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Guiding lights in the early postoperative computed tomography following cranial surgery for traumatic brain injury patients

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Abstract

Background Computed tomography (CT) can be a substantial source of guiding lights during the early postoperative hours in traumatic brain injury (TBI) patients. However, controversy still exists regarding: What is the appropriate time for the first postoperative CT? And what are the guiding lights that can be gained from an early follow-up CT? Therefore, our objective was to reach more clear answers for these questions and to design a simple algorithm for the follow-up of TBI patients during the first 24 h after cranial surgery.

Methods This is a retrospective study included 164 TBI patients who were surgically treated for various traumatic cranial and/or intracranial lesions in our neurosurgery department from January 2022 to April 2023. Pre- and postoperative clinical and radiological data of these patients were collected and analyzed.

Results The mean age was (23.46 ± 15.126) years. The mean glasgow coma scale (GCS) on presentation was (11.62 ± 3.004). 51.2% of patients had their first follow-up CT done within the first postoperative hour (0–1 h). Postoperative remarkable CT findings were detected in 39 patients (23.8%), with 13 cases (33.3%) of them required re-surgery. 69.2% of the postoperative remarkable findings were recognized in the first hour CT ($P = 0.025$). Acute subdural hematoma was the only significant primary lesion associated with the need for re-surgery ($P = 0.015$). Postoperative development of remarkable CT findings was significantly ($P < 0.001$) associated with increased possibility of re-surgery, high mortality rate, prolonged hospital stay and poor outcome.

Conclusions Immediate (0–1 h) follow-up CT brain can be more lucrative in the early postoperative assessment for TBI patients. The first hour CT can provide distinct guiding lights of significant value for the subsequent postoperative management and prediction of patients' clinical course and discharge outcome.

Keywords Guiding lights, Computed tomography, Cranial surgery, Postoperative, Traumatic brain injury

Background

Being a leading cause for mental and physical morbidity, traumatic brain injury (TBI) becomes one of the most disabling traumatic injuries particularly in adolescents and young adults [1–3]. The early postoperative period following emergency cranial surgery is the most crucial period for recovery potential in TBI patients. So, vigilant care is mandatory to achieve the best possible outcome [4, 5].

Traumatic intracranial lesions may have different potential sequel following cranial surgery which may affect the patient clinical course and outcome. A residual hematoma may follow extradural hematoma (EDH) evacuation that may expand and require re-surgery; acute subdural hematoma (ASDH) may show expansion of the concomitant contusions or diffuse cerebral swelling;

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traumatic intracerebral hemorrhage (ICH) may also show re-hemorrhage [6, 7].

Because of its wide availability and relatively low cost, computed tomography (CT) becomes the primary investigating tool in TBI patients on initial presentation and during follow-up [8]. Although there is agreement regarding the need for follow-up CT after cranial surgery in TBI patients, there is no consensus on its optimal timing. Also, its clinical importance and impact on management has some debate [9–12].

So, in TBI patients after emergency cranial surgery, controversy still exists regarding: What is the most appropriate time for the first postoperative CT? And what are the guiding lights that can be gained from the early postoperative CT? Therefore, our main objective was to reach more clear answers for these questions and to design a simple, easy applicable algorithm for the follow-up of TBI patients during the first 24 h after cranial surgery.

Materials and methods

Study design and patients population

This study was approved by the local ethical scientific committee of our institution (IRB approval number: 10-2023.NEUS.6-2). We retrospectively analyzed the data of TBI patients admitted to our neurosurgery department over a period of 15 months from January 2022 to April 2023. We included TBI patients operated upon for post-traumatic cranial and/or intracranial lesions and had a postoperative follow-up CT brain done during admission. We excluded (1) patients with postoperative intracranial hemorrhage; (2) patients operated elsewhere for traumatic intracranial lesion and came for follow-up; and (3) patients with significant systemic injury that affected the hospital course.

Data collection

General, clinical and radiographic data were collected from patients' medical records of our department including: data on admission, operative notes and postoperative data from the end of surgery till discharge.

General and clinical data on admission included: age; sex; mechanism of trauma including road traffic accident (RTA), fall from height (FFH), or assault; Glasgow Coma Scale (GCS); severity of head injury including mild (GCS 13–15), moderate (GCS 9–12) or severe (GCS 3–8); positive findings in neurological examination (NE); injury to other body systems; coagulation abnormalities.

Radiographic data on admission included: type of the primary lesion in CT scan including EDH, ASDH, depressed skull fractures (DSF) either isolated or with concomitant pathology (hemorrhage or contusion), intracerebral hemorrhage or contusions (ICH/C); side, location and size of the primary lesion; the degree of midline shift (MLS); and concomitant other intracranial injuries.

Postoperative data included: timing and remarkable findings in the first postoperative CT; postoperative GCS; postoperative neurological status including same as preoperative, deteriorated, or improved; hospital course and discharge outcome.

We defined the remarkable findings in the early postoperative CT by the new findings that were not present in the preoperative CT or findings already presented in the preoperative CT but developed increase in size including (considerable residual or recurrent hemorrhage at the surgical site; size expansion of a concomitant intracranial lesion; cerebral swelling with significant MLS; appearance of new intracranial lesion including brain contusion, hemorrhage, or cerebral infarction).

Management

First of all, resuscitation efforts were carried out including ABC (assessment and stabilization of airway patency, breathing and circulation). Dehydrating measures, cerebro-protective agents, and anti-convulsive drugs were given in certain cases. Initial laboratory investigations such as complete blood picture, electrolytes, and international normalized ratio (INR) were performed after emergency resuscitation. Diagnosis was established based on CT scan of brain and skull bones. Surgical decision was taken by the neurosurgeon consultant on-duty. All surgical lesions were treated under general anesthesia with the standard surgical procedures. Notably, in our institute we did not have the facilities to perform intracranial pressure (ICP) monitoring for TBI patients. So, the postoperative assessment was relying on repeated neurological examinations and follow-up CT scans.

Outcome measures

Outcome measures included: (1) percentage of patients developed remarkable postoperative CT findings; (2) percentage of patients required re-surgery; (3) mortality rate; (4) length of hospital stay; and (5) discharge outcome based on the Extended Glasgow Outcome Scale (GOSE) score [13] represented in Table 1. Patients who had moderate disability or good recovery (GOSE score from 5 to 8) were included together in the good outcome group. Patients who were severely disabled, vegetative or died (GOSE score from 1 to 4) were included together in the poor outcome group.

Statistical analysis

To tabulate and statistically analyze the results, SPSS V.22 (IBM Corporation, 1 Orchard Rd, Armonk, NY 10504, USA) and Microsoft Excel 2010 (Microsoft Corporation,

Table 1 The extended glasgow outcome scale (GOSE) score [13]

Category Number	Name	Definition
8	Good recovery *(Upper)*	No current problems related to the brain injuries that affect daily life
7	Good recovery *(Lower)*	Minor problems that affect daily life; resumes > 50% of the pre-injury level of social and leisure activities
6	Moderate disability *(Upper)*	Reduced work capacity; resumes < 50% of the pre-injury level of social and leisure activities
5	Moderate disability *(Lower)*	Unable to work or only in sheltered workshop
4	Sever disability *(Upper)*	Can be left alone > 8 h during the day, but unable to travel and/or go shopping without assistance
3	Sever disability *(Lower)*	Requires frequent help of someone to be around at home most of the time every day
2	Persistent vegetative state	Unresponsive and speechless
1	Death	

One Microsoft Way Redmond, WA 98052-6399 USA) were used. The descriptive statistics included mean (x), median, and standard deviation (SD). The count data were expressed as the rate and analyzed using the chi-square test (X^2). Standard Student's t-test (t), for independent samples was used for comparing the means between the 2 groups (patients with remarkable findings and those with unremarkable findings) in various factors of the study. P value ≤ 0.05 was considered statistically significant.

Results

A total of 164 head injury patients were included in our study series; all of them were surgically treated in our neurosurgery department for a variety of cranial and/or intracranial traumatic lesions. The mean age for included patients was (23.46 ± 15.126) years; range (1–64 years); Fig. 1 illustrates the distribution of included patients among different age groups. The mean GCS on presentation was (11.62 ± 3.004); range (4–15). Our study included 101 males (61.6%) and 63 females (38.4%). Eleven patients (6.7%) had abnormal coagulation profile (high INR). Table 2 demonstrates the general and detailed radiographic data of the included patients on admission.

A total of 427 follow-up CT scans were obtained during the postoperative period from the end of surgery till discharge. The mean time to the first postoperative CT was (2.96 ± 3.486) hours. Postoperatively, 39 patients (23.8%) showed remarkable findings in their first follow-up CT scan. For the included patients, timing and remarkable findings in the early follow-up CT scans are demonstrated in Table 3.

Table 4 elicits the differences in preoperative data between the group of patients with postoperative remarkable CT findings and the other group with unremarkable CT scans.

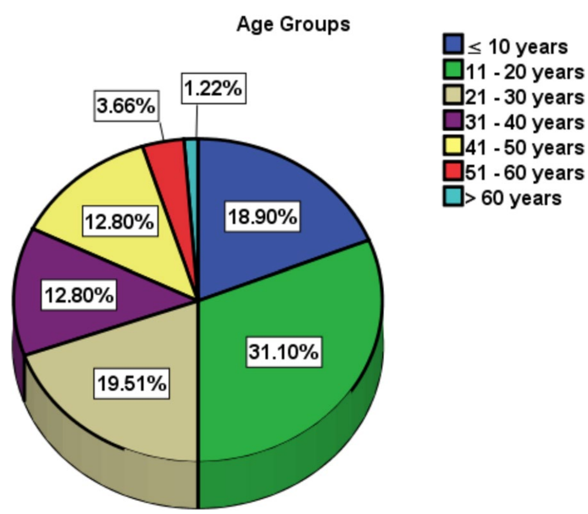

Fig. 1 Distribution of patients among different age groups: 51 patients representing the highest percent (31.10%) was in the age group from (11–20 years), comes next patients with age from (21–30 years) representing 32 cases (19.51%) then children ≤ 10 years representing 31 patients (18.9%). So, adolescents and young adults constituted the main bulk of our study populations

For the entire sample, the mean GOSE score on discharge was (5.66 ± 2.143). The mean duration of hospital stay was (7.26 ± 5.620) days. A total of 116 patients (70.7%) had good discharge outcome, while 48 patients (29.3%) had poor discharge outcome. The overall mortality rate was 10.4% (17 cases).

Table 5 elicits the differences in postoperative data between the group of patients with postoperative remarkable CT findings and those with unremarkable

Table 2 General and radiological data of included patients

Parameter	Number	%
Mechanisms of injury		
RTA	81	49.4
FFH	60	36.6
Assault	23	14
Severity of TBI		
Mild	80	48.8
Moderate	52	31.7
Severe	32	19.5
Type of primary lesion		
EDH	52	31.7
DSF (isolated)	36	22
ASDH	33	20.1
DSF + pathology	23	14
ICH/C	20	12.2
Location of primary lesion		
Parietal	66	40.2
Frontal	45	27.4
Temporal	39	23.8
Occipital	10	6.2
Posterior fossa	4	2.4
Side of primary lesion		
Right	81	49.4
Left	83	50.6

RTA Road traffic accident; *FFH* Fall from height; *TBI* Traumatic brain injury; *EDH* Extradural hematoma; *DSF* Depressed skull fracture; *ASDH* Acute subdural hematoma; *DSF + Pathology* Depressed skull fracture with concomitant pathology (hematoma or contusion); *ICH/C* Intra-cerebral hemorrhage/contusion

Table 3 Timing and remarkable findings in the early postoperative CT scans

Parameter	Number	%
Timing of first postoperative CT		
0–1 h	84	51.2
> 1–6 h	57	34.8
> 6 h	23	14
Total	164	100
Remarkable findings in first postoperative CT		
Residual hematoma	2	5.1
New hematoma	8	20.5
New contusion	8	20.5
Edema and MLS	12	30.8
Expanding contusions	6	15.4
Infarction	3	7.7
Total	39	100
Number of postoperative CT scans		
One	24	14.6
Two	61	37.2
Three	39	23.8
Four	36	22.0
Five	4	2.4
Total	164	100

CT Computed tomography; *MLS* Midline shift; *New* not found in the preoperative CT scan; *Hematoma* included (extradural, acute subdural or intracerebral) hematoma; *Number of postoperative CT scans* the total number of follow-up CT scans done during the postoperative period from the end of surgery till discharge

CT scans. Thirteen patients required re-surgery and all of them showed remarkable findings in their first follow-up CT. Among them: 7 patients (53.8%) had their first postoperative CT within (0–1 h) after surgery; 5 patients (38.5%) had their first postoperative CT between (> 1–6 h) after surgery and the remaining patient (7.7%) had his first postoperative CT later than 6 h.

Discussion

Unfortunately various intracranial lesions are encountered in the daily neuro-trauma practice and frequently most of which require surgical intervention. After emergency cranial surgery for TBI patients, close clinical monitoring together with radiological follow-up are essential to achieve the best possible outcome [14, 15].

Preoperative data

The mean age for patients in our study was (23.46 ± 15.126) years; adolescents and young adults are more vulnerable to risk situations during their daily activities. This result has a great consensus among most of previous studies that addressed TBI [16–19]. Males constitute the main bulk of our study population (61.6%). Males are more commonly involved in active outdoor daily practices and therefore, they are more prone to TBI. Among studied cases, RTA was the most frequent mechanism of trauma (49.4%). These results come in agreement with most of previous studies [12, 17, 20].

Various post-traumatic cranial and intracranial lesions were encountered among our study population with DSF and EDH were the most frequent primary lesions (36% and 31.7%, respectively). In the study of Paci et al. [4], ASDH followed by EDH was the most frequent post-traumatic lesions (62.4% and 14.7%, respectively). In Rehman et al. [12] study, EDH and ASDH were the most common lesions (41.4% and 26.8%, respectively). Mohammed FA and associates [21] reported that EDH was the most frequent lesion (51.7%) followed by DSF (28.9%) and then ASDH (15.9%).

Timing for the early postoperative CT

The time for postoperative CT follow-up after emergency cranial surgery is always the decision of the operating neurosurgeon and mostly depending upon either

Table 4 Comparison of preoperative data between patients with and without remarkable CT findings

Parameters	Remarkable findings (*n* = 39)	Unremarkable findings (*n* = 125)	*P* value
Age (mean ± SD)	22.05 ± 16.248	23.90 ± 14.799	0.506
Gender (M/F)	24/15	77/48	0.994
GCS on presentation (mean ± SD)	10.26 ± 2.798	12.04 ± 2.950	0.001*
Severity of TBI			< 0.001*
Mild	8 (20.5%)	72 (57.6%)	
Moderate	22 (56.4%)	30 (24%)	
Sever	9 (23.1%)	23 (18.4%)	
Coagulopathy			< 0.001*
High INR	9 (23.1%)	2 (1.6%)	
Normal INR	30 (76.9%)	123 (98.4%)	
Type of primary lesion			< 0.001*
EDH	7 (17.9%)	45 (36%)	
DSF (isolated)	2 (5.2%)	34 (27.2%)	
ASDH	13 (33.3%)	20 (16%)	
DSF + Pathology	6 (15.4%)	17 (13.6%)	
ICH/C	11 (28.2%)	9 (7.2%)	
Location of primary lesion			0.106
Parietal	20 (51.3%)	46 (36.8%)	
Frontal	5 (12.8%)	40 (32.0%)	
Temporal	12 (30.8%)	27 (21.6%)	
Occipital	1 (2.6%)	9 (7.2%)	
Posterior Fossa	1 (2.6%)	3 (2.4%)	

SD Standard deviation; *M* Male; *F* Female; *GCS* Glasgow coma scale; *TBI* Traumatic brain injury; *INR* International normalized ratio; *EDH* Extradural hematoma; *DSF* Depressed skull fracture; *ASDH* Acute subdural hematoma; *DSF + Pathology* Depressed skull fracture with concomitant pathology (hematoma or contusion); *ICH/C* Intra-cerebral hemorrhage/contusion; *CT* Computed tomography

* Statistically significant

Table 5 Comparison of postoperative data between patients with and without remarkable CT findings

Parameters	Remarkable findings (*N* = 39)	Unremarkable findings (*N* = 125)	*P* value
Timing of the first CT			0.025*
0–1 h	27 (69.2%)	57 (45.6%)	
> 1–6 h	10 (25.6%)	47 (37.6%)	
> 6 h	2 (5.2%)	21 (16.8%)	
Postoperative GCS (mean ± SD)	9.28 ± 3.043	12.72 ± 2.705	< 0.001*
Postoperative neurological status			< 0.001*
The same	19 (48.7%)	49 (39.2%)	
Improvement	0	73 (58.4%)	
Deterioration	20 (51.3%)	3 (2.4%)	
Re-surgery	13 (33.3%)	0	< 0.001*
Mortality	15 (38.5%)	2 (1.6%)	< 0.001*
Hospital stay in days (mean ± SD)	12.28 ± 5.073	5.70 ± 4.820	< 0.001*
GOES score on discharge (mean ± SD)	3.26 ± 1.943	6.41 ± 1.582	< 0.001*
Discharge outcome			< 0.001*
Good outcome	11 (28.2%)	105 (84.0%)	
Poor outcome	28 (71.8%)	20 (16.0%)	

CT Computed tomography; *Postoperative GCS* Glasgow coma scale in the first 24 h after surgery; *SD* Standard deviation; *GOES* Extended glasgow outcome scale

* Statistically significant

the severity of primary lesion, intraoperative circumstances or the patient's postoperative neurological condition. More than half of our patients (51.2%) had their first postoperative CT done immediately (0–1 h) after surgery. And, 69.2% of the remarkable CT findings were detected in the first hour (0–1 h) CT scans. This result ennobles the value of the first hour postoperative CT in TBI patients, and this result is similar to that reported in Takeuchi et al. [25] study, where the majority of the new findings were detected in CT scans done in the first hour after cranial surgery.

Although most of previous studies recommended doing a follow-up CT scan early after cranial surgery in TBI patients, there is no consensus on its appropriate timing. Lubillo et al. [22] recommend that CT scans to be obtained shortly after craniotomy. Caroli et al. [23] reported that immediate postoperative CT was mandatory to detect additional surgically treatable lesions. Paci GM et al. [4] concluded that early if not immediate postoperative CT after craniotomy for TBI patients appears to be warranted. Fokin AA and associates [11] recommended doing postoperative CT at 6 h in TBI patients to allow timely detection of intracranial deterioration.

On the other hand, few studies were against doing an early follow-up CT. In Rehman et al. [12] study, the mean time to the first postoperative CT was (21.45 ± 9.83) hours. Khaldi and associates [24] reported that routine postoperative CT at (0–7 h) or at (8–24 h) was not predictive of return to the operating room (OR). And, early postoperative CT (0–7 h) fails to predict intracranial changes, which might evolve over time.

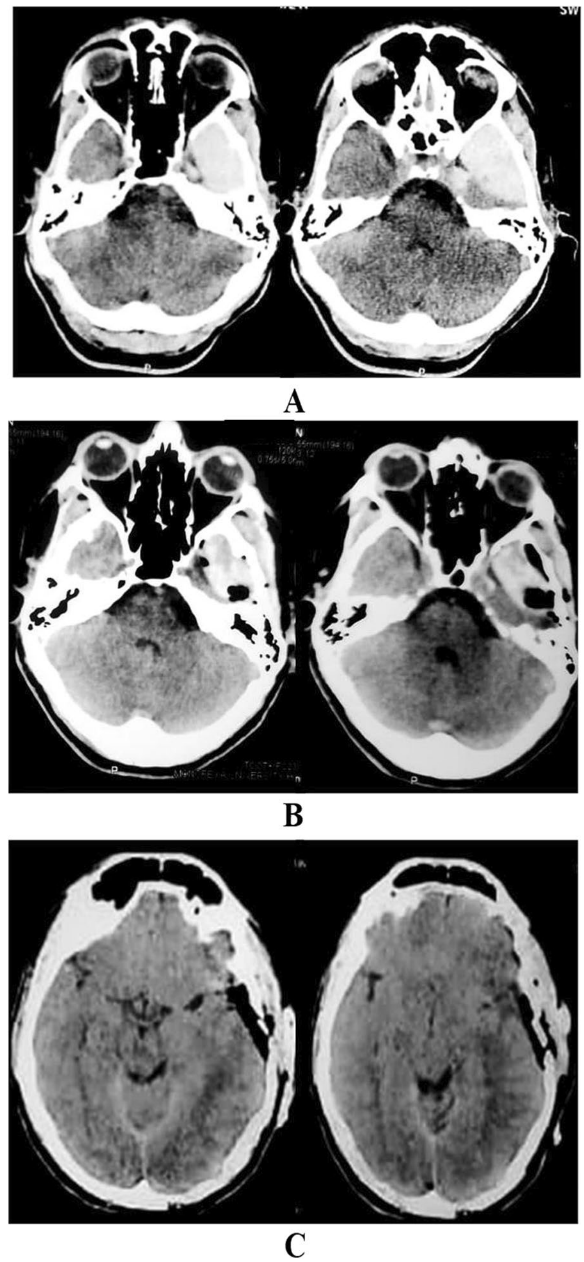

Fig. 2 **A**–**C** Young adult patient presented after road traffic accident with GCS (10/15). **A** Initial CT brain after trauma showing left temporal extradural hematoma, the patient underwent craniotomy and hematoma evacuation; **B** Immediate (0–1 h) postoperative CT following craniotomy showing large residual extradural hematoma. The patient was shifted for re-surgery; **C** Follow-up CT after the second surgery with good hematoma evacuation. GCS was improved (14/15) and the patient had good discharge outcome

Remarkable findings in the early postoperative CT

After craniotomy or decompressive craniectomy (DC), development of postoperative hemorrhagic lesions could be the result of brain shift or due to the hypothesis that these lesions were not detected on initial CT scans, but continued to evolve [25, 26]. Figures 2 and 3 illustrate the pre- and postoperative CT scans done for two head injury patients who developed postoperative remarkable hemorrhagic lesions.

Among our study population, 39 patients (23.8%) developed remarkable findings in their early postoperative CT and 13 patients (33.3%) of them required repeated surgery. Among these 13 patients, the first postoperative CT was done from (0–1 h) in 7 patients (53.8%); from (> 1–6 h) in 5 patients (38.5%); and later than 6 h in only one patient (7.7%).This finding magnifies the importance of early follow-up CT in the postoperative management of TBI patients.

In the literature, the rate of positive findings in the early postoperative CT for head injury patients showed a wide range of difference and this can be attributed to the difference in types of primary lesions, severity in head injury, types of cranial surgeries and intraoperative circumstances. Lubillo and associates [22] in their study on patients with traumatic intracranial hematoma encountered 22% rate of new findings on postoperative

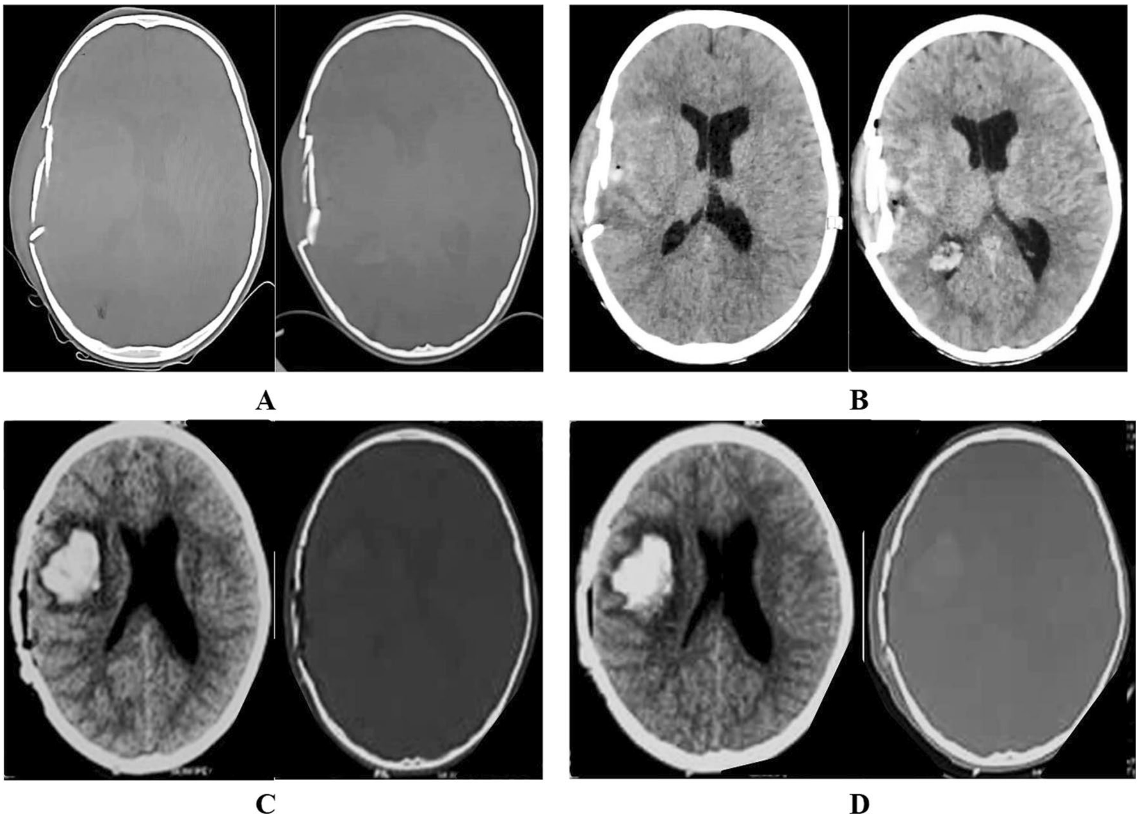

Fig. 3 **A**–**D** A child presented after road traffic accident with GCS (14/15). **A** Initial CT (bone window), showing right parietal depressed skull fracture; **B** Initial CT brain showing small cerebral contusion; **C** Immediate (0–1 h) postoperative CT brain and bone window showing good elevation of bone chips but with the development of new intracerebral hemorrhage, patient didn't require second surgery; **D** Follow-up CT after 24 h was the same as the first postoperative CT. This patient had good discharge outcome

CT. Caroli and associates [23] found unexpected new findings on immediate postoperative CT that required re-surgery in 29% of the 55 patients who underwent cranial surgery. In Paci GM and associates [4] study, postoperative CT scans revealed a variety of unexpected findings in 6 patients (3.0%). In Rehman ZU and associates [12] study, which was conducted on 157 TBI patients, 18.5% had positive postoperative CT and 55.1% of those cases ($n=16$) required repeated surgery. In the study of Takeuchi S and associates [25], new findings were observed in postoperative CT scans of 26 patients (25.5%) out of 102 patients who underwent DC for TBI. In Mohammed FA and associates [21] study, 24 patients (16.6%) out of 145 patients had positive findings in the postoperative CT and 9 patients of them went to the OR again.

In our study, the most frequent remarkable finding in postoperative CT was the development of new hemorrhagic lesions (EDH, SDH, ICH or contusions) in (41%). Other findings included cerebral swelling with increased MLS in 30.8%, expansion of preexisting contusions in 15.4%, cerebral ischemia (infarction) in 7.7% and lastly considerable residual hematoma in 5.1%. In Paci et al. [4] study, 6 patients developed unexpected findings in postoperative CT; recurrent SDH or EDH in two, new SDH or EDH in two and ICH in two. In Mohammed et al. [21] study, positive findings in the immediate follow-up CT included re-bleeding, new cerebral contusion in the operation site, contralateral contusion with MLS, brain edema and significant hematoma recollection.

In our study series, the postoperative remarkable CT findings were more frequently observed in moderate head injury patients (GCS 9–12), patients with high preoperative INR and patients with ICH/C or ASDH as primary intracranial lesions. As illustrated in Fig. 4, ASDH was the only significant primary lesion associated with the need for re-surgery ($P=0.015$). This result is similar to that reported in Paci et al. [4] study, where the only variable statistically associated with unexpected findings was ASDH as an indication for re-operation ($P<0.01$). Also, our result comes in agreement with that of Mohammed et al. [21] who reported that both of ASDH and ICH was associated with a high rate of re-operation ($P=0.037$ and 0.034, respectively), where out of the 9 patients who

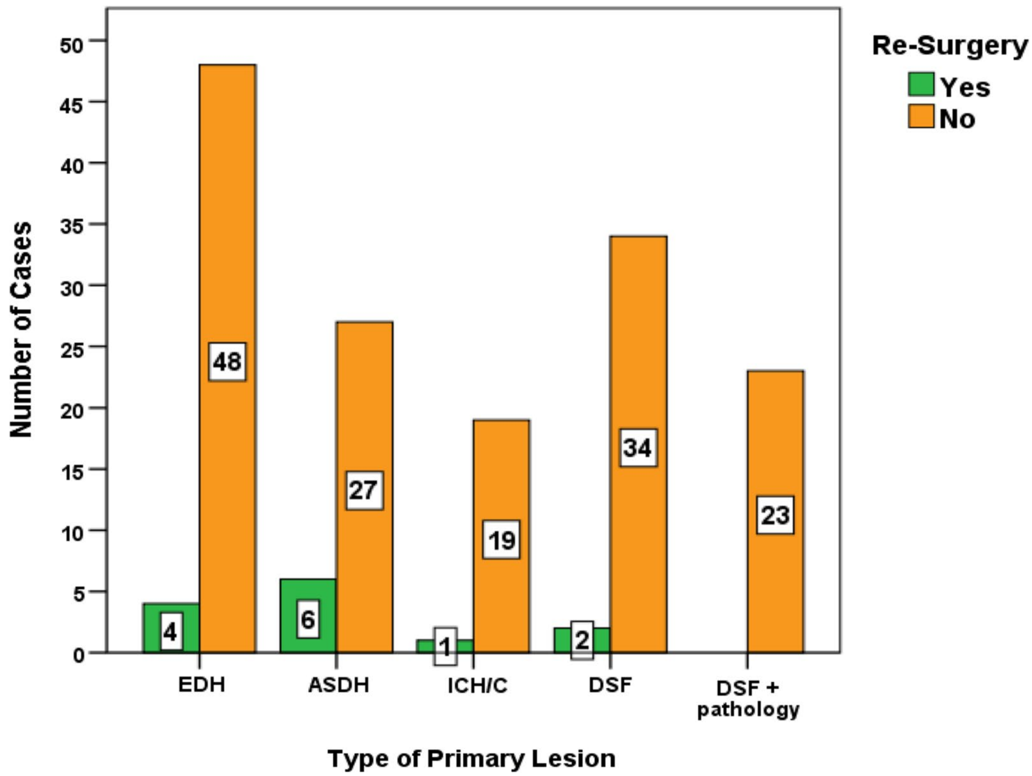

Fig. 4 Correlation between the type of primary lesion and the need for re-surgery: Out of the 39 patients who developed postoperative remarkable findings in the first follow-up CT, 13 patients (33.3%) required second surgery. ASDH was the only significant primary lesion associated with the need for re-surgery ($P = 0.015$). *Notes EDH* Extradural hematoma; *ASDH* Acute subdural hematoma; *ICH/C* Intra-cerebral hemorrhage/contusion; *DSF* Depressed skull fracture

went to the OR again 4 patients had ASDH and 2 had ICH.

In our study, coagulopathy (high INR) was a significant predictor in TBI patients going for cranial surgery, where out of the 11 patients who had preoperative high INR, 9 cases (81.8%) developed remarkable postoperative findings ($P < 0.001$). Our result is in accordance with the result of Rehman et al. [12] study where in patients who had a positive follow-up CT the mean INR was significantly higher than those with negative postoperative CT ($P < 0.001$).

Postoperative NE and early follow-up CT

In TBI patients, neurological deterioration during the early postoperative hours after cranial surgery can be attributed to either re-expansion of the existing lesion; appearance of new hemorrhagic lesion; or development of diffuse cerebral swelling [27, 28].

In our study, during the early postoperative hours, 68 patients (41.5%) had the same neurological status as preoperative; however, 19 patients (27.9%) of them showed remarkable findings in the early postoperative CT including 5 patients who required second surgery ($P < 0.001$). This result magnifies the value of early CT scan as a complementary diagnostic tool to the NE in the early postoperative assessment particularly in comatose patients.

In agreement with our result, Paci et al. [4] reported that neither NE nor postoperative ICP monitoring reliably predicted the presence of new or recurrent hemorrhage or other significant CT findings. Takeuchi S and associates [25] recommended doing a routine CT after craniotomy or DC regardless of the neurological status in GCS ≤ 8 and absence of basal cisterns on preoperative CT. Also, in the study of Fokin et al. [11] the postoperative CT in some TBI patients was more beneficial in predicting a need for a second surgery. On the other hand, Khaldi et al. [24] reported that some postoperative changes might evolve over time and may influence patients' management and the early postoperative CT may fail to predict these changes. Also, in Mohammed et al. [21] unexpected change in the NE was the single most influential factor in determining the need for re-surgery.

Guiding lights in the early postoperative CT

In comparison with patients who had unremarkable postoperative CT, the development of remarkable findings in the early follow-up CT was significantly ($P<0.001$) associated with: increased possibility of re-surgery (13 versus 0 patients); higher mortality rate (15 versus 2 patients); prolonged hospital stay (12.28 ± 5.073 versus 5.70 ± 4.820 days); and higher risk of poor outcome (71.8% versus 16.0% patients). Flint and associates [29] reported 58% re-expansion of hemorrhagic contusions after unilateral DC in severe TBI and this was associated with higher mortality and prolonged morbidity. Also, similar results were reported by Rehman et al. [12] study, where 69.6% of patients with negative postoperative CT achieved favorable outcome versus only 41.4% in the positive CT group ($P<0.0001$).

It is worth noting that unremarkable postoperative CT scans can also provide valuable guiding lights about: appropriate hematoma evacuation; successful elevation of depressed bone chip; proper hemostasis; and no development of new pathologies. Among our study population, 125 cases (76.2%) had unremarkable first postoperative CT and only 8 patients (6.4%) of them showed new findings in the second follow-up CT. Notably, none of these patients required re-surgery.

Based on our results and literature review, we designed a simple algorithm (Fig. 5) for the postoperative 24-h follow-up after emergency cranial surgery

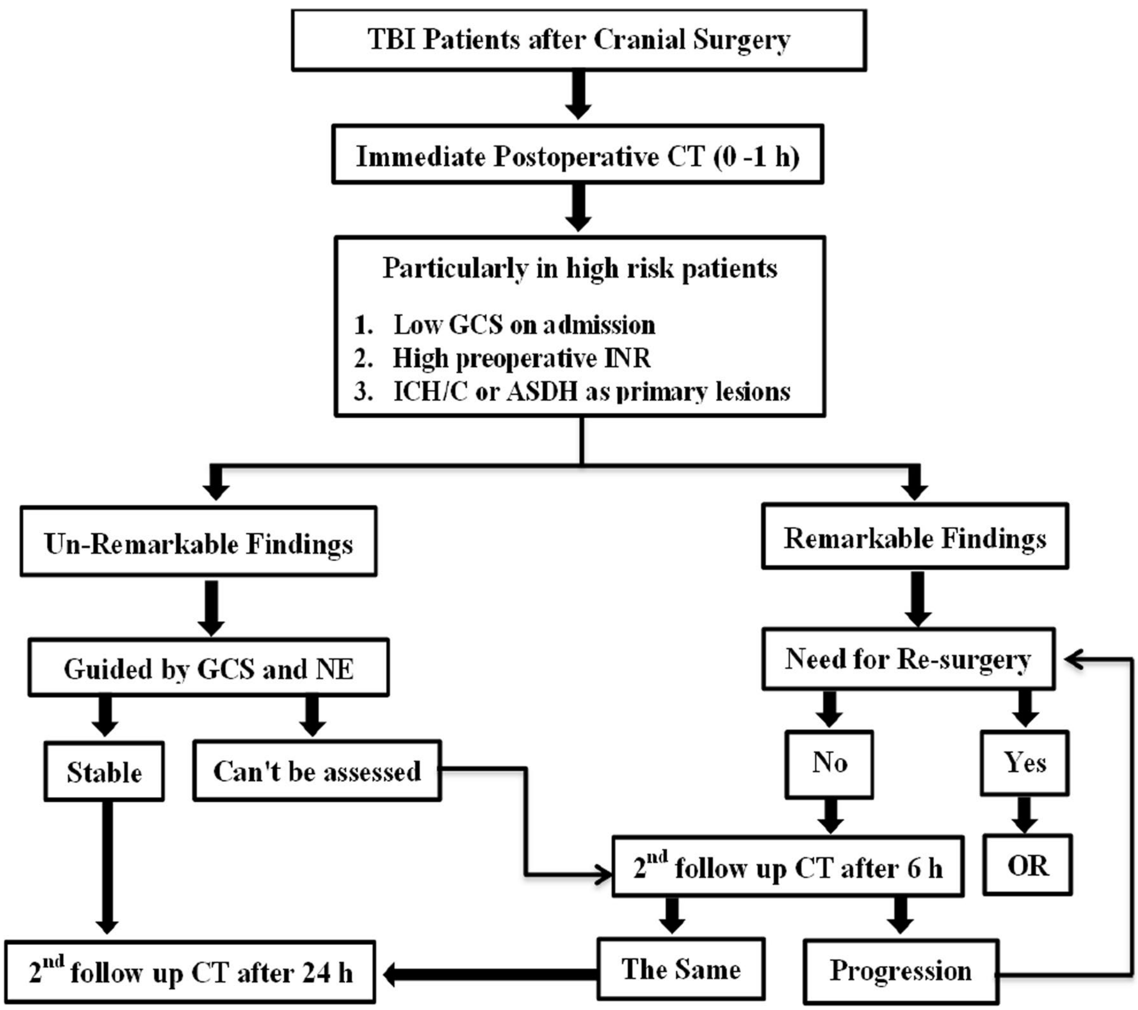

Fig. 5 Algorithm for the postoperative 24-h follow-up in TBI patients after cranial surgery: Any time there is drop in the GCS or appearance of new signs in the neurological examination, urgent CT brain should be done immediately. *Notes TBI* Traumatic brain injury; *CT* Computed tomography; *GCS* Glasgow coma scale; *INR* International normalized ratio; *ICH/C* Intra-cerebral hemorrhage/contusion; *ASDH* Acute subdural hematoma; *NE* Neurological examination; *OR* Operating room; *h* hour

that can provide beneficial contributions for the post-operative management in TBI patients.

Study limitations

Our study had some limitations that come from its retrospective nature and to a lesser extent it is a single center experience. Additionally, cranial surgeries were performed by different neurosurgeons and the time for the early follow-up CT was the decision of the operating neurosurgeon with no fixed criteria for that. However, we believe that this baseline information and our recommended follow-up algorithm can provide a basis for comparison in future trials.

Conclusions

Immediate (0–1 h) follow-up CT brain can be more lucrative in the early postoperative assessment for TBI patients. The first hour CT can provide distinct guiding lights of significant value for the subsequent postoperative management and prediction of patients' clinical course and discharge outcome.

Abbreviations

ABC	Airway patency; breathing and circulation
ASDH	Acute subdural hematoma
CT	Computed tomography
DC	Decompressive craniectomy
DSF	Depressed skull fracture
EDH	Extradural hematoma
FFH	Fall from height
GCS	Glasgow coma score
GOSE	Extended glasgow outcome score
ICH	Intra-cerebral hemorrhage
INR	International normalized ratio
ICP	Intracranial pressure
ICH/C	Intra-cerebral hemorrhage or contusion
MLS	Midline shift
NE	Neurological examination
OR	Operating room
RTA	Road traffic accident
TBI	Traumatic brain injury
vs.	Versus

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Author contributions

All authors made a significant contribution to the work reported, whether that was in the conception; study design; execution; and acquisition, analysis and interpretation of data. All authors took part in drafting, revising and final approval of the article. All agreed to be accountable for all aspects of the work.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consents for participate

This study was approved by the local ethical scientific committee of Faculty of Medicine, Menoufia University and the (IRB approval number: 10-2023.NEUS.6-2). Being a retrospective study, patients' consents for participation in the study and for publication were not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declares that they have no competing interest.

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