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Criteria for CT and Initial Management of Head Injured Infants: A Review

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Abstract

Criteria for computed tomography (CT) to head injured infants have not been established. Since the identification of neurological findings is difficult in infants, examination by CT may be necessary in some cases, but it may be difficult to perform CT because of problems with radiation exposure and body movement. Moreover, even though no intracranial abnormality was found immediately after injury, abnormal findings may appear after several hours. From this viewpoint, course observation after injury may be more important than CT in the initial treatment of head trauma in infants. The complaints and neurological manifestations of infants, particularly those aged 2 or younger, are frequently unclear; therefore, there is an opinion that CT is recommended for all pediatric patients. However, the appropriateness of its use should be determined after confirming the mechanism of injury, consciousness level, neurological findings, and presence/absence of a history of abuse. Among the currently available rules specifying criteria for CT of infants with head trauma, the Pediatric Emergency Care Applied Research Network (PECARN) study may be regarded as reliable at present. In Japan, where the majority of emergency hospitals are using CT, it may be necessary to develop criteria for CT in consideration of the actual situation. CT diagnosis for pediatric head trauma is not always necessary. When no imaging is performed, this should be fully explained at the initial treatment before selecting course observation at home. Checking on a state of the patients by telephone is useful for both patients and physicians.

Key words: head injured infants, predictors of intracranial injury, criteria for CT, initial management

Introduction

The majority of head injured infants using emergency medical services are in a normal state of consciousness, and their injuries are mild in the absence of neurological abnormalities. In such cases, computed tomography (CT) is generally unnecessary, as most of them can be appropriately managed by observing the course after injury. However, when treating infants compared with adults, it tends to be more difficult to understand complaints and obtain accurate neurological findings. Therefore, to address such difficulty, the necessity of CT has been noted on some occasions.[1–4] In emergency medical services, radiation exposure[5,6] and body movements are the challenges frequently faced by those conducting examination for infants. The necessity of CT as part of initial management has been a matter of argument, and opinions regarding this remain divided. Even when no intracranial abnormalities have been detected by CT immediately after injury, they may occur shortly afterward; therefore, it is necessary to observe the course for at least several hours after injury. From this viewpoint, for the initial management of head injured infants, observation immediately after injury is likely to be more important than imaging.

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Characteristics of Head Trauma in Infants

Anatomical characteristics

As infants' skulls are proportionally larger than those of adults, with undeveloped motor abilities, the incidence of head trauma among them is higher.

The loose connection among the soft tissues of their heads is associated with a higher incidence of subgaleal or subperiosteal hematoma. Traumatic changes in the infant skull also differ from those in the adult skull. Being relatively softer and more elastic, in general, the former is subject to depressed fracture more frequently than the latter. The strong connection between their bone and dura mater occasionally leads to specific fractures, involving a pierced dura mater, such as growing skull fracture. The developing infant brain is soft and immature, and, although contusion is rare, diffuse brain injury and swelling are prevalent. Acute epidural hematoma is relatively rare, and the incidence of skull fracture complicating it is low among those aged 2 or younger.[7]

Mechanism of injury

During the neonatal period, delivery-related injuries, such as caput succedaneum, subgaleal hematoma, cephalohematoma, and linear fracture, may occur, while the incidence of head trauma related to falls to or on the ground increases at the beginning of an unsteady independent gait during infancy.[8] Even in the case of mild injury due to falls on soft floors, such as tatami, acute subdural hematoma without contusion may occur.[9]

Symptoms

Consciousness assessment of infants is generally difficult. As such pediatric patients are vulnerable to localized cerebral edema, convulsion easily occurs. An increased head circumference, protrusion of the anterior fontanel, and expansion of the cranial suture are the important findings to know increased intracranial pressure of infants. Retinal hemorrhage to be complicated for subdural hematoma is also important findings in the evidence of child abuse.

In the case of a rapidly increased intracranial pressure, particularly in infants, fundal abnormalities, such as retinal hemorrhage, are observed. Infants are also subject to hemorrhagic shock due to severe subgaleal or intracranial hematoma.

Possibility of abuse

It is necessary to consider the possibility of abuse whenever treating infants.[10] Abuse-related head trauma is called non-accidental (non-accidental TBI) or inflicted traumatic brain injury (ITBI).[11] Signs of child abuse include: unnatural bruises which are inconsistent with parents' explanations and a mixture of fresh and old bruises. It is also important to examine the cleanliness of clothes and developmental status to detect inappropriate parenting. Retinal findings are also important, as retinal hemorrhage are observed in 65–89% of cases of abuse.[12,13]

Predictors of Intracranial Injury

In actual clinical environments, pediatric patients with the chief complaint of a head trauma are usually brought to hospitals for consultation by their parents (attendants), suspecting intracranial hemorrhage. As previously mentioned, the majority of such patients are in a normal state of consciousness, and their injuries are mild without neurological abnormalities. However, despite their possibly low levels of need for imaging, it is frequently performed to accommodate parents' wishes. Particularly in Japan, where CT is used in most emergency hospitals, CT tends to be performed without sufficiently examining the appropriateness of its use. If established predictors of intracranial injury are made available, it may be possible to avoid unnecessary CT. In line with this, the results of an investigation on such predictors are reported in the following section.

Age

In the guidelines on head trauma established by the European Federation of Neurological Societies (EFNS), an age younger than 2 years is regarded as a risk factor associated with intracranial lesions complicating mild head trauma.[14] In a study, examining 97 cases of mild head trauma in infants aged 3 or younger, intracranial injury was frequently occurred within 12 months.[15] In another study involving those aged 2 years or younger, intracranial lesions were frequently detected by CT within 2 months.[16] In short, a large number of reports have indicated that the age is a predictor of intracranial injury.[17,14,18]

Clinical symptoms

Related clinical symptoms include: a loss of consciousness, amnesia for the event, a Glasgow Coma Scale (GCS) score lower than 15, a neurologic deficit, vomiting, headache, seizure, and an abnormal mental state. Among these, an abnormal mental status, headache, and vomiting have been noted as important predictors of intracranial injury.[19–21] However, there are many reports to assume that clinical symptoms after head trauma do not become a predictor of intracerebral hemorrhage,[16,22] presumably due to difficulty in accurately identifying clinical symptoms in infants aged 2 years or younger.

Objective findings on examining head traumas

A scalp hematoma has frequently been reported to be a predictor of intracranial lesions; those in infants aged 2 years or younger have been regarded as particularly important.[20,21] Greenes et al. (1999)

reported the predictability of intracranial injury in infants with an asymptomatic head trauma,[16] based on the age, as well as the size, and region of the hematoma; for example, fracture is not associated with scalp hematomas in the frontal region, but is associated with those in the parietal and temporal regions. Furthermore, they noted that radiography is unnecessary for infants with asymptomatic head trauma, not involving a clear scalp hematoma that persists for 3 months or longer.

Regarding intracranial predictors of head trauma in infants, eight representative reports listed in Table 1 are available at present.[15–17,20–25]

Currently Available Criteria for CT

CT is useful for the detection of acute intracranial hemorrhage due to a head bruise. Even among patients with mild symptoms in the absence of consciousness disturbance, 1.2–5.2% show abnormalities on head

Table 1 Representative reports for infants with minor head injury

Authors	Year of publication	Rule tested in study	No. of study patients	No. of patients who had CT	Ratio of ICI	An important point of report
Dietrich et al.[22]	1993	Dietrich et al.	322	322	10.90%	This study demonstrates a poor correlation between the clinical symptoms of significant traumatic brain injury and findings on CT.
Greenes et al.[16]	1999	Greenes et al.	608	188	16.00%	Asymptomatic infants older than 3 months of age who have no significant scalp hematoma may safely managed without radiographic imaging.
Greenes et al.[17]	2001	Greenes et al.	422	172	7.60%	Among asymptomatic head-injured infants, the risk of skull fracture and associated intracranial injury is correlated with scalp hematoma size, hematoma location, and weakly with patient age.
Palchak et al.[20]	2003	UCD	2043	1271	7.70%	Important factors for identifying children at low risk for traumatic brain injuries after blunt head trauma included the absence of : abnormal mental status, clinicaal signs of skull fracture, a history of vomiting, scalp hematoma, and headache.
Oman et al.[23]	2006	NEXUS II	1666	1666	8.30%	Clinically important ICI were rare in children who did not exhibit at least 1 of the NEXUS II risk criteria.
Sun et al.[21]	2007	UCD	1666	1666	8.30%	We demonstrate that using stricter definitions of headache and vomiting and different wording than in the original study may have unintended or negative consequences.
Buchanich et al.[15]	2007	Buchanich et al.	97	97	25%	While similarity exists between decision-making rules for older children and that found for this cohort, very young children have unique characteristics that merit further study and many require a separate decision-making process.
Kuppermann et al.[26]	2009	Kuppermann et al.	42412	14969	0.90%	We obtained CT scans on 14969; ciTBIs occurred in 376 (0.9%), and 60 (0.1%) underwent neurosurgery.

ICI: intracranial injury, UCD: University of California-Davis rule, NEXUS II: National Emergency X-Radiography Utilization Study II, ciTBI: clinically-important traumatic brain injuries.

CT, and 0.2–0.6% require neurosurgery.[24,26,27] Based on these data, CT may be necessary for patients with a head trauma; however, it is not realistic to perform it in all cases in terms of efficiency and costs.

When treating infants requiring CT, it is necessary to address two major challenges: body movements and radiation exposure. The former leads to difficulty in obtaining accurate findings. On some occasions, the procedure was performed while holding distressed infants down or administering sedatives to them; however, in general, sedatives should not be used without sufficient consideration for patients with low levels of need for examination, as their use not only makes consciousness assessment even more difficult, but also leads to adverse events, such as respiratory depression.

As CT compared with general radiography involves radiation exposure at several times higher doses, its use should be avoided whenever possible in infants who are particularly vulnerable to radiation.[28–30] A third of all CT devices available in the world are being used in Japan, enabling most Japanese emergency hospitals to perform emergency CT. The risk of radiation-induced cancer has been reported to be higher in Japan compared with Western countries. It has also been reported that CT-related radiation exposure at doses of 50 and 60 mGy trebles the risks of leukemia and brain tumors, respectively, highlighting the necessity of avoiding unnecessary CT, particularly in infants.[31] It is important to examine methods to appropriately select those targeted for CT from a large number of patients with mild symptoms.

Among the currently available rules specifying criteria for CT of infants with head trauma, the PECARN study is regarded as the most reliable.[24] This rule was established based on the results of a study examining 42,412 cases managed in 25 emergency centers located in the United States, in which pediatric patients younger than 18 years showing a GCS score of 14 or 15 within 24 h after injury were divided into 2 age-based groups: those younger than 2; and those aged 2 or over. The following factors; 1) a normal mental status, 2) no scalp hematoma except frontal, 3) no loss of consciousness or a loss of consciousness for <5 s, 4) non-severe injury mechanisms, 5) no palpable skull fracture, and 6) normal activity reported by parents, were nominated for the prediction rule to exclude clinically-important traumatic brain injuries (ciTBI). If there were these predictors, the probability without ciTBI calculated in the study was 100%. Bressan et al. (2012) examined the outcomes of treatment based on it, and reported that all those who had been provided with intervention, accounting for 0.8% of all patients, were CT group members.[32] We have shown modified CT algorithm in the PECARN study for Fig. 1.

In addition to the PECARN study, there are also two widely recognized rules: the Canadian Assessment of Tomography for Childhood Head Injury (CATCH)[27] and Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE);[26] however, their scopes are not limited to infants.

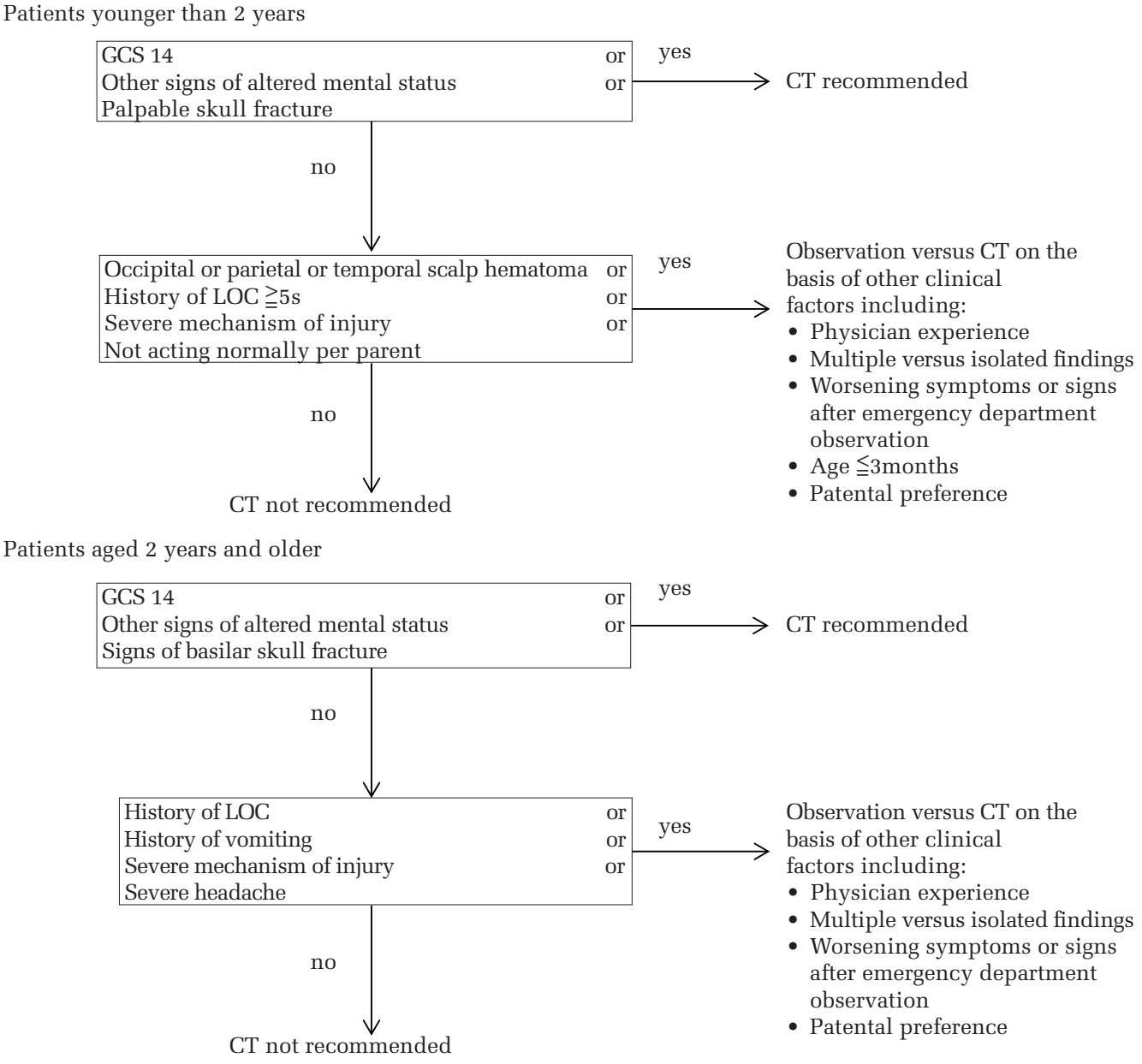
Initial Management of Patients with Mild Head Trauma

Even when hemorrhage is observed on CT, it is possible to appropriately manage patients with minor hematoma not involving brain compression only by observing the course. In consideration of the possibility of the hematoma increasing with time, it is necessary to sufficiently observe the consciousness level after injury. Consciousness disturbance is the most important symptom when observing the course following a head trauma.

If the patients are able to independently open their eyes, understand circumstances, and communicate, intracranial hematoma possibly involving brain herniation or requiring emergency surgery is likely to be absent, at least at that time. On the other hand, the size of a hematoma found to be small immediately after injury may increase with time. In such cases, the consciousness levels of pediatric patients, able to communicate immediately after injury, may also rapidly decrease, leading to a comatose state. As the size of a hematoma is generally maximal within 6–8 h after injury, it is crucial to sufficiently observe the consciousness level during this period.

Considering that, intracranial hemorrhage may occur within several hours after injury even when abnormalities have not been detected by CT, observation is important, regardless of the use/disuse of CT. Observation was conducted in the hospital in most cases, as this enables medical staff to immediately perform CT when detecting new symptoms or deterioration. Emergency procedures can also be promptly performed whenever needed in such cases. On the other hand, in-hospital observation involving environmental changes increases infants' stress. As parents' presence is basically necessary when treating infants, such a burden is loaded on both patients and their parents.

It has been reported that observation after head injury is also feasible at home if no abnormalities are detected by CT.[33] This method is less stressful for pediatric patients and their parents. At the same time, for the latter, it is necessary to appropriately observe patients' conditions in the absence of medical



GCS: Glasgow Coma Scale, LOC: loss of consciousness.

Fig. 1 Modified CT algorithm for head injured infants in the PECARN study.

professionals. Some of them face difficulty in determining the necessity of taking their children with decreased vigor or repeated vomiting to hospitals. As an effective approach in such situations, it may be appropriate for the doctor or another medical professional in charge to contact them at home by telephone to confirm patients' conditions. This allows parents to directly ask questions regarding the status of their children to medical professionals while staying at home, and consequently alleviates their anxiety. In fact, there have been reports supporting the usefulness of such confirmation by telephone.[34]

Although standards on the period of observation after injury have yet to be established, it is set at within 24 h, in general.

Conclusion

Criteria for CT of infants and points to be noted when observing the course following head trauma have been discussed in this study. The complaints

and neurologic manifestations of infants, particularly those aged 2 or younger, are frequently unclear; therefore, there is an opinion that CT is recommended for all pediatric patients. The appropriateness of its use should be determined after confirming the circumstances of injury, consciousness level, neurologic manifestations, and presence/absence of a history of abuse. Among the currently available rules specifying criteria for CT of infants with head trauma, the PECARN[24] may be regarded as reliable at present. In Japan, where the majority of emergency hospitals are using CT, it may be necessary to develop criteria for CT in consideration of the actual situation.[35–37] When treating infants with a head bruise, sufficient observation after injury is more important than discussions on the appropriateness of CT. If no abnormalities are detected by CT, it is desirable to conduct observation at home to reduce pediatric patients' and their parents' stress. In such cases, medical professionals' telephone calls to confirm patients' conditions at home may be an effective approach.

Conflicts of Interest Disclosure

The authors no report conflicts of interest concerning the materials or methods used in this study.

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