistern Obliteration

Basal cisterns were obliterated in the initial scan of 28 (50%) patients and were patent in rest of the 28 (50%) patients. The good outcomes were significantly correlated with patent basal cisterns on the initial CT scan (►**Fig. 1**).

Underlying Contusions

Underlying contusions were present in 40 (71.4%) patients out of total 56, whereas in 16 patients the contusion or intraparenchymal hematoma was not visible on the first CT scan. On comparing both these groups, there was no significant correlation in the presence of underlying contusion and the outcomes of patients. Contusions may not be fully evident on the first scan performed early after trauma as it takes some time for the evolution of contusions. Hence, repeat scans after an interval are important rather than the first scan for watching contusions.

Underlying Subarachnoid Hemorrhage

Underlying cortical/cisternal SAH was recorded in 33 (58.9%) patients, and the rest 23 (41.1%) patients had no SAH. When it was compared with the outcomes of patients, those having SAH underlying SDH had significantly poorer outcomes than those who had no SAH (►**Fig. 2**).

Sulcal Effacement

Sulcal effacement on the initial CT scan was defined as loss of gray white differentiation due to the loss of the sulcal spaces and pushing of the adjacent gyri together. This was seen in 48 (85.7%) out of 56 patients. There was no significant correlation in the outcomes of patients with respect to sulcal effacement. Among 48 patients, 17 (35.5%) had good outcomes, 10 (20.8%) had moderate outcomes, and 31 (74.55%) had poor outcomes. In 8 (14.3%) patients, the sulcal effacement was not present. In these, 6 (75%) patients had good outcomes and 2 (25%) had poor outcomes.

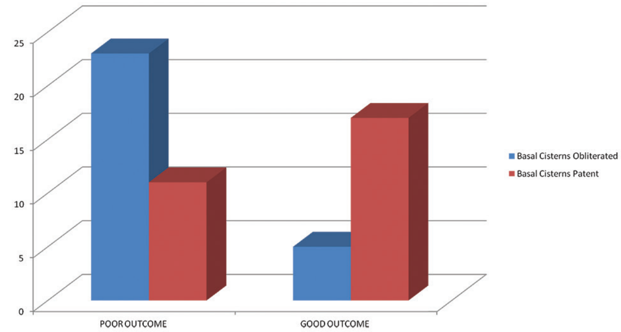

Fig. 1 Correlation between the patency of basal cisterns and the outcome of patients.

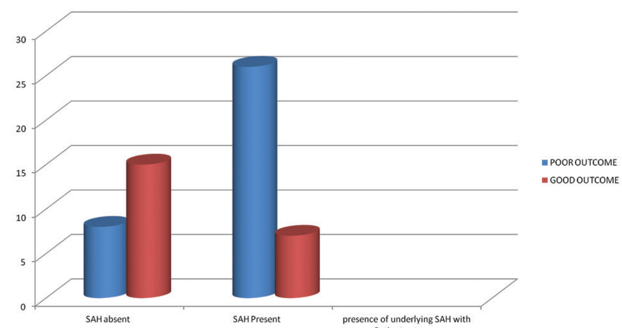

Fig. 2 Correlation between the presence of underlying subarachnoid hemorrhage and the outcome of patients.

Discussion

Many investigators have examined the relationships between initial CT findings and outcomes in patients with traumatic ASDH.[1,4,5,9,11,12] In our study, we investigated all the commonly used CT parameters (hematoma thickness, midline shift, presence of SAH, BCO, presence of IPH/C, and sulcal effacement) in one group of patients. Our aim was to determine the value of these parameters for predicting prognosis in patients with ASDH.

On analysis of previous studies, we found no statistically significant correlation of age, sex, and mode of injury with the outcomes of patients in traumatic acute SDH. But GCS at the time of admission had a strong correlation with outcomes.

Subdural Hematoma Thickness

In our study, the hematoma thickness was not significantly correlated with either the initial GCS score of patients or the outcomes of patients (►**Fig. 3**). It is because the SDH is usually associated with underlying brain damage (e.g., cerebral contusions, hematomas, SAH, diffuse axonal injury). It is the primary brain damage that determines the outcomes of patients. SDH thickness may progressively increase with

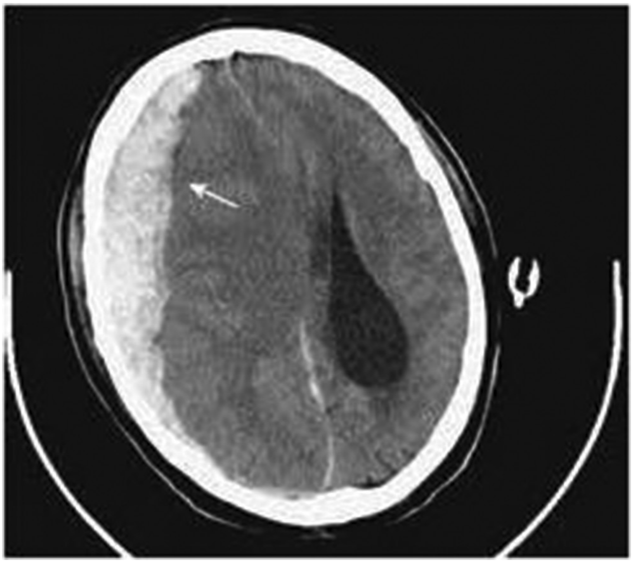

Fig. 3 Axial computed tomography showing subdural hematoma thickness.

Fig. 4 Measuring the extent of the midline shift on axial computed tomography.

time, which may not be evident on the initial CT scan. This finding is also supported by various previous studies.[10,12,13]

Midline Shift

Numerous reports describe the association of a large amount of midline shift on CT scan (usually described as >5 mm) with poor outcomes or other adverse sequelae of TBI (►**Fig. 4**). Our study also shows that patients may tolerate midline shift of up to 1 cm better than more than 1 cm, as all patients with midline shift more than 1 cm had a poor GCS score on presentation, and also none of these patients had good outcomes at three-month follow-up.

Fig. 5 Axial computed tomography showing obliterated basal cisterns with acute subdural hematoma.

Basal Cistern Obliteration

Compression of basal cisterns closely correlated with an intracranial pressure (ICP) greater than 20 mm Hg, with clinical signs of midbrain dysfunctions and worse prognosis (►**Fig. 5**).[14] In modern CT scanning, no matter how young the patient, it should always be possible to identify the third ventricle and basal cisterns; in normal situation, the ambient cistern is smallest and most easily compressed followed by the quadrigeminal cistern. When ICP rises either due to hematoma (SDH/contusion) or due to parenchymal edema, there is a downward shift of the brain, leading to obliteration of basal cisterns. Hence BCO is an indicator of raised ICP and impending downward herniation of the brain. In elderly patients, the brain is atrophic, and these patients tolerate more midline shift or hematoma thickness as compared with young, but when they show obliteration of basal cisterns, it is surely a predictor of significantly raised ICP and the brain herniates. Similarly, in cases of bilateral side head injury, the midline shift may not contribute to the clinical status, but BCO will be a more reliable predictor of outcomes. On statistical analysis, comparing the outcomes of patients with effaced cisterns was significantly poorer as compared with patients with patent basal cisterns (p = 0.001 and < 0 0.05, respectively), which is also in accordance with literature and previous studies

Underlying Contusions/Hematoma

Brain contusion in patients with traumatic ASDH leads to decreased cerebral blood flow, increased ischemic damage, and rapid development of brain swelling (►**Fig. 6**).[15-17] Furthermore, intraparenchymal hematomas may result in increased ICP and midline shift. These intracranial space-occupying lesions should be considered poor prognostic

Fig. 6 Large underlying ipsilateral occipital hematoma with acute subdural hematoma.

Fig. 7 Underlying cortical subarachnoid hemorrhage in patients with acute subdural hematoma.

factors. Servadei et al in their study of 206 acute SDH patients concluded that early CT underestimates the ultimate size of parenchymal contusions and may not be reliable for secondary brain damage due to associated underlying contusions.[18] Various authors have reported an incidence of progression of intracranial lesions or appearance of a new lesion on repeat CT scan ranging from less than 10% to as high as 68%.[19-29] Progressive hemorrhagic injury was reported overall in 42.3% and in 87% of patients who underwent their first CT within 2 hours of injury.

In this study, there was no significant correlation between the presence of underlying contusion and the outcomes of patients.

Underlying Subarachnoid Hemorrhage

Traumatic SAH has cisternal (basal cisterns, interhemispheric spaces, and Sylvian fissures) or sulcal (cortical convexity) distributions and results from a relatively severe injury to the brain (►**Fig. 7**). High angular acceleration of considerable duration is necessary to produce sufficient strain to rupture superficial vessels in the subarachnoid spaces. Posttraumatic vasospasm can also occur early (within 5 days) and induce focal or diffuse cerebral edema.[13]

Accordingly, the presence of combined contusion or SAH with ASDH indicates ASDH associated with substantial impact and more severe brain parenchymal injury, which can worsen the course of the ASDH during the acute phase by the aforementioned mechanisms. Patients with traumatic SAH have a significantly worse outcomes than those without SAH. Son et al concluded that the presence of SAH with ASDH was found to be significantly related, and correlated with the severity of initial injury as estimated by initial GCS scores.[13]

Servadei et al. in their study of prognostic value of worst CT scan in acute SDH patients found evidence of SAH on the first CT examination, which was a powerful predictor of poor outcomes (odds ratio: 0.37; $p < 0.004$). SDH tends to develop secondary parenchymal damage, which is underestimated by the first CT.[18] CT signs of associated SAH on admission identify a population with the highest risk of developing parenchymal damage.

Harders et al reviewed the data from 683 patients in the HIT II nimodipine study and found that among those with SAH, contusions were seen in 13% more patients on the second CT than on the first one. This finding confirms our data showing that SAH can be an early sign of cortical contusion even when parenchymal damage is not yet evident on the first CT.[30]

In their study of patients with traumatic ASDH, Domenicucci et al. identified intact subarachnoid space as a favorable prognostic factor. They suggested that the integral visceral membrane of the hematoma prevents diffusion of neurotoxic and vasoactive substances into the subarachnoid space.[7]

Solaroglu et al reported no statistically significant difference in outcomes between patients with intact subarachnoid space and those who had hemorrhage in the subarachnoid space. But they did note a trend toward poorer prognosis in patients with SAH.[31]

In our study, underlying cortical/cisternal SAH was recorded in 33 (58.9%) patients, and the rest 23 (41.1%) patients had no SAH. When it was compared with the outcomes of patients, those having SAH underlying SDH had significantly poorer outcomes than those who had no SAH. Out of 33 patients of SAH underlying SDH, 20 patients (60.61%) had poor outcomes, 6 (18.18%) had moderate outcomes, and 7 (21.21%) had poor outcomes. In 23 patients who had no underlying SAH, 16 (69.5%) had good outcomes, 4 (17.4%) had moderate outcomes, and 3 (13%) had poor outcomes. The presence of SAH along with ASDH was statistically significant ($p = 0.001$).

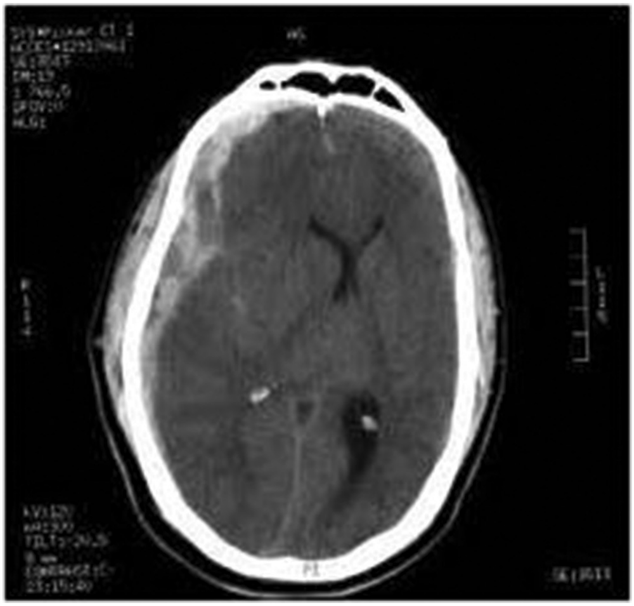

Fig. 8 Effaced sulci in patients with acute subdural hematoma.

Sulcal Effacement

Sulcal effacement is a local secondary sign of mass effect in the cranium (►**Fig. 8**). Any lesion exerting a mass effect on brain parenchyma can push the adjacent gyri together, thereby displacing the cerebrospinal fluid from the sulci and leading to sulcal effacement on CT scan. There are two types of cerebral edema: vasogenic, due to the disruption of the blood–brain barrier allowing accumulation of extracellular water, and cytotoxic, due to the failure of cell membrane pumps, resulting in intracellular water leakage. Of these two types of edema, cytotoxic edema may be primarily responsible for cerebral swelling, as demonstrated by the increased water content and reduced apparent diffusion coefficient values in one magnetic resonance imaging (MRI) study.[32]

On imaging, cerebral swelling due to hyperemia is represented as the loss of sulci (sulcal effacement), compression of the basilar cisterns, and flattening of the ventricular margins. Children are particularly susceptible to diffuse cerebral swelling following TBI, with the incidence of diffuse swelling being approximately twofold higher in children than in adults.[32] Children and young adults are more prone to posttraumatic dysautoregulation, which leads to vasodilatation, hyperemia, and cerebral swelling. When swelling is severe, ICP increases and cerebral perfusion pressure falls, resulting in infarction and cerebral damage.

Conclusions

We found that the following factors had a significant influence on the outcomes of ASDH in our study:

- The presence of combined contusion or SAH with ASDH indicates that ASDH is associated with substantial impact and more severe brain parenchymal injury and is also a strong predictor of poor outcomes in head injury patients.
- BCO, which is an indirect indicator of increased ICP, is the most important factor responsible for unfavorable outcomes.
- Still the outcomes of patients mainly depend on their clinical status and initial GCS score.
- SDH thickness, midline shift, sulcal effacement, and underlying contusions in acute SDH patients may progress with time, and although these findings affect the outcomes, on the initial scan they are not strong indicators of outcome prediction.

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Conflict of Interest
None declared.

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