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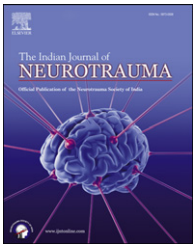

Original article

Role of repeat CT scans in the management of traumatic brain injury

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ABSTRACT

Background: In trauma practice, there are no guidelines on the necessity or value of repeat CT scan. The purpose of the present study was to determine the role of serial CTs in demonstrating changes in intracranial lesions and the influence on management.
Methods: In this study, 201 patients of traumatic brain injury were followed with serial CT scans for a maximum of up to 5 scans. The presence of different types of intracranial lesions at each CT scan as well as the evolution of lesions was recorded. The development of new lesions was noted. The management decisions at the time of each CT was detailed.
Results: Progression of lesion was seen most often in patients with mixed lesions (21.8%). New lesions were seen in 5.5% of patients at CT-2 and in 5.8% at CT-3. Out of total 201 patients, 47 (23%) had change in management. 26 (55%) decisions of change in management were based upon clinical deterioration and 21 (45%) upon radiological changes only. A higher incidence of surgical intervention was seen in patients who had the first CT scan within 6 h of initial trauma. However, a few patients in whom the first CT scan was 6 h after trauma as well as some patients in whom CT scan was repeated as a routine without any clinical deterioration also had a change in their management.
Conclusions: Repeat CT scans resulted in management changes even in patients with no clinical deterioration and thus may be of value in detecting changes at an early stage.
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1. Introduction

In current trauma practice, a computed tomography (CT) scan is the initial study of choice to determine the type, extent and severity of traumatic brain injury as well as to determine the management protocol. However, there are no guidelines on the necessity or the value of repeat CT scan. There are reports emphasizing the importance of serial CT scans in patients with head trauma.[1–4] while others feel it to be unnecessary in most patients.[5–7] The purpose of the present study was to determine whether serial CT scans demonstrated significant change from the findings in the first CT scan and whether repeat scans had influence on management options.

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2. Material and methods

This was a prospective observational study done over a period of 6 months. A total of 201 patients were included in the study.

2.1. *Inclusion criteria*

Patients of traumatic brain injury above 15 years of age who were subjected to two or more CT scans of the brain. Patients were followed for a maximum of up to 5 scans. The decision of repeat scan was taken by the treating neurosurgeon.

2.2. *Exclusion criteria*

Patients who were taken up for surgery based upon the findings of the first CT scan.

Patients who were discharged or who expired after the first CT scan.

The first CT scan of the brain was referred to as the admission CT (CT-1) and the subsequent CT scans were labeled as serial CTs (CT-2 to CT-5). The first CT scan was done as soon as possible after trauma. The indications for repeating the CT scan were specified:

1. First CT scan done less than 6 h after trauma.
2. Patient showing neurological deterioration during the course of management after the first CT scan.
3. As a routine follow up in patients who did not show any clinical deterioration but to look for the evolution of the lesions seen in the first CT scan.

Details like age, sex, time and mode of injury, interval between trauma and the CT examination, the Glasgow coma score were recorded. The findings on each CT scan, the type of brain injury, presence or absence of intracranial hematoma, type, site and number of intracranial lesions were recorded for each scan.

The CT scan findings were recorded by the attending neurosurgeon.

The alterations occurring in the management protocol based on the changes in the serial CT scans were measured as outcome.

The management options were recorded in the following headings:

1. Observation: Observation and monitoring of clinical status.
2. Medical management: Management of raised intracranial pressure by decongestants, ventricular drainage or hyperventilation.
3. Surgery: craniotomy for evacuation of intracranial hematoma, decompressive craniectomy etc.

3. Observations and results

3.1. *Distribution of intracranial lesions on serial CT scans*

A total of 201 consequent head injury patients with 2 or more CT scans were studied. 192 were male. The mean age was 38.6 years (Range: 16–80). Road traffic accidents was the most common cause of trauma (134, 67%) followed by fall from height (47, 24%) and assault (17, 10%). The mean time interval between injury and CT-1 was 4 h (range: 45 min to 53 h). CT-1 was done within 6 h of trauma in 140 (69.7%) patients while in 61 (30%), the time interval between trauma and CT-1 was more than 6 h.

CT-1 and CT-2 was done in all patients. 86 underwent a CT-3, 10 had a CT-4 while 3 had a CT-5. The mean time between injury and CT-2 was 26.1 h, between injury and CT-3 was 45.8 h, time to CT-4 was 67.2 h while the time to CT-5 was 87 h.

Contusions alone were the most common lesions seen in CT-1 through CT-4. Up to 5 CT scans were done in a few patients with contusions or extradural hematomas (EDH).

Of the 32 patients who had an EDH on CT-1, EDH was seen in 32 patients on CT-2, while 2 patients of EDH developed contusions as a new lesion on CT-2. Out of the 24 patients with SDH on CT-1, 2 showed resolution of subdural hematoma (SDH) on CT-2. No new lesion appeared in patients with SDH alone on serial CTs.

The number of patients showing contusion increased from 68(CT-1) to 70(CT-2). No new contusion appeared on CT-3 to CT-5 and the contusions continued to persist in all patients who underwent serial CTs up to CT-5 (Table 1).

3.2. *Changes in intracranial lesions on serial CT scan*

The changes in the intracranial lesions in the serial CTs were categorized as; same in size, increase in size, decrease in size/disappearance (Table 2).

Table 1 – Distribution of intracranial lesions on serial CT scans.

CT scan finding	CT-1 *n* (%)	CT-2 *n* (%)	CT-3 *n* (%)	CT-4 *n* (%)	CT-5 *n* (%)
Normal	13 (6.5)	15 (7.5)	4 (4.7)	1 (10)	0
EDH alone	32 (15.9)	32 (15.9)	15 (17.4)	2 (20)	2 (66.6)
SDH alone	24 (11.9)	22 (10.9)	9 (10.5)	0	0
Contusions alone	68 (33.8)	70 (34.8)	38 (44.2)	5 (50)	1 (33.3)
Mixed lesions	55 (27.4)	55 (27.4)	22 (25.6)	2 (20)	0
DBE	4 (2)	2 (1)	1 (1.1)	0	0
DAI	3 (1.4)	3 (1.4)	2 (2.3)	0	0
IVH	2 (1)	2 (1)	1 (1.1)	0	0
Total	201	201	86	10	3

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Table 2 – Changes in intracranial lesions on serial CT scan.

	CT-1 to CT-2, *n* (%)	CT-2 to CT-3, *n* (%)	CT-3 to CT-4, *n*
EDH			
Same	27 (84.3)	9 (60)	2
Increase	2 (6.2)	4 (26.7)	
Decrease	3 (9.3)	2 (13.3)	
SDH			
Same	19 (37.5)	6 (66.7)	
Increase	3 (12.5)	1 (11.1)	
Decrease	2 (8.3)	2 (13.3)	
Contusion			
Same	56 (82.4)	28 (73.7)	4
Increase	8 (11.8)	5 (13.2)	
Decrease	4 (8.5)	5 (13.2)	1
Mixed			
Same	38 (69)	10 (45.5)	1
Increase	12 (21.8)	8 (36.4)	
Decrease	5 (9)	4 (18.2)	1

Changes in intracranial lesions were seen in a significant proportion of patients between CT-1 and CT-2. Progression of lesion was seen more frequently in mixed lesions (21.8%), followed by SDH (12.5%) and EDH (6.2%). Among patients with mixed lesions, out of 12 patients showing progression, 8 showed an increase in size of contusion, 2 had an increase in EDH and 2 had enlargement in SDH.

From CT-2 to CT-3, an increase in size of EDH was seen in 26.7%. In rest of the lesions, changes were seen in the same proportion as from CT-1 to CT-2.

No lesion showed increase between CT-3 and CT-4.

Of the 3 patients who had a CT-5, 2 had an EDH while one showed a contusion. There was no change in size as compared to CT-5.

New lesions were seen in 20 patients. On CT-2, a new EDH was seen in one, contusion in 7 and diffuse brain edema (DBE) in 3. Thus a total of 11 (5.5%) showed a new lesion. Five (5.8%) patients demonstrated a new lesion on CT-3: contusion-1, DBE-2 and infarct-1. At CT-4, 4 (3.3%) had a new lesion; contusion-2, DBE-1, infarct-1.

3.3. *Changes in management based upon serial CT scans*

EDH: Out of the 32 patients who were initially kept under observation alone based on the findings of CT-1, 6 underwent surgery after CT-2. Two patients developed occipital contusions as new lesions on CT-2 and were thus shifted to mixed lesion group and were put on medical management. CT-3 through CT-5 did not result in any further management alteration (Table 3).

SDH: 20 patients were under observation and 4 on medical treatment after CT-1. CT-2 resulted in surgery in 5 patients. Of the 19 patients on observed after CT-2, 9 had a CT-3 which resulted in surgery being performed in an additional one patient. Rest of the serial CTs did not cause any change in treatment (Table 3).

Contusions: There were 68 patients with contusions alone at CT-1, 12 were observed and 56 were on medical management. After CT-2, 3 underwent surgery and 8 patients were shifted from observation group to medical management. Among the 38 patients with contusions at CT-3, 2 were put on medical therapy (from the observation group) and 3 from the medical management group were operated. Two more patients were operated after CT-4 (Table 3).

Mixed Lesions: Significant proportion of patients had alteration in management in this group also. After CT-2, 9 patients were operated from the observation group (24) and 5 from the medical management group (31) underwent surgery. An additional 5 patients from the medical group were operated at CT-3 (Table 3).

3.4. *Change in management in relation to clinical status and timing of first CT scan*

Out of the 28 patients operated based on the findings of CT-2, 21 had CT-1 done less than 6 h after the injury. Similarly of the 9 patients who underwent surgery after CT-3, 6 had the CT-1 within 6 h of trauma (Table 4).

3.5. *CT within 6 h*

There were 140 patients in whom the first CT scan was within 6 h of the initial trauma. Based upon the findings of the first CT scan, 72 were observed. Out of these 72, 52 underwent a repeat CT without a change in their clinical status. A second CT in these 52 patients who were initially kept under observation alone led to institution of medical therapy in 10 and surgery in 2. In the other 20 patients, a second CT was based upon clinical worsening. Out of these 20, surgery was done in 6 and medical therapy started in another 6.

Sixty-eight patients were on medical therapy, 40 patients had a second CT without clinical worsening and this resulted in surgical intervention in 3 and continuation of medical therapy in 31 while 5 were shifted to observation alone. Of the 28 patients in whom a second CT was done after clinical deterioration, 10 underwent surgery.

Similarly a third CT scan led to change in management protocol even in patients in whom there was no change in clinical condition. Out of the 40 patients who continued to be observed even after the second CT scan, there was no neurological deterioration in 19 of these at the time of third CT scan. After the third scan, 1 of these 19 had a surgery and 1 was switched to medical therapy. Out of the 31 patients who continued to on medical therapy after the second CT, there was no change in clinical condition of 10 patients before the third CT scan and this repeat CT resulted in a craniotomy in one patient. Out of the 2 patients who had a third CT on clinical worsening, 1 underwent a surgery.

3.6. *CT after 6 h*

The first CT scan was obtained after 6 h of the initial injury in 61 patients, and 23 patients were just observed. At the time of second CT, 21 of these were clinically stable. The second CT resulted in institution of medical therapy in 2 of these. Of the 2 patients who worsened before their second CT, one underwent surgery and the other was put on medical therapy.

Thirty-eight were on medical therapy. In 34 of these, the second CT scan was done without corresponding neurological

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Table 3 – Changes in management based upon serial CT scans.

Treatment based on CT-1	Treatment change based on CT-2			
	Observation *n* (%)	Medical *n* (%)	Surgical *n* (%)	Total *n*
EDH				
Observation	26 (81)	0	6 (18.8)	32
Medical	0	0	0	0
Total	26	0	6	32
SDH				
Observation	15 (75)	0	5 (25)	20
Medical	4 (25)	0	0	4
Total	19	0	5	24
Contusion				
Observation	4 (66.7)	8 (3.3)	0	12
Medical	0	53 (94.3)	3 (5.7)	56
Total	4	61	3	68
Mixed Lesions				
Observation	12 (50)	5 (20.8)	9 (37.5)	24
Medical	2 (6.5)	24 (77.4)	5 (16.1)	31
Total	14	29	14	55
Treatment based on CT-2	**Treatment change based on CT-3**			
	Observation *n* (%)	Medical *n* (%)	Surgical *n* (%)	Total *n*
EDH				
Observation	15 (100)	0	0	15
Medical	0	0	0	0
Total	15	0	0	15
SDH				
Observation	8 (85.7)	0	1 (14.3)	9
Medical	0	0	0	0
Total	6	0	0	9
Contusion				
Observation	1 (33.3)	2 (66.7)	0	3
Medical	2 (5.7)	30 (85.7)	3 (8.6)	35
Total	3	32	3	38
Mixed Lesions				
Observation	7 (63.6)	4 (36.4)	0	11
Medical	1 (4.8)	15 (71.4)	5 (23.8)	21
Total	8	19	5	32

worsening. This led to surgery in 3 patients. Four had a second CT coinciding with clinical worsening and 3 of these subsequently were operated. A third CT scan led to surgery in 2 patients, both of whom had shown neurological deterioration before the repeat CT.

4. Discussion

Significant changes in post-traumatic hematomas and the appearance of new hematomas may occur without changes in the clinical status of the patient. One of the major goals of neurotrauma management is detection before deterioration, allowing for early treatment of new mass lesions that require surgery. Wider availability of CT scan has resulted in a tendency to scan earlier in peripheral or regional hospitals. It is thus particularly important to recognize how to detect further evolution of intracranial processes of patients.[8]

The initial CT scan may be followed by a second CT within 24 to 48 h for detection of evolving lesions. The need for serial CT scans and quantification of the yield of these in terms of change in the lesions seen on the first CT, development of new

Table 4 – Change in management in relation to clinical status and timing of first CT scan.

Time between injury & CT-1	CT-2 No. of patients undergoing craniotomies *n* (%)			CT-3 No. of patients undergoing craniotomies *n* (%)		
	Routine follow up CT	CT on clinical worsening	Total	Routine follow up CT	CT on clinical worsening	Total
<6 h	5	16	21 (75)	1	6	7 (77.8)
>6 h	3	4	7 (25)	2	0	2 (22.2)
Total	8 (29)	20 (71)	28	3 (33)	6 (67)	9

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lesions and the role of serials CTs in influencing management requires clarification.

Several studies have recommended that patients with significant head injury undergo serial scanning to allow prompt intervention to minimize secondary brain injury.[2,7–11] It has also been suggested that as many a time, a CT is done within an hour or two after head injury, and that, in these patients, repeat scans should be obtained to study progression of hemorrhagic lesions.[12] At the same time, there are reports questioning the need of routine repeat CT scans.[6,7,13] In some of the studies the time interval between trauma and subsequent CTs is not mentioned while in a few, the clinical status at the time of repeat CT is not detailed. In the present study we attempted to quantify the evolution of different intracranial lesions on repeat scans and to measure the changes in management thus caused.

5. Evolution of lesions on serial CTs

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%.[2,8,9,11,12,14–19] Servadei et al found that subdural hematomas were prone to re-absorption while intracerebral and extradural hematomas were more likely to increase in size or appear as new lesions.[8] EDHs were more prone to enlarge when detected within 6 h after injury. Brown et al reported that 42% of the repeat scans were unchanged, with 22% improving and 35% showing a progression of injury.[5] In their study 81% of repeat scan were performed as a routine without any evidence of neurological deterioration. Progressive hemorrhagic injury was reported overall in 42.3% and in 87% of patients who underwent their first CT within 2 h of injury. Oertal et al. also observed that early progressive hemorrhage occurred in almost 50% of head injured patients who underwent CT scanning within 2 h of injury.[12] Cope et al concluded that repeat CT scan demonstrated lesions earlier than clinical monitoring.[20] On the contrary, Sifri et al were of the opinion that repeat CT scan in patients with mild head injury and a normal neurological examination, resulted in no change in management.[6] Yadav et al reported that the incidence of expanding hematomas was higher in patients with lower GCS.[19] A prospective observational study by Narayan et al demonstrated that traumatic intracerebral hematoma expansion between the baseline and 24-h CT scans occurred in approximately half of the subjects.[21] The time frame during which hemorrhagic expansion occurs provides an opportunity for early intervention to limit a process with adverse prognostic implications.

In the present study, progression of hematomas was seen in 12.4% of patients on CT-2 and in 20.9% patients on CT-3. No progression of was seen in subsequent serial CTs. Since the mean time between the initial trauma and CT-3 was about 46 h, we may conclude that in majority of cases, the progression of the primary lesion, if it occurs, does so within the first 48 h. Therefore, the utility of a routine CT scan after the first 48 h is debatable and may be dictated by the clinical status of each individual patient rather as a routine protocol. As reported by others, increase in size was seen mostly in patients with EDH or with contusions, either alone or in patients with mixed lesions.

Another important finding in this study was the observation that new lesions were detected in repeat CT scans, mostly in the form of appearance of a contusion or development of an infarct. A statistically significant relationship between appearance of a new lesion and a bad outcome has been reported by several authors.[14] In the study by Servadei et al in addition to an increase in hematoma size in the first 12 h post injury, there was a high incidence of hematomas forming as new lesions.[8] ICH and traumatic hemorrhagic brain contusions were more prone to increase or appear as new lesions within the first 12 h.[18,22] A link between coagulopathy and the development of delayed hematomas has been shown by Stein et al.[23] The fact that new intracranial lesions in the form of intracranial as well as extradural hematomas can develop following the initial lesions increases the relevance and importance of having repeat CT scans in patients with traumatic brain injury. Detection of a new lesion can have a significant impact on management decisions.

6. Change in management based on repeat CT scans

In the present study, a change in the management decisions was seen in as many as 20% of patients based upon the findings in the repeat CTs in the present study. This resulted in surgical treatment in 14% of patients who were just observed based on 1st CT scan, while 9.7% of patients underwent surgical intervention based on the findings in the 3rd CT scan. In a review by Wang et al. neurosurgical intervention after 2nd CT was reported in an average of 3% (range 2–11%).[11] An average of 8% underwent neurosurgical intervention after 2nd CT (range 0%–20%). Givner et al. reported that overall 32% of patients with progression of injury on repeat CT underwent one or more changes in nonsurgical management.[15] Brown et al concluded that CT scans performed after clinical worsening prompted medical or surgical intervention in 38% of cases, while scans ordered routinely triggered an intervention in only 1% of patients.[13] In a retrospective analysis, Smith and Miller[24] concluded that early diagnosis by timely CT scan should be done in patients with risk factors like contusions, midline shift with raised intracranial pressure, coagulopathy and with poor GCS.

Use of routine serial head CT in patients without neurologic deterioration is not supported by the findings of Brown et al.[13] However Stein et al. concluded that awaiting clinical deterioration in patients with mild TBI whose first CT scan reveals intracranial injury is not cost-effective compared with routine follow-up CT scans.[4] Although the difference is not statistically significant, routine follow-up scanning is slightly more cost-effective, especially in younger patients.

The impact of repeat CT scan in altering management decisions in patients of traumatic brain injury, thus, remains controversial. It is generally accepted that a subset of patients are likely to benefit from repeat CT scan. As a rule, patients showing clinical worsening are subject to CT scan. Our findings demonstrate that change in intracranial lesion, in the form of expansion of existing lesions or appearance of new

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lesions may occur in some patients even without clinical deterioration. It is not possible to accurately identify all these patients purely on clinical findings. If a repeat CT scan is governed by clinical deterioration, it is possible some patients warranting a management change will be missed till they deteriorate. Therefore, we recommend a repeat CT, at least once, in all patients of traumatic brain injury. The management alteration after a third CT scan in patients who do not show neurological deterioration was much less as compared to second CT scan. This is probably dependent upon the time interval between the initial trauma and the CT scan. In the present study, we had a few patients, albeit small, in whom a third CT resulted in significant change in management protocol. The need for a third CT probably has to be decided on case to case basis, depending upon the time of first CT (within 6 h of trauma or later), the findings of the first CT (normal or abnormal) as well as the clinical course of the patient.

A higher incidence of surgical intervention was seen in patients who had the first CT scan within 6 h of initial trauma. Therefore, it is suggested that in patients who have the first CT scan within 6 h of the trauma, the second CT scan may be done earlier, within 12 h of trauma rather than the recommended 24 h time. Also, the incidence of surgical intervention was higher when the repeat CT scan followed clinical deterioration than when it was done as a routine protocol. Similar finding were reported by Yamaki et al. and Servadai et al.[8,22] However, it should also be recognized that there was significant proportion of patients with a CT scan done after 6 h who had to undergo surgery after the second CT. Similarly there were patients in whom a repeat CT scan done as a routine protocol without any change in neurological status led to significant changes in management, including surgery. Therefore, if one does a repeat CT scan purely on the basis of clinical deterioration, there are chances of missing potentially curable lesion changes.

The alteration in management decision, based upon repeat CT scan, may not always be surgical. Expansion of or development of a new lesion, may warrant addition of decongestants to reduce intracranial pressure, shifting to an intensive care unit or alteration of ventilator settings. Waiting to institute these measures till there is a clinical worsening may be detrimental at least in some patients. This can be avoided to some extent by a protocol of routine CT. Most evolutionary changes in the lesions occurred in the first 48 h, and in a small percentage of patients, even after that. It would be reasonable to have repeat CT scans in all patients up to this time period and be selective at a later time period.

7. Conclusions

Repeat CT scans were found to be of value in detecting new lesions or enlargement of existing lesions resulting in change of management in a significant proportion of patients.

Declaration of interest

The authors report no declaration of interest.

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