

Chapter 7. Neuroimaging

I. RECOMMENDATIONS

Strength of Recommendation: Weak.

Quality of Evidence: Low from one poor-quality class III study.

A. Level I

There are insufficient data to support a level I recommendation for this topic.

B. Level II

There are insufficient data to support a level II recommendation for this topic.

C. Level III

In the absence of neurologic deterioration or increasing intracranial pressure (ICP), obtaining a routine repeat computed tomography (CT) scan >24 hrs after the admission and initial follow-up study may not be indicated for decisions about neurosurgical intervention.

II. EVIDENCE TABLE (see Table 1)

III. OVERVIEW

Early neuroimaging has assumed an increasingly important role in evaluating the extent and severity of traumatic brain injury (TBI) in children (1). CT is important for the rapid detection of different types of intracranial injury including extra-axial hemorrhage (e.g., subdural or epidural hematomas), acute hydrocephalus, fractures, or other intracranial lesions that may require acute neurosurgical intervention. The early use of CT is also useful for triage of patients to detect those who are likely to need neurosurgery, require management in an intensive care unit vs. general hospital setting as well as those who can be safely discharged from the emergency department and managed at home. Although magnetic resonance imaging (MRI) sensitivity is understood to be superior to CT for intracranial evaluation, it is not as easily

obtained acutely after injury and has not been as widely validated in large studies, particularly regarding influence on management decisions. At the current time, there is little evidence to support the use of MRI in influencing management of patients with severe TBI.

It is understood that acute CT imaging is universally performed in the developed world for patients with severe TBI. Two studies (2, 3) show that children with severe TBI have a high incidence of intracranial injury on CT scan (75% and 62%, respectively). In these studies, intracranial injury included brain contusion, extracerebral hematoma, intracerebral hematoma, diffuse axonal injury, acute brain swelling, penetrating cranio-cerebral injury, pneumocephalus, subarachnoid hemorrhage, alterations to cisterns, midline shift, or fractures. Neither study included treatment-related outcome data related to the findings on CT scan and thus could not be used as specific evidence for this guideline.

Although CT is always obtained acutely in patients with severe TBI, the use of two or more CT studies is not agreed on. Repeating a CT scan in children with severe TBI is usually considered when there is 1) no evidence of neurologic improvement; 2) persistent or increasing ICP; or 3) an inability to assess neurologic status (e.g., sedation, paralytic agents) (4). Studies have reported delayed or progressive lesions in 1% to 50% of adult/pediatric patients with TBI (5). Because epidural hematoma/subdural hematoma requiring surgical intervention can develop hours to days after the acute injury, some investigators have suggested that a follow-up CT scan be routinely acquired at 1–3 days postinjury even when clinical deterioration is not evident under the assumption that early diagnosis prompts early intervention leading to a better long-term outcome (4). However, because children with severe TBI are medically unstable and (if portable CT is not available) may further deteriorate during transport to the CT scanner (hemodynamic instability, increased ICP, oxygen desaturation), the decision to order a repeat scan is a treatment decision,

weighing the knowledge gained against the risk of additional secondary brain injury. Likewise, because of the long-term effects of CT radiation exposure (lifetime risk of fatal cancer resulting from one head CT in a 1-yr-old child is as high as one in 1500), the neurosurgical decision to order a CT scan also should be considered a treatment decision, weighing the knowledge gained against the risk of long-term radiation exposure (6). This guideline addressed the issue of the value of routinely acquiring repeat CT scans in children with severe TBI.

IV. PROCESS

For this new topic, MEDLINE was searched from 1950 through 2010 (Appendix B for search strategy), and results were supplemented with literature recommended by peers or identified from reference lists. Of 120 potentially relevant studies, one was included as evidence for this topic.

V. SCIENTIFIC FOUNDATION

One class III study met the inclusion criteria for this topic and provides evidence to support the recommendation (7).

A retrospective study of 40 children with severe TBI (Glasgow Coma Scale score <8, age 2 months to 17 yrs; US, January 1990 to December 2003) examined whether serial CT scans led to urgent neurosurgical operative intervention (7). Entry criteria also included ICP monitoring during hospitalization, no craniotomy at admission to study, and at least a second CT scan within the first 48 hrs. One hundred fifteen serial CT scans were ordered (76% routine follow-up, 21% increased ICP; 3% neurologic change). Results of these scans showed no change (53%), improvement (34%), and worsening (13%). Five (4.3%) patients had a surgical intervention based on the results of the serial CT scan (one epidural hematoma, craniotomy; one subdural hemorrhage, burr hole; three for additional ventriculostomy placements). All five scans were ordered based on a clinical indicator (ICP or neurologic status), not as routine follow-up. The au-

Table 1. Evidence table

Reference	Study Description	Data Class, Quality, and Reasons	Results and Conclusion
New study Figg et al, 2006 (7)	Design: case series N = 40 942 screened Age: mean 9.6 yrs (SD 4.4) Glasgow Coma Scale score: Mean 5.1 (SD 1.5) Purpose: Examined whether serial computed tomography scans lead to urgent neurosurgical operative intervention	Class III Poor quality: no control for potential confounders	Serial scans after the admission and initial follow-up study (N = 115 scans) showed: no change (53%), improvement (34%), or worsening (13%) Five (4.3%) patients had a surgical intervention based on findings from the serial computed tomography scans; however, all five scans were ordered as a result of clinical indicators (intracranial pressure or neurologic status), not as routine follow-up

thors recommended that a highly selective approach to ordering serial CT scans should be practiced with the understanding that only scans ordered for increased ICP or neurologic change are likely to lead to surgical interventions.

VI. INFORMATION FROM OTHER SOURCES

Several additional studies had data regarding the value of acquiring a second CT scan in children with severe TBI but none had information regarding treatment-related outcomes and therefore could not be included as evidence for this guideline. One retrospective cohort study of 521 pediatric patients with TBI who met inclusion criteria from a total of 8505 blunt trauma admissions (1994–2003) described the prevalence of worsening brain injury on repeat CT, predictors of worsening CT findings, and the frequency of neurosurgical intervention after the repeat CT (4). Potential predictors of worsening CT findings and neurosurgical intervention were recorded by chart review. Logistic regression and recursive partitioning were used to identify predictors. Patients were grouped into three categories (moderate/severe, mild, all TBI). In the moderate/severe group (n = 252), 202 (80%, mean Glasgow Coma Scale score 3.7) had severe and 50 (20%, Glasgow Coma Scale score 10.5) had moderate injury. For children with severe TBI, the multivariate adjusted odds ratio for worsening or new second CT findings was 2.4 (95% confidence interval, 1.6–3.8). Children with moderate/severe head injuries, especially if they had intracranial injury, were more likely to have deteriorating CT findings (107 of 248 [43%]) and of these children, 4% (n = 11) required surgery. In contrast,

141 (57%) had stable CT scans and only 2% (n = 4) required surgery. In most surgical patients, repeat CT was preceded by rapid decline in neurologic status or elevated ICP. Four clinical factors were identified for stratifying risk of worsening brain injuries on repeat CT (normal initial CT scan, abnormal initial CT scan, moderate or severe head injury by Glasgow Coma Scale, and coagulopathy). This method identified 100% of patients who underwent surgery and 89% of patients who had worsening brain injuries on repeat CT.

Another retrospective study of 173 consecutive children (ages 8 months to 16 yrs; mean 7.1 yrs) with severe (83%) or moderate (17%) TBI (mean Glasgow Coma Scale score of 6.8 ± 2.1) assessed the yield of a routine predetermined repeat CT scan within 24–36 hrs (5). Forty-seven (27%) of the second CT scans showed new lesions including six with intracranial hypertension, 17 cases of worsening brain edema, and 18 newly diagnosed brain contusions. None of these findings necessitated surgical intervention or any change in therapy. Of the 67 patients who underwent a third CT scan, two cases required surgical intervention because of new findings on the third CT. The authors stated that a second routine prescheduled head CT scan within 24–36 hrs after admission in pediatric patients with moderate to severe head trauma is unlikely to yield any change in therapy. Clinically oriented and ICP-directed CT scans may better select and diagnose patients who require changes in therapy, including surgery.

Another retrospective study of 351 children with severe TBI who had two or more CT scans within 72 hrs of admission found that 41% had delayed and progres-

sive lesions (3). The decision to repeat the scan was based on clinical judgment and although the morbidity and mortality of these patients were worse, the rate of surgical intervention or change in therapy after the second CT was not reported; hence, the yield of the imaging is unknown. Injury progression correlated with the severity of the initial head trauma, presence of extracranial injury, and the presence of coagulopathy on admission.

VII. SUMMARY

One study met the criteria for inclusion as evidence for this topic given that we required that publications about imaging link the assessment to a treatment decision and the decision to an outcome. Our level III recommendation, based on one class III study, questions the use of repeat CT scans in the absence of neurologic deterioration or increasing ICP.

VIII. KEY ISSUES FOR FUTURE INVESTIGATION

There is a dearth of information regarding the use of neuroimaging in directing targeted therapies and stratification. Although MRI is being used more frequently in the acute evaluation of children with TBI, particularly for suspected abusive head trauma, most of the literature is directed at evaluating diagnostic sensitivity or outcome prediction. It is also known that advanced MRI techniques provide unique information about brain function that is not available by CT, but it remains uncertain how this information can alter management or improve treatment-related outcomes. Adult TBI literature also suggests that patterns of injury on neuroimaging may be helpful

for improving stratification of injury severity and therefore aid in selecting patients for targeted treatment. Important questions to address are:

- Do patterns of injury (from findings provided by multimodality neuroimaging) improve accuracy of injury stratification?
- Does MRI provide added value to CT in influencing management of children with severe TBI?
- What is the use of neuroimaging (CT, MRI, etc.) in directing targeted therapies and improving treatment-related outcomes?
- What is the use of repeat neuroimaging in special settings, such as in patients

who cannot be examined or in the presence of coagulopathy?

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