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Original Article

Role of scheduled repeat CT scan in traumatic brain injuries: A prospective observational study

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ABSTRACT

Background: Scheduled CT scan is a routine practice at many centers after traumatic brain injury (TBI), but it has been questioned by few authors. The majority of the studies are reported in mild TBI; however, no specific data exist for the same in moderate and severe TBI.

Methods: This was a single-center and 1-year prospective study. All cases with TBI who underwent scheduled repeat scans were included in the study. Patients who underwent emergency surgery after first computed tomography (CT) and those who expired before repeat CT were excluded from the study. Data included demographics, Glasgow coma scale (GCS) score, initial head CT findings, findings of repeat CT, and the need for any intervention (medical/surgical).

Results: A total of 231 cases were analyzed. The mean time interval for the repeat CT was 7.8 h. One hundred and seventy-one patients underwent scheduled repeat CT (Group 1), 53 patients with GCS >13 were discharged from emergency before the repeat scan (Group 2), and seven cases underwent repeat CT before the scheduled time in view of clinical deterioration (Group 3). The mean age and gender did not vary significantly between the three groups. Mixed lesions predominated in all; however, the proportion significantly differed between groups. In Group 1, two patients required surgery; in Group 3, all patients required a significant change in treatment, whereas none deteriorated or required a repeat scan in Group 2.

Conclusion: In our study, the yield of routine repeat CT scans requiring surgery was 3.5%. Based on the results of our study and the observations from previous studies, we have proposed a few general working statements regarding indications for repeat CT scans in TBI.

Keywords: Follow-up computed tomography scan, Prospective, Repeat computed tomography scan, Scheduled computed tomography scan, Traumatic brain injury

INTRODUCTION

The incidence of traumatic brain injury (TBI) has been reported to be around 350/100,000 population and is also a major cause of permanent disability.[12] TBI is usually classified based on morphology, injury mechanism, and clinical severity. Conventionally, the clinical severity of TBI is graded based on Glasgow coma scale (GCS) scores as mild (scores 13–15), moderate (scores 9–12), and severe (scores 3–8). Brain imaging with computed tomography (CT) is the mainstay and the most important imaging for any patient with TBI. This is due to the fact that the decision to manage a patient, either operatively or conservatively, is based on CT findings (such as midline shift, cisternal effacement, and volume of hematoma) combined with clinical

examination findings. There are enough data and guidelines regarding the indications for surgery in patients with TBI with regard to different intracranial pathologies such as extradural hematoma (EDH), subdural hematoma (SDH), posterior fossa hematomas, lobar contusions, and depressed fractures.[5] Based on existing literature, the Brain Trauma Foundation (BTF) has formulated numerous guidelines and recommendations for the management of patients with TBI with regard to various aspects such as decompressive craniectomy, intracranial pressure (ICP) monitoring, ventilation, blood pressure management, hyperosmolar therapy, and hypothermia.[6]

Radiation exposure is a concern in CT, and to avoid injudicious radiation exposure, researchers have formulated criteria and guidelines for performing CT brain in TBI.[13,16,20] A scheduled repeat CT scan or follow-up scan is still a routine at many centers for patients with TBI and there exists a lot of debate on this topic. However, there are no specific guidelines regarding the indications for performing the repeat scan. Even there has been no mention of this topic in the BTF guidelines. The time interval for this repeat scan also varies, with most of them choosing 24 hours as a standard time frame. Proponents of the routine CT scan believe that it assists clinicians to detect the early progression of traumatic lesions which may, in turn, help in performing early interventions as there may be a silent progression of lesions without any neurological changes. On the contrary, those opposing the routine repeat scan are of the opinion that patients with unchanged or improving neurologic status who are appropriately monitored may not require a repeat CT scan or any neurosurgical intervention.[1,2,4,7-11,14,17-19,21] In addition, with the easy availability of CT scans in almost every trauma hospital, any neurological deterioration due to a missed intracranial pathology as a result of a delay in getting a scan can prove harmful for the patient and also may result in medicolegal implications for the treating physician. In the existing literature, many of the studies are retrospective, with variable inclusion criteria (e.g., specific GCS subgroups), and are mostly from the Western world and very few from the Indian subcontinent.[11,17] Hence, we conducted this prospective study including TBI patients of all GCS scores, with an aim to know the relevance and impact of a scheduled CT scan after TBI in our clinical setting. In addition, based on the results of our study and previous studies, we intend to propose a few general statements about the requirements of the routine repeat scan in different TBI categories, which may serve as important points for future multicentric prospective studies.

MATERIALS AND METHODS

This was a single-center and 1-year prospective study from October 2020 to October 2021 conducted in the Department of Neurosurgery, Kasturba Medical College Hospital, Manipal, India. IEC approval was taken before the start of the study (IEC 481/2021 dated 24/10/2021). All patients with TBI who underwent scheduled repeat CT scans within 12 hours of the first scan were included in the study. The following were excluded: patients who had normal findings on the first CT scan, who underwent emergency surgery after the first CT brain, who already had a prior repeat CT scan within 12 h, who expired before the scheduled repeat CT scan, and who underwent repeat CT for nontrauma findings.

We divided the study cohort into three groups: Group 1: patients who had their scheduled repeat CT scan performed as per our protocol; and Group 2: patients who got discharged from the emergency department before the repeat scan, and all of them had a GCS score of 15. The reasons were as follows: not consenting for admission or staying at a nearby place; and Group 3: patients who underwent repeat CT scans before the scheduled time interval in view of a change in neurologic examination (drop in GCS score or pupillary abnormalities). If the patient wishes not to get admitted as in Group 2, then a repeat scan would be performed only if they come back with new symptoms. All patients in Group 2 were followed up, either in the outpatient department (OPD) or telephonically.

The following data were collected and analyzed: age, gender, mechanism of injury, GCS score, associated injuries, radiological data (findings of initial CT, indication for repeat CT, and findings of repeat CT), and need for intervention. The lesions seen on repeat CT were classified as better, same, or worse than the initial findings. Lesions were considered better if there was a resolution of contusion/hematoma or reduction in mass effect and were considered worse if there were new lesions or worsening edema/mass effect or increase in the size of contusions. TBI-related interventions were classified as medical (mannitol/hypertonic saline or hyperventilation) or surgical (craniotomy/decompressive craniectomy). All CT scans were read by attending neurosurgeons. As per the literature, a mild TBI with an intracranial pathology on a CT scan is often termed a complicated mild TBI (cMTBI). Since we included only those cases of mild TBI with abnormal scan findings, the terms mild TBI and cMTBI are used interchangeably.

Statistical tests

All statistical tests were performed using the Statistical Package for the Social Sciences software (version 29.0). Qualitative variables were tested using the Chi-square test, and quantitative variables (for testing three groups) were tested using analysis of variance test. $P < 0.05$ was considered significant.

RESULTS

Among a total of 328 cases, 98 cases were excluded and the remaining 231 cases were included in the study and analyzed.

Males predominated, and the most common age groups were 3rd and 5th decades. The mean time interval for the repeat CT from the first scan was 7.8 h (range, 6–12 h).

There were 171 patients in Group 1, 53 in Group 2, and seven patients in Group 3. In our series, we did not have any patients in Group 2 who returned to the hospital with new symptoms warranting a scan. Many of them consulted our OPD for suture removal (for a sutured lacerated wound) or regular follow-up, and the remaining patients were followed up telephonically.

The mean age and gender did not vary significantly between the three groups; however, the severity of TBI varied. In Group 1, there was a predominance of moderate TBI. Group 2 comprised mild TBI alone (cMTBI), whereas Group 3 had more severe TBI cases, and this difference was statistically significant ($P < 0.05$).

With regard to radiology, mixed lesions predominated in all three groups; however, the proportion varied significantly between them ($P < 0.05$). Basal cisterns were preserved in >90% of cases in Group 1, whereas it was compressed in >40% of Group 3 patients ($P < 0.05$). Twenty-eight cases had changes in the CT findings, and this was statistically different between Groups 1 and 3 ($P < 0.05$) (Group 2 was not considered. No repeat scan was done in those patients). Among them, nine cases had worsened, whereas 19 cases showed improvement in CT findings. In Group 1, there were 12 patients with isolated EDHand; two out of those 12 (16.6%) cases needed surgery in view of new scan findings. Of the seven patients in Group 3, five underwent surgery, and two received additional anti-edema measures for the changes noted on repeat CT scans.

Overall, on statistical analysis, we found that age and gender did not differ between the groups, while the severity of TBI, proportion of mixed lesions, basal cistern effacement, and radiological changes in the new scan were significantly different between the groups.

The clinicoradiological characteristics between the three groups (with statistical results) are shown in Tables 1 and 2.

Illustrations

Figures 1 and 2 illustrate two cases of Group 1 who underwent surgery in view of significant findings on repeat scan; Figure 3 illustrates a patient of Group 1 who had worsening contusions on repeat scan but required no change in management, and Figure 4 illustrates a Group 3 patient who deteriorated in GCS score before the scheduled repeat scan.

Table 1: The clinical characteristics of the study cohort.

Variable	Group 1 (*n*=171) (%)	Group 2 (*n*=53) (%)	Group 3 (*n*=7) (%)	*P*-value
Age	38.54±17.14	39.54±17.4	41±18.22	0.54
Gender	Male – 146 (85.4)	Male – 37 (80.7)	Male – 6 (85.7)	0.83
	Female – 25 (14.6)	Female – 16 (19.3)	Female – 1 (14.3)	
Type of HI	Mild – 61 (35.6)	Mild – 53 (100)	Mild – 1 (14.3)	**0.01**
	Moderate – 71 (41.5)		Moderate – 2 (28.6)	
	Severe-39 (22.8)		Severe – 4 (57)	

Bold value indicate significance on statistical tests

Table 2: The radiological characteristics of the study cohort.

CT findings	Group (*n*=171) (%)	Group 2 (*n*=53) (%)	Group 3 (*n*=7) (%)	*P*-value
Contusion	26 (14.8)	11 (20.7)	0	0.54
EDH	12 (6.8)	2 (3.7)	1 (14.3)	0.38
DAI	2 (1.1)	1 (1.8)	1 (14.3)	0.34
SDH	17 (8.9)	10 (18.8)	0	0.62
SAH	11 (6.2)	11 (20.7%)	0	0.05
Mixed	**103 (58.5)**	**18 (33.9)**	**5 (71.4)**	**0.001**
Basal cisterns	Compressed – 11 (6.4)	Compressed – 0	Compressed – 3 (43)	0.02
	Preserved – 160 (93.6)	Preserved – 53 (100)	Preserved – 4 (57)	
Changes in a repeat scan				
Worsened	4 (2.5)	Nap	5 (71.4)	0.04
Improved	19 (11)	Nap	0	
Same	148 (86.5)	Nap	2 (28.6)	

P<0.05 was considered significant. CT: computed tomography, EDH: Extradural hematoma, SDH: Subdural hematoma, DAI: Diffuse axonal injury, SAH: Subarachnoid hemorrhage, Bold values indicate significance on statistical tests.

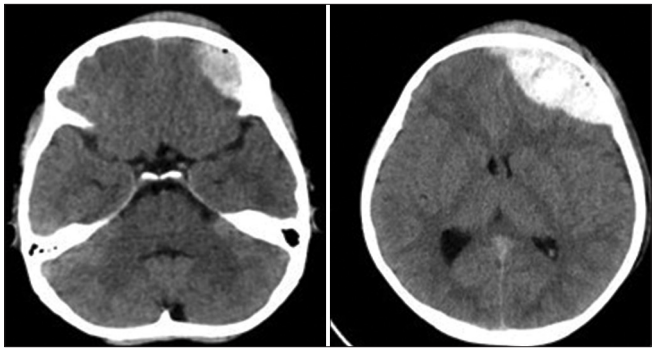

Figure 1: An 8-year-old boy with Glasgow Coma scale 15 and small left frontal extradural hematoma (EDH) (left); repeat computed tomography showing significant enlargement of the EDH (right). He underwent surgery.

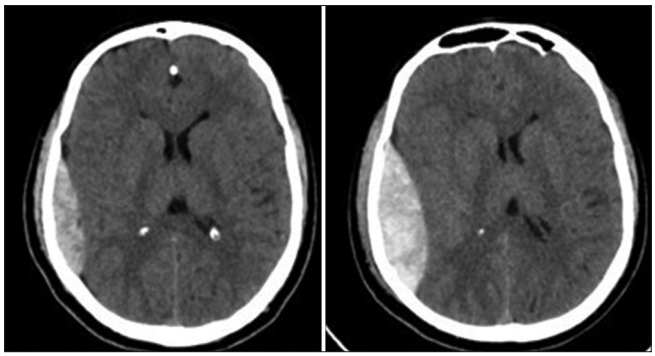

Figure 2: A 23-year-old male with Glasgow Coma scale 15 and small right temporal extradural hematoma (EDH) (left); repeat computed tomography showing significant enlargement of the EDH (right). He underwent surgery.

DISCUSSION

The hazards of radiation are well known, and the most severe ones include the risk of secondary malignancy due to DNA damage.[3] As clinicians, our efforts should be to reduce the radiation dose from medical imaging as much as possible and to avoid injudicious investigations involving radiation exposure. This is because the radiation dose of one CT brain is equivalent to 2 mSv, and that of a repeat scan is 3.2 mSv, whereas that of one chest radiograph is 0.1 mSv.[15] Furthermore, TBI is one of the most common indications for investigating a patient with CT scans. Hence, considering these facts, various researchers have formulated guidelines for performing the first CT scan (on evaluation in emergency) in patients with mild TBI. The most important ones include the Canadian CT Head rule, New Orleans Criteria, and Nexus II criteria.[13,16,20] However, with regard to the repeat CT scan, there are no guidelines available to date. Various studies have been published regarding the necessity/requirement of a routine repeat scan after TBI, and one can find both proponents and opponents for this topic which have been highlighted below in two separate sections.

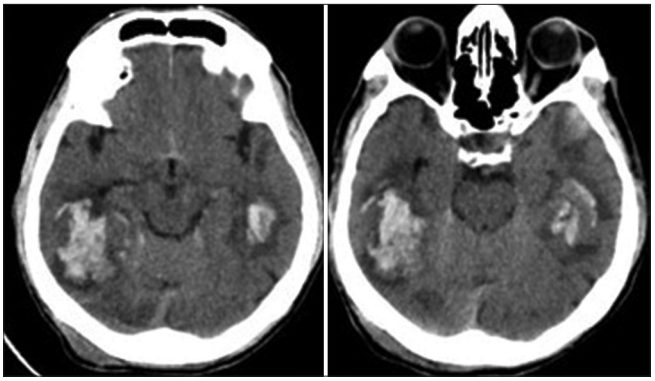

Figure 3: A 60-year-old male with Glasgow Coma scale 12 showing bitemporal contusions (left); repeat computed tomography showed worsening of the left temporal contusion (right). There was no change in management.

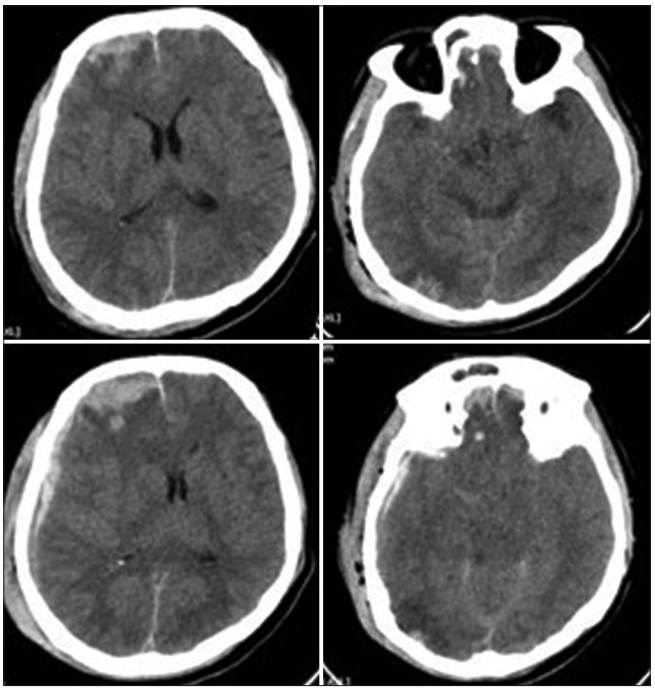

Figure 4: A 55-year-old male with Glasgow Coma scale (GCS) 12 on admission and computed tomography showing thin frontal subdural hematoma (SDH) and contusion with preserved basal cisterns (top panel). He deteriorated in GCS score with pupillary asymmetry and repeated scan showing worsening of the SDH and compressed basal cisterns (bottom panel).

Studies against a routine repeat CT scan

In their prospective 1-year study by Sifri *et al*., the authors included 130 adult patients with minimal head injury (HI) (LOC, amnesia, GCS>13) and IC bleed. A repeat CT scan was done within 24 hours of admission. Around 3/4^{ths} of them (n = 99) had a normal neurologic examination at the time of their repeat cranial CT. They observed that none required immediate neurosurgical intervention or had

delayed neurologic deterioration related to their head injury after the repeat CT scan, and the negative predictive value (NPV) of a normal neurologic examination was 100%. They concluded that repeat CT in patients with minimal HI and a normal neurologic examination is therefore not indicated.[18] da Silva *et al*. conducted a retrospective study of 63 pediatric patients with moderate and severe HI over 7 years. The mean age was 72 months, and the repeat CT time interval was 25.7 h. They noted that the GCS score improved in 66.6%, was the same in 15.9%, and worsened in 17.5% of patients. The CT appearance was better, same or worse in 41.3%, 34.9%, and 23.8% of patients, respectively. There was a significant correlation between GCS and repeat CT findings (odds ratio = 34.5, P = 0.000009). The positive predictive value and NPV values were 82% and 89%, respectively. There was one patient with a worsened GCS who required surgical intervention based on the repeat CT scan. They concluded that an unchanged or improving neurologic status in children sustaining moderate or severe TBI who are appropriately monitored may be adequate to exclude the possibility of neurosurgical intervention and, hence, a repeat CT scan.[9]

Connon *et al*. conducted a 20-month prospective study and included all adult blunt trauma patients. They categorized brain CT as "routine" or "indicated" and included 591 patients, of whom around 80% were mild TBI. Among them, 401 were discharged without a repeat scan (similar to Group 2 in our study), and the remaining 190 patients had undergone 305 repeat scans. They noted that 28 patients had changes in CT findings necessitating change in management, and all of them belonged to the "indicated" category. The authors concluded that the decision to perform routine repeat CT brain should be reconsidered, and repeat CT brain is indicated in patients with deteriorating neurological status, especially younger and more severely head-injured patients.[7] Abdelfattah *et al*. conducted a prospective study including 145 patients with a GCS score of 13–15. They were divided into two groups, namely, routine CT and selective CT groups. They observed that, in the selective group, 6 patients (11%) required a repeat CT for a neurologic change. However, no patient in either group required medical or neurosurgical intervention based on the repeat scan findings. They also noted that the number of CT scans performed differed between the two groups (three scans in Routine vs. one scan in Selective), and the discharge GCS score was similar for both groups. They concluded that the NPV of a repeat CT scan leading to neurosurgical intervention with no change in the neurological examination was 100%.[1] Cooper *et al*. studied the necessity of repeat CT scans in isolated traumatic subarachnoid hemorrhage (SAH) in 299 mild TBI patients retrospectively over 5 years.[6,8] They observed that the average time between the first and second CT was 11.3 hours. Around 90% (n = 267) of patients had either no change or had an improvement, and only 26 patients (8.7%) had either worsening or new findings on CT.[8] In a similar study, Devulapalli *et al*. studied the necessity of repeat CT scans in small isolated falcotentorial SDH. They studied 80 patients with a mean GCS of 14 and observed no changes in any patient on repeat CT.[10] Stippler *et al*. conducted a prospective study in patients with cMTBI. They included 178 patients, and they were triaged into CT or no CT based on GCS score (13–15), anticoagulants/antiplatelets, and EDH/SDH (>1 cm). If there was a clinical change, a repeat CT was performed. With this strategy, the authors could safely reduce the use of routine repeat CT by 71% without any missed injuries or delayed surgery.[21]

Studies supporting repeat CT scan

Kaups *et al*. conducted a 5-year retrospective study. The mean time to 2nd CT was 22.6 h. Sixteen patients had intervention after repeat CT. They concluded that elevated ICP, hypotension, and coagulopathy were risk factors.[14] Brown *et al*. conducted a 2-year prospective study including patients of all GCS scores. Of the 274 patients, 81% underwent routine CT, while 19% underwent due to a neurologic change, 38% of whom had intervention. In the Routine category, two cases of severe TBI had intervention (1%), whereas none had any change in mild and moderate TBI. They concluded that routine repeat head CT is indicated for patients with a GCS score <8.[4]

Stein *et al*. conducted a review including only mild TBI. They included articles published between 1980 and 2006. A decision tree was assembled to compare whether routine repeat CT was cost-effective versus selective CT after clinical deterioration. They observed that awaiting clinical deterioration in patients with mild TBI with initial abnormal CT is not cost-effective as compared to routine repeat scans. They concluded that, despite the difference being not statistically significant, routine follow-up scanning is slightly more cost-effective, especially in younger patients.[19] Bee *et al*. conducted a 3-year retrospective study of 207 patients with minimal TBI. They observed that 58 patients (28%) developed worsening findings on repeat CT or examination, and 18 required invasive neurosurgical intervention. Five patients underwent surgery without any clinical change. They concluded that routine follow-up CT scans are beneficial in those patients with minimal TBI and may lead to higher levels of medical management or neurosurgical intervention in patients with worsening CT findings.[2]

In their 6-month prospective study, Doddamani *et al*. analyzed 201 patients and observed that 20% showed a change in management. However, the information about neurological changes is unclear in their paper. They concluded that repeat CT scans were of value in detecting new lesions or enlargement of existing lesions resulting in change of management in a significant proportion of

patients.[11] Nagesh *et al*. conducted a 1-year retrospective study including patients with a GCS score >8 and an initial abnormal scan. There were 1033 patients, and there was a mean of 2.5 scans per patient. They noted that 90 cases (8.7%) had a progression of an existing lesion or the appearance of a new lesion on repeat CT. One hundred and one cases (9.8%) required neurosurgical intervention, of whom 75 (7%) underwent surgery due to worsening of repeat CT without neurological deterioration. They concluded that low GCS score at admission, abnormal international normalized ratio, midline shift, effaced basal cisterns, and multiple hemorrhagic lesions were associated with worsening of repeat CT, neurological deterioration, and/or need for neurosurgical intervention.[17]

In our study, the positive yield of the scheduled repeat CT scan requiring surgical intervention due to a silent progression of hematoma was 3.5%. In isolated EDH, younger patients had a change in management following the scheduled repeat CT scan. In mixed lesions and no clinical deterioration, routine repeat CT showed changes in lesions but none required any change in management. In isolated traumatic SAH, DAI, tentorial SDH, fractures, and none required any change in management after routine repeat CT brain.

In our study, we included patients with all GCS scores which are not very commonly seen in other studies. In the first group of studies (opposing a routine repeat scan), except two studies by da Silva *et al*. and Connon *et al*.,[7,9] all have included only mild head injuries and have concluded against doing a routine repeat scan. In the latter group of studies (proponents of a routine repeat scan), we can find few studies that have included the entire spectrum of TBI.[4,11,17] A review of patients with mild TBI by Stein *et al*. also suggested a routine scan for all patients as it seems to be more cost-effective than a wait-and-watch approach.[19] One of the main arguments against a routine repeat scan is the risk of radiation exposure. One small reason might be the cost involved and the logistics involved in shifting the patient to the scan, especially if an in-house CT facility is not available. On the flip side, if there occurs any neurological deterioration due to a clinically silent progression of a traumatic lesion that could have been operated on, there might be issues related to medico-legal aspects in addition to irreversible brain damage or death.

Due to the inherent heterogeneity involved in TBI and also conflicting results from the previous studies, it would be very difficult to formulate guidelines regarding a routine repeat scan after TBI. However, based on the observations of our prospective study and the previous studies, the following general statements may be proposed. We want to reiterate the fact that these are not guidelines or recommendations but may serve as important points for future larger studies.

1) In an isolated SAH, falcine, and tentorial SDH, repeat CT is not required (Cooper *et al*.[8] and Devulapalli *et al*.[10] and from our observations)
2) In mild TBI with an initial abnormal CT (cMTBI), repeat CT is necessary only if clinical deterioration except in cases of isolated EDH and younger pts, in whom a routine CT may be beneficial (from our observations and Stein *et al*.[19])
3) In other GCS scores with an initial abnormal scan, repeat CT is probably beneficial and should be performed (Doddamani *et al*.,[11] Nagesh *et al*.,[17] Brown *et al*.[4])

Strengths of the study

Ours was a prospective study from a single center, and we included patients with all GCS scores which are not commonly seen in previous studies.

Limitations

The relatively lesser number of cases was the major limitation of our study. Other than younger age and isolated EDH, we could not identify any specific factors that could predict deterioration and requirement of repeat scan.

CONCLUSION

We prospectively analyzed patients with TBI to assess the impact of a scheduled repeat CT scan at our center. In our study, the yield of the scheduled repeat CT scan requiring surgery was 3.5%. Based on the results of our study and the observations from previous studies, we have proposed a few general working statements regarding indications for repeat CT scans in TBI. Well-designed and prospective multicentric trials, including all categories of TBI patients, are necessary to provide reliable answers.

Ethical approval

IEC approval of Kasturba Medical College was taken for the study. No.: IEC 481/2021 dated 24/10/2021.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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