Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. Pinto PS, Poretti A, Meoded A, Tekes A, Huisman TA. The unique features of traumatic brain injury in children. Review of the characteristics of the pediatric skull and brain, mechanisms of trauma, patterns of injury, complications and their imaging findings--part 1. *J Neuroimaging.* 2012;22(2):e1-e17.	Review/Other-Dx	N/A	To discuss the unique epidemiology, mechanisms, and characteristics of traumatic head/brain injury in children, and to review the anatomical and functional imaging techniques that can be used to study common and rare pediatric traumatic brain injuries and their complications.	CT scans are rapid and cost effective and should be utilized with a low threshold to study acute head injury, particularly in the nonaccidental trauma population. However, especially in childhood, MRI constitutes an important alternative or second line imaging modality due to its high sensitivity and specificity, better correlation with the outcome, and lack of radiation.	4
2. Faul M, Xu L, Wald MM, Coronado VG. Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002–2006. Atlanta (GA): Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. 2010; http://www.cdc.gov/traumaticbraininjury/tbi_ed.html. Accessed September 16, 2013.	Review/Other-Dx	N/A	A report on TBI in the U.S. The report presents data on TBI-related emergency department visits, hospitalizations, and deaths for the years 2002 through 2006.	N/A	4
3. Schnadower D, Vazquez H, Lee J, Dayan P, Roskind CG. Controversies in the evaluation and management of minor blunt head trauma in children. *Curr Opin Pediatr.* 2007;19(3):258-264.	Review/Other-Dx	N/A	To present data from recently conducted research regarding controversial aspects of the evaluation and management of children with minor blunt head trauma.	The authors recommend pediatric follow-up after a concussion and appropriate behavioral intervention with or without pharmacologic therapy for children with persistent symptoms. Finally, return-to-play guidelines, though lacking high-level evidence, have become standard of care, and clinicians should convey this information to patients and their parents.	4
4. Willis AP, Latif SA, Chandratre S, Stanhope B, Johnson K. Not a NICE CT protocol for the acutely head injured child. *Clin Radiol.* 2008;63(2):165-169.	Review/Other-Dx	1,428 children	To assess the impact of the introduction of the Birmingham Children's Hospital (BCH) head injury CT guidelines, when compared with the National Institute of Health and Clinical Excellence (NICE) guidelines, on the number of children with head injuries referred from the emergency department undergoing a CT examination of the head.	4% of children were referred for a CT using BCH guidelines and were appropriately examined. If the NICE guidelines had been strictly adhered to a further 8% of children would have undergone a CT examination of the head. All of these children were discharged without complication. The remaining 88% had no indication for CT examination by either BCH or NICE and appropriately did not undergo CT.	4
5. Schutzman SA, Greenes DS. Pediatric minor head trauma. *Ann Emerg Med.* 2001;37(1):65-74.	Review/Other-Dx	N/A	To review the current data and practice in assessing and treating minor head trauma in children.	Recommendations are presented for children with acute closed head trauma who are alert or easily aroused to voice or light touch.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
6. Haydel MJ, Shembekar AD. Prediction of intracranial injury in children aged five years and older with loss of consciousness after minor head injury due to nontrivial mechanisms. *Ann Emerg Med.* 2003;42(4):507-514.	Observational-Dx	175 patients	To determine whether a clinical decision rule developed for adults could be used in children aged 5 years and older.	Throughout a 30-month period, 175 patients were enrolled, with a mean age of 12.8 years. 14 (8%) patients had ICI or depressed skull fracture on CT. The presence of any of the 6 criteria was significantly associated with an abnormal CT scan result (P<.05) and was 100% (95% CI, 73%-100%) sensitive for identifying patients with ICI.	3
7. Kuppermann N, Holmes JF, Dayan PS, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet.* 2009;374(9696):1160-1170.	Observational-Dx	42,412 children	To identify children at very low risk of clinically-important traumatic brain injuries for whom CT might be unnecessary.	The authors obtained CT scans on 14,969 (35.3%); clinically-important TBIs occurred in 376 (0.9%), and 60 (0.1%) underwent neurosurgery. In the validation population, the prediction rule for children <2 years (normal mental status, no scalp hematoma except frontal, no loss of consciousness or loss of consciousness for less than 5 s, nonsevere injury mechanism, no palpable skull fracture, and acting normally according to the parents) had a negative predictive value for clinically-important TBI of 1176/1176 (100.0%, 95% CI, 99.7-100 0) and sensitivity of 25/25 (100%, 86.3-100.0). 167 (24.1%) of 694 CT-imaged patients <2 years were in this low-risk group. The prediction rule for children aged 2 years and older (normal mental status, no loss of consciousness, no vomiting, nonsevere injury mechanism, no signs of basilar skull fracture, and no severe headache) had a negative predictive value of 3798/3800 (99.95%, 99.81-99.99) and sensitivity of 61/63 (96.8%, 89.0-99.6). 446 (20.1%) of 2,223 CT-imaged patients aged 2 years and older were in this low-risk group. Neither rule missed neurosurgery in validation populations.	2
8. Tavarez MM, Atabaki SM, Teach SJ. Acute evaluation of pediatric patients with minor traumatic brain injury. *Curr Opin Pediatr.* 2012;24(3):307-313.	Review/Other-Dx	N/A	To evaluate the most recent literature regarding clinical prediction rules for the use of cranial CT in children presenting with minor TBI, review the evidence on the need for hospitalization in children with minor TBI, and evaluates the role of S100B testing.	Clinical prediction rules, most notably the PECARN rules, can be applied to determine children with low-risk TBI and help decrease unnecessary CT use and hospitalizations. S100B testing requires further investigation, but may serve as an adjunct in determining children with low-risk TBI.	4

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9. Maguire JL, Boutis K, Uleryk EM, Laupacis A, Parkin PC. Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics. 2009;124(1):e145-154.	Review/Other-Dx	3,357 titles and abstracts assessed and 8 clinical prediction rules identified	To systematically review the quality and performance of published clinical prediction rules for ICI in children with head injury.	For all studies, the rule derivations were reported; no study validated a rule in a separate population or assessed its impact in actual practice. The rules differed considerably in population, predictors, outcomes, methodologic quality, and performance. Five of the rules were applicable to children of all ages and severities of trauma. Two of these were high quality (≥11 of 14 quality items) and had high performance (lower confidence limits for sensitivity >0.95 and required ≤56% to undergo CT). 4/8 rules were applicable to children with minor head injury (GCS ≥13). One of these had high quality (11/14 quality items) and high performance (lower confidence limit for sensitivity = 0.94 and required 13% to undergo CT). Four of the 8 rules were applicable to young children, but none exhibited adequate quality or performance.	3
10. Halley MK, Silva PD, Foley J, Rodarte A. Loss of consciousness: when to perform computed tomography? *Pediatr Crit Care Med.* 2004;5(3):230-233.	Observational-Dx	98 patients	To determine the diagnostic value of physical examination (including neurologic exam) for positive CT scan findings in children with closed head injury, GCS score 13-15 in the emergency department, and loss of consciousness or amnesia.	CT scans revealed evidence of ICI in 13/98 subjects (13%). Normal examination increased the probability of a normal CT scan from .87 pretest to .90 post-test. 4/38 subjects with normal examination were noted to have evidence of ICI on CT. These 4 subjects did not require neurosurgical intervention. 2/98 subjects underwent neurosurgical procedures. One intracranial pressure monitor was placed for decreasing level of consciousness. One subject underwent surgical elevation of a depressed skull fracture.	3

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11. Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. *Lancet.* 2012;380(9840):499-505.	Observational-Dx	178,604 individuals in leukemia analyses and 176,587 in brain tumor analyses	To assess the excess risk of leukemia and brain tumors after CT scans in a cohort of children and young adults.	During follow-up, 74/178,604 patients were diagnosed with leukemia and 135/176,587 patients were diagnosed with brain tumors. The authors noted a positive association between radiation dose from CT scans and leukemia (excess relative risk per mGy 0.036, 95% CI, 0.005-0.120; P=0.0097) and brain tumors (0.023, 0.010-0.049; P<0.0001). Compared with patients who received a dose of <5 mGy, the relative risk of leukemia for patients who received a cumulative dose of at least 30 mGy (mean dose 51.13 mGy) was 3.18 (95% CI, 1.46-6.94) and the relative risk of brain cancer for patients who received a cumulative dose of 50-74 mGy (mean dose 60.42 mGy) was 2.82 (1.33-6.03).	3
12. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. N Engl J Med. 2007;357(22):2277-2284.	Review/Other-Dx	N/A	To review the nature of CT scanning and its main clinical applications, both in symptomatic patients and in the screening of asymptomatic patients.	The widespread use of CT represents probably the single most important advance in diagnostic radiology. However, as compared with radiography, CT involves much higher doses of radiation, resulting in a marked increase in radiation exposure in the population.	4
13. How to Develop CT Protocols for Children. Available at: http://spr.affiniscape.com/associations/5364/files/Protocols.pdf. Accessed September 16, 2013.	Review/Other-Dx	N/A	To provide guidance in either developing CT protocols for children or verifying that current protocols are appropriate.	N/A	4
14. Datta S, Stoodley N, Jayawant S, Renowden S, Kemp A. Neuroradiological aspects of subdural haemorrhages. *Arch Dis Child.* 2005;90(9):947-951.	Review/Other-Dx	74 children	To review the neuroimaging of a series of infants and young children admitted to hospital with subdural hemorrhage.	Neuroradiological review of images identified radiological features which were highly suggestive of nonaccidental head injury. Interhemispheric hemorrhages and subdural hemorrhages in multiple sites or of different densities were almost exclusively seen in nonaccidental head injury. MRI was more sensitive in identifying subdural hemorrhages of different signal characteristics, posterior and middle cranial fossa bleeds, and parenchymal changes in the brain. CT scans, if performed with suboptimal protocols, were likely to miss small subdural bleeds.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
15. Kemp AM, Rajaram S, Mann M, et al. What neuroimaging should be performed in children in whom inflicted brain injury (iBI) is suspected? A systematic review. *Clin Radiol.* 2009;64(5):473-483.	Review/Other-Dx	18 studies	To investigate the optimal neuroradiological investigation strategy to identify inflicted brain injury.	Of the 320 studies reviewed, 18 met the inclusion criteria, reflecting data on 367 children with inflicted brain injury and 12 were published since 1998. When an MRI was conducted in addition to an abnormal early CT examination, additional information was found in 25% (95% CI: 18.3%-33.16%) of children. The additional findings included further subdural hematoma, subarachnoid hemorrhage, shearing injury, ischemia, and infarction; it also contributed to dating of injuries. DWI further enhanced the delineation of ischemic changes, and assisted in prognosis. Repeat CT studies varied in timing and quality, and none were compared to the addition of an early MRI/DWI.	4
16. Hunter JV, Wilde EA, Tong KA, Holshouser BA. Emerging imaging tools for use with traumatic brain injury research. *J Neurotrauma.* 2012;29(4):654-671.	Review/Other-Dx	N/A	To address some of the potential uses of more advanced forms of imaging in TBI as well as highlight some of the current considerations and unresolved challenges of using them.	Although MRI is currently the mainstay of instrumentation for both current and emerging techniques, other technologies are also available.	4
17. Skandsen T, Kvistad KA, Solheim O, Strand IH, Folvik M, Vik A. Prevalence and impact of diffuse axonal injury in patients with moderate and severe head injury: a cohort study of early magnetic resonance imaging findings and 1-year outcome. *J Neurosurg.* 2010;113(3):556-563.	Observational-Dx	106 patients	To explore the occurrence of DAI and determine whether DAI was related to level of consciousness and patient outcome.	DAI was detected in 72% of the patients and a combination of DAI and contusions or hematomas was found in 50%. The GCS was significantly lower in patients with "pure DAI" (median GCS 9) than in patients without DAI (median GCS 12; P<0.001). The GCS score was related to outcome only in those patients with DAI (r = 0.47; P=0.001). Patients with DAI had a median GOSE score of 7, and patients without DAI had a median GOSE score of 8 (P=0.10). Outcome was better in patients with DAI Stage 1 (median GOSE Score 8) and DAI Stage 2 (median GOSE Score 7.5) than in patients with DAI Stage 3 (median GOSE Score 4; P<0.001). Thus, in patients without any brainstem injury, there was no difference in good recovery between patients with DAI (67%) and patients without DAI (66%).	2

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18. Tong KA, Ashwal S, Holshouser BA, et al. Hemorrhagic shearing lesions in children and adolescents with posttraumatic diffuse axonal injury: improved detection and initial results. *Radiology*. 2003;227(2):332-339.	Observational-Dx	7 children and adolescents	To compare the effectiveness of a high-spatial-resolution SWI MRI technique with that of a conventional gradient-recalled-echo MRI technique for detection of hemorrhage in children and adolescents with DAI.	Hemorrhagic lesions were much more visible on SWI MRI than on conventional gradient-recalled-echo MRIs. SWI MRI depicted 1,038 hemorrhagic DAI lesions with an apparent total hemorrhage volume of 57,946 mm3. Gradient-recalled-echo MRI depicted 162 lesions with an apparent total hemorrhage volume of 28,893 mm3. SWI MRI depicted a significantly higher mean number of lesions in all patients than did gradient-recalled-echo MRI, according to results of visual (P=.004) and computer (P=.004) counting analyses. The mean hemorrhage volume load for all patients also was significantly greater (P=.014) by using SWI MRI according to computer analysis. SWI MRI appeared to depict much smaller hemorrhagic lesions than gradient-recalled-echo MRI. The majority (59%) of individual hemorrhagic DAI lesions seen on SWI MRIs were small in area (<10 mm(2)), whereas the majority (43%) of lesions seen on gradient-recalled-echo images were larger in area (10-20 mm(2)).	3

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19. Holmes JF, Borgialli DA, Nadel FM, et al. Do children with blunt head trauma and normal cranial computed tomography scan results require hospitalization for neurologic observation? *Ann Emerg Med.* 2011;58(4):315-322.	Observational-Dx	13,543 patients	To identify the frequency of neurologic complications in children with minor blunt head trauma and normal emergency department CT scan results.	Children (13,543) with GCS scores of 14 or 15 and normal emergency department CT scan results were enrolled, including 12,584 (93%) with GCS of 15 and 959 (7%) with GCS of 14. Of 13,543 patients, 2,485 (18%) were hospitalized, including 2,107 of 12,584 (17%) with GCS of 15 and 378 of 959 (39%) with GCS of 14. Of the 11,058 patients discharged home from the emergency department, successful telephone/mail follow-up was completed for 8,756 (79%), and medical record, continuous quality improvement, and morgue review was performed for the remaining patients. 179 (2%) children received subsequent CT or MRI; 5 (0.05%) had abnormal CT/MRI scan results and none (0%; 95% CI, 0%-0.03%) received a neurosurgical intervention. Of the 2,485 hospitalized patients, 137 (6%) received subsequent CT or MRI; 16 (0.6%) had abnormal CT/MRI scan results and none (0%; 95% CI, 0%-0.2%) received a neurosurgical intervention. The negative predictive value for neurosurgical intervention for a child with an initial GCS score of 14 or 15 and a normal CT scan result was 100% (95% CI, 99.97%-100%).	3
20. Reed MJ, Browning JG, Wilkinson AG, Beattie T. Can we abolish skull x rays for head injury? *Arch Dis Child.* 2005;90(8):859-864.	Observational-Dx	1,535 patients	To assess the effect of a change in skull x-ray policy on the rate of admission, use of CT, radiation dose per head injury, and detection of intracranial injuries; and to compare the characteristics of patients with normal and abnormal head CT.	The abolition of skull x-rays in children aged over 1 year prevented about 400 normal skull x-rays being undertaken in period 2. The percentage of children undergoing CT rose from 1.0% to 2.1% with no change in the positive CT pick up rate (25.6% vs 25.0%). There was no significant change in admission rate (10.9% vs 10.1%), and a slight decrease in the radiation dose per head injury (0.042 mSv compared to 0.045 mSv).	4

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21. Nakahara K, Shimizu S, Utsuki S, et al. Linear fractures occult on skull radiographs: a pitfall at radiological screening for mild head injury. *J Trauma.* 2011;70(1):180-182.	Observational-Dx	278 patients	To compare the visualization of atypical linear fractures that is not easily seen on routine skull radiographs with their detection on CT scans and alert to diagnostic pitfalls.	Of the 278 patients aged between 2 months and 66 years, 8 (2.9%) manifested a linear fracture on CT scans that presented as a cross section of the fracture oblique to the direction of the x-rays. 4/8 developed acute epidural hematoma; 2 of these patients underwent craniotomy.	4
22. Crowe L, Anderson V, Babl FE. Application of the CHALICE clinical prediction rule for intracranial injury in children outside the UK: impact on head CT rate. *Arch Dis Child.* 2010;95(12):1017-1022.	Observational-Dx	1,065 cases	To determine the impact of children's head injury algorithm for the prediction of important clinical events (CHALICE) on the proportion of head injured patients receiving a CT scan in a major Australian pediatric emergency department.	There were 1,091 head injuries of all severities during the study period. 18% of head injured patients had a GCS <15, 19% a CT scan and 1.4% neurosurgical intervention. Application of the CHALICE algorithm would result in 46% receiving a CT scan. 303 patients who fit CHALICE criteria did not have a CT scan. These patients were managed with admission for observation or discharge and head injury instructions. Only 5 of these (1.6% or 0.5% of total head injuries) received a CT scan on representation for ongoing symptoms, 4 of which showed abnormalities on CT scan.	3
23. Dunning J, Daly JP, Lomas JP, Lecky F, Batchelor J, Mackway-Jones K. Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. *Arch Dis Child.* 2006;91(11):885-891.	Observational-Dx	22,772 patients	To conduct a prospective multicenter diagnostic cohort study to provide a rule for selection of high-risk children with head injury for CT scanning.	22,772 children were recruited over 2 1/2 years. 65% of these were boys and 56% were <5 years old. 281 children showed an abnormality on the CT scan, 137 had a neurosurgical operation and 15 died. The CHALICE rule was derived with a sensitivity of 98% (95% CI, 96%-100%) and a specificity of 87% (95% CI, 86%-87%) for the prediction of clinically significant head injury, and requires a CT scan rate of 14%.	3
24. Oman JA, Cooper RJ, Holmes JF, et al. Performance of a decision rule to predict need for computed tomography among children with blunt head trauma. *Pediatrics.* 2006;117(2):e238-246.	Observational-Dx	1,666 pediatric patients	To assess the ability of the NEXUS II head trauma decision instrument to identify patients with clinically important ICI from among children with blunt head trauma.	NEXUS II enrolled 1,666 children, 138 (8.3%) of whom had clinically important ICI. The decision instrument correctly identified 136/138 cases and classified 230 as low-risk. A total of 309 children were younger than 3 years, among whom 25 had ICI. The decision instrument identified all 25 cases of clinically important ICI in this subgroup.	3

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25. Schachar JL, Zampolin RL, Miller TS, Farinhas JM, Freeman K, Taragin BH. External validation of the New Orleans Criteria (NOC), the Canadian CT Head Rule (CCHR) and the National Emergency X-Radiography Utilization Study II (NEXUS II) for CT scanning in pediatric patients with minor head injury in a non-trauma center. *Pediatr Radiol.* 2011;41(8):971-979.	Observational-Dx	2,101 patients	To evaluate whether a strict application of the New Orleans Criteria (NOC), Canadian CT Head Rule (CCHR) and NEXUS II in pediatric patients with head trauma presenting to a nontrauma center (level II) could reduce the number of cranial CT scans performed without missing clinically significant ICI.	92 (4.4%) of 2,101 patients had positive head CT findings. The sensitivities for the NOC, CCHR and NEXUS II were 96.7% (95% CI, 93.1-100), 65.2% (95% CI, 55.5-74.9) and 78.3% (95% CI, 69.9-86.7), respectively, and their negative predictive values were 98.7%, 97.6% and 97.2%, respectively. In contrast, the specificities for these aids were 11.2% (95% CI, 9.8-12.6), 64.2% (95% CI, 62.1-66.3) and 34.2% (95% CI, 32.1-36.3), respectively. Therefore, in our population it would have been possible to scan at least 10.9% fewer patients.	3
26. Bainbridge J, Khirwadkar H, Hourihan MD. Vomiting--is this a good indication for CT head scans in patients with minor head injury? Br J Radiol. 2012;85(1010):183-186.	Observational-Dx	151 CT head scans (124 adults, 27 children)	To determine whether vomiting is a good indication for CT head scans in patients with minor head injury.	There were 1,264 CT head scans performed during the study period. 151 (124 adults, 27 children) were indicated owing to vomiting following head injury. 5/124 adult scans and 1 of the 27 pediatric scans showed an abnormal finding, giving positive predictive value of 4% and 3.7%, respectively. None of these patients required either acute or delayed neurosurgical intervention.	4
27. Nigrovic LE, Lee LK, Hoyle J, et al. Prevalence of clinically important traumatic brain injuries in children with minor blunt head trauma and isolated severe injury mechanisms. Arch Pediatr Adolesc Med. 2012;166(4):356-361.	Review/Other-Dx	42,099 patients	To determine the prevalence of clinically important TBIs with severe injury mechanisms in children with minor blunt head trauma but with no other risk factors from the Pediatric Emergency Care Applied Research Network (PECARN) TBI prediction rules (defined as isolated severe injury mechanisms).	Of the 42,412 patients enrolled in the overall study, 42,099 (99%) had injury mechanisms recorded, and their data were included for analysis. Of all study patients, 5,869 (14%) had severe injury mechanisms, and 3,302 (8%) had isolated severe injury mechanisms. Overall, 367 children had clinically important TBIs (0.9%; 95% CI, 0.8%-1.0%). Of the 1,327 children younger than 2 years with isolated severe injury mechanisms, 4 (0.3%; 95% CI, 0.1%-0.8%) had clinically important TBIs, as did 12 of the 1,975 children 2 years or older (0.6%; 95% CI, 0.3%-1.1%).	4
28. Pickering A, Harnan S, Fitzgerald P, Pandor A, Goodacre S. Clinical decision rules for children with minor head injury: a systematic review. *Arch Dis Child.* 2011;96(5):414-421.	Review/Other-Dx	16 publications, representing 14 cohorts, with 79,740 patients	To identify clinical decision rules for children with minor head injury and compare their diagnostic accuracy for detection of ICI and injury requiring neurosurgical intervention.	Only 4 rules were tested in more than one cohort. Of the validated rules the PECARN rule was most consistent (sensitivity 98%; specificity 58%). For neurosurgical injury all had high sensitivity (98%-100%) but the CHALICE rule had the highest specificity (86%) in its derivation cohort.	4

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29. Mannix R, Meehan WP, Monuteaux MC, Bachur RG. Computed tomography for minor head injury: variation and trends in major United States pediatric emergency departments. *J Pediatr.* 2012;160(1):136-139 e131.	Review/Other-Dx	8,976,378 pediatric emergency department visits	To investigate the variation and trends in neuroimaging in children examined for minor head injury at major US pediatric emergency departments.	In the 5 years, the median rate of imaging for minor head injured patients was 36% (IQR, 29%-42%; range, 19%-58%). There was no correlation between institution-specific rates of CT imaging and intracranial hemorrhage, admission, or return-visit rates. Age-adjusted rates of CT use decreased in the 5-year period (odds ratio, 0.94; 95% CI, 0.92-0.97; P<.001).	4
30. Gorelick MH, Atabaki SM, Hoyle J, et al. Interobserver agreement in assessment of clinical variables in children with blunt head trauma. *Acad Emerg Med.* 2008;15(9):812-818.	Observational-Dx	1,500 subjects	To determine the interobserver agreement in the assessment of historical and physical examination findings of children undergoing emergency department evaluation for blunt head trauma.	1,500 pairs of observations were obtained. Acceptable agreement was achieved in 27 of the 32 variables studied (84%). Mechanism of injury (low, medium, or high risk) had kappa = 0.83. For subjective symptoms, kappa ranged from 0.47 (dizziness) to 0.93 (frequency of vomiting); all had 95% lower confidence limit >0.4. Of the physical examination findings, kappa ranged from 0.22 (agitated) to 0.89 (GCS). The 95% lower confidence limit for kappa was <0.4 for four individual signs of altered mental status and for quality (i.e., boggy or firm) of scalp hematoma if present.	2
31. Holmes JF, Palchak MJ, MacFarlane T, Kuppermann N. Performance of the pediatric glasgow coma scale in children with blunt head trauma. *Acad Emerg Med.* 2005;12(9):814-819.	Observational-Dx	2,043 children; 327 were 2 years and younger	To compare the accuracy of a pediatric GCS score in preverbal children with blunt head trauma with the standard GCS score in older children.	Among the 327 children, 15 (7.7%; 95% CI = 4.4% to 12.4%) of 194 who underwent imaging with CT had TBI visible and 9 (2.8%; 95% CI = 1.3% to 5.2%) had TBI needing acute intervention. In children older than 2 years, 83 (7.7%; 95% CI = 6.2% to 9.5%) of the 1,077 who underwent imaging with CT had TBI visible and 96 (5.6%; 95% CI = 4.6% to 6.8%) had TBI needing acute intervention. For the pediatric GCS in children 2 years and younger, the area under the receiver operator characteristic curve was 0.72 (95% CI = 0.56 to 0.87) for TBI on CT scan and 0.97 (95% CI = 0.94 to 1.00) for TBI needing acute intervention. For the standard GCS in older children, the area under the receiver operator characteristic curve was 0.82 (95% CI = 0.76 to 0.87) for TBI on CT scan and 0.87 (95% CI = 0.83 to 0.92) for TBI needing acute intervention.	2

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32. Margulies SS, Thibault KL. Infant skull and suture properties: measurements and implications for mechanisms of pediatric brain injury. *J Biomech Eng.* 2000;122(4):364-371.	Review/Other-Dx	N/A	To determine the age-dependent changes in skull properties, the authors tested human and porcine infant cranial bone in three-point bending.	No results stated in abstract.	4
33. Claret Teruel G, Palomeque Rico A, Cambra Lasaosa FJ, Catala Temprano A, Noguera Julian A, Costa Clara JM. Severe head injury among children: computed tomography evaluation as a prognostic factor. *J Pediatr Surg.* 2007;42(11):1903-1906.	Review/Other-Dx	156 pediatric patients	To determine clinical characteristics and outcome of severely head-injured children admitted to the pediatric intensive care unit of a pediatric third-level university hospital and to evaluate the use of neuroimaging as a prognostic factor of morbimortality in these patients.	Data for 156 pediatric patients, aged 1 to 18 years, were collected. The authors reclassified neuroimaging patterns into 2 groups: those with few imaging findings and those with important lesions. These 2 groups were significantly correlated with initial GCS ($P<.05$). The authors classified patients into favorable evolution, moderate disability, and unfavorable evolution. Poorer evolution correlated with poorer initial neuroimaging patterns, and these differences were statistically significant ($P<.05$).	4
34. Sigmund GA, Tong KA, Nickerson JP, Wall CJ, Oyoyo U, Ashwal S. Multimodality comparison of neuroimaging in pediatric traumatic brain injury. *Pediatr Neurol.* 2007;36(4):217-226.	Observational-Dx	40 children and adolescents	Several imaging methods were assessed in children with TBI: CT, T2-weighted MRI, fluid-attenuated inversion recovery MRI, and SWI MRI to determine which of these methods of detection of pediatric TBI was most accurate at predicting outcome.	T2-weighted, fluid-attenuated inversion recovery, and SWI showed no significant difference in lesion volume between normal and mild outcome groups, but did indicate significant differences between normal and poor and between mild and poor outcome groups. CT revealed no significant differences in lesion volume between any groups. The findings suggest that T2-weighted, fluid-attenuated inversion recovery, and SWI MRI sequences provide a more accurate assessment of injury severity and detection of outcome-influencing lesions than does CT in pediatric TBI patients. Although CT was inconsistent at lesion detection/outcome prediction, it remains an essential part of the acute TBI work-up to assess the need for neurosurgical intervention.	2
35. Ball WS, Jr. Nonaccidental craniocerebral trauma (child abuse): MR imaging. Radiology. 1989;173(3):609-610.	Review/Other-Dx	N/A	To review the role of MRI in physically abused children.	No results stated in abstract.	4
36. Ashwal S, Wycliffe ND, Holshouser BA. Advanced neuroimaging in children with nonaccidental trauma. *Dev Neurosci.* 2010;32(5-6):343-360.	Review/Other-Dx	N/A	To review 4 MRI techniques as they apply to children who present acutely after nonaccidental trauma.	The neuroimaging techniques described in this review have significant potential to assist in the early evaluation of children with nonaccidental trauma.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
37. Duhaime AC, Gennarelli TA, Thibault LE, Bruce DA, Margulies SS, Wiser R. The shaken baby syndrome. A clinical, pathological, and biomechanical study. *J Neurosurg*. 1987;66(3):409-415.	Review/Other-Dx	48 cases	To review cases of infants and young children with shaken baby syndrome seen between 1978 and 1985 at the Children's Hospital of Philadelphia.	Severe head injuries commonly diagnosed as shaking injuries require impact to occur and that shaking alone in an otherwise normal baby is unlikely to cause the shaken baby syndrome.	4
38. Jenny C, Hymel KP, Ritzen A, Reinert SE, Hay TC. Analysis of missed cases of abusive head trauma. *JAMA*. 1999;281(7):621-626.	Review/Other-Dx	173 children	To determine how frequently AHT was previously missed by physicians in a group of abused children with head injuries and to determine factors associated with the unrecognized diagnosis.	54 (31.2%) of 173 abused children with head injuries had been seen by physicians after AHT and the diagnosis was not recognized. The mean time to correct diagnosis among these children was 7 days (range, 0-189 days). AHT was more likely to be unrecognized in very young white children from intact families and in children without respiratory compromise or seizures. In 7 of the children with unrecognized AHT, misinterpretation of radiological studies contributed to the delay in diagnosis. 15 children (27.8%) were reinjured after the missed diagnosis. 22 (40.7%) experienced medical complications related to the missed diagnosis. 4/5 deaths in the group with unrecognized AHT might have been prevented by earlier recognition of abuse.	4
39. Rubin DM, Christian CW, Bilaniuk LT, Zazyczny KA, Durbin DR. Occult head injury in high-risk abused children. *Pediatrics*. 2003;111(6 Pt 1):1382-1386.	Review/Other-Dx	65 patients	Primary aim was to estimate the prevalence of occult head injury in a high-risk sample of abused children with normal neurologic examinations. The secondary aim was to describe characteristics of this population.	Of the 65 patients, 51 (78.5%) had a head CT or MRI in addition to skeletal survey. Of these 51 patients, 19 (37.3%, 95% CI, 24.2%-50.4%) had an occult head injury. Injuries included scalp swelling (74%), skull fracture (74%), and ICI (53%). All except 3 of the head-injured patients had at least a skull fracture or ICI. Skeletal survey alone missed 26% (5/19) of the cases. Head-injured children were younger than non-head-injured children (median age 2.5 vs 5.1 months); all but 1 head-injured child was <1 year of age. Among the head-injured children, 72% came from single parent households, 37% had mothers whose age was <21 years, and 26% had a history of prior child welfare involvement in their families. Ophthalmologic examination was performed in 14/19 cases; no retinal hemorrhages were noted.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
40. Laskey AL, Holsti M, Runyan DK, Socolar RR. Occult head trauma in young suspected victims of physical abuse. *J Pediatr*. 2004;144(6):719-722.	Review/Other-Dx	51 patients	To determine the frequency of neuroimaging and ophthalmology consults in children evaluated for physical abuse without neurologic symptoms and the diagnostic yield of these studies.	51 patients had a skeletal survey and no clinical signs of ICI. 75% of patients had CT or MRI; 69% had formal evaluation for retinal hemorrhages. 29% had evidence of ICI without neurologic symptoms. Age less than 12 months was the only factor significantly associated with neuroimaging (90% vs 55%, P=.004). Sex, race, insurance, and having an unrelated male caretaker were not significantly associated with performance of neuroimaging or findings of ICI.	4
41. Mogbo KI, Slovis TL, Canady AI, Allasio DJ, Arfken CL. Appropriate imaging in children with skull fractures and suspicion of abuse. *Radiology*. 1998;208(2):521-524.	Observational-Dx	87 children	To define the role of CT in children aged 2 years and younger with head trauma, suspected abuse, and normal neurologic findings.	Of 67 children with normal neurologic findings, 35 (52%) were not referred for CT. No patient in this group developed delayed findings requiring further evaluation. Of the 32 (48%) who underwent head CT, only 6 (19%) had evidence of acute ICI, despite the presence of minimal depression and stellate, multiple, and diastatic fractures. Of 20 children with acute neurologic findings, 16 (80%) had positive CT scans, which led to neurosurgical intervention in 9 (45%).	3

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
42. Brown RL, Brunn MA, Garcia VF. Cervical spine injuries in children: a review of 103 patients treated consecutively at a level 1 pediatric trauma center. *J Pediatr Surg.* 2001;36(8):1107-1114.	Review/Other-Dx	103 injuries	To retrospectively analyze consecutive C-spine injuries treated at a level 1 pediatric trauma center over a 9(1/2)-year period (January 1991 through August 2000).	The most common mechanism of injury was motor vehicle related (52%), followed by sporting injuries (27%). Football injuries accounted for 29% of all sports-related injuries. 68% of all children sustained injuries to C1 to C4; 25% to C5 to C7; and 7% to both. Spinal cord injury without radiographic abnormality occurred in 38%. 5 patients had complete cord lesions involving the lower C-spine (C4 to C7); 4 of these were motor vehicle related, and all 4 patients died. Isolated C-spine injuries occurred in 43%, whereas 38% had associated closed head injuries. The overall mortality rate was 18.5%, most commonly motor vehicle related (95%), occurring in younger children (mean and median age 5 years) and associated with upper C-spine injuries (74%) and closed head injuries (89%). C1 dislocations occurred in younger children (mean age, 6.6 years), most often as a result of motor vehicle-related trauma (especially pedestrians) and were associated with the highest injury severity score, longest length of stay, most closed head injuries, and the highest mortality rate (50%). C-spine fractures with or without spinal cord injuries occurred most commonly as a result of falls and dives. Sporting injuries occurred almost exclusively in adolescent boys (mean age, 13.8 years) and were isolated injuries associated with a relatively low injury severity score and shorter length of stay. Interestingly, 75% of sporting injuries showed spinal cord injury without radiographic abnormality, and all infants suffering from child abuse had spinal cord injury without radiographic abnormality.	4
43. Ghatan S, Ellenbogen RG. Pediatric spine and spinal cord injury after inflicted trauma. *Neurosurg Clin N Am.* 2002;13(2):227-233.	Review/Other-Dx	N/A	To review pediatric spine and spinal cord injury after inflicted trauma.	No results stated in abstract.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
44. Davis PC, Wippold FL II, Cornelius RS, et al. American College of Radiology. ACR Appropriateness Criteria® head trauma. Available at: http://www.acr.org/~/media/ACR/Documents/AppCriteria/Diagnostic/HeadTrauma.pdf. 2012. Accessed July 29, 2013.	Review/Other-Dx	N/A	ACR Appropriateness Criteria guideline on head trauma.	N/A	4
45. Keiper MD, Zimmerman RA, Bilaniuk LT. MRI in the assessment of the supportive soft tissues of the cervical spine in acute trauma in children. *Neuroradiology*. 1998;40(6):359-363.	Review/Other-Dx	52 children	To retrospectively analyze imaging and clinical findings in children with a history of cervical spinal trauma.	MRI was positive in 16 (31%) of 52 patients. Posterior soft-tissue or ligamentous injury was the most common finding in the 10 patients with mild to moderate trauma, while acute disc bulges and longitudinal ligament disruption, each seen in one case, were uncommon. MRI was superior to CT for assessment of the extent of soft-tissue injury and for identification of spinal cord injuries and intracanalicular hemorrhage in the 6 patients with more severe trauma. MRI specifically influenced the management of all four patients requiring surgery by extending the level of posterior stabilization.	4
46. Kadom N, Khademian Z, Vezina G, Shalaby-Rana E, Rice A, Hinds T. Usefulness of MRI detection of cervical spine and brain injuries in the evaluation of abusive head trauma. *Pediatr Radiol.* 2014:[E-pub ahead of print].	Review/Other-Dx	74 children	To determine both the incidence and the spectrum of cervical spine and brain injuries in children being evaluated for possible AHT. Article also examined the relationship between cervical and brain MRI findings and selected study outcome categories.	Study outcomes were categorized as: n = 26 children with accidental head trauma, n = 38 with AHT (n = 18 presumptive AHT, n = 20 suspicious for AHT), and n = 10 with undefined head trauma. The authors found cervical spine injuries in 27/74 (36%) children. Most cervical spine injuries were ligamentous injuries. One child had intrathecal spinal blood and 2 had spinal cord edema; all 3 of these children had ligamentous injury. MRI signs of cervical injury did not show a statistically significant relationship with a study outcome of AHT or help discriminate between accidental and AHT. Of the 30 children with supratentorial brain injury, 16 (53%) had a bilateral hypoxic-ischemic pattern. There was a statistically significant relationship between bilateral hypoxic-ischemic brain injury pattern and AHT ($P<0.05$). In addition, the majority (81%) of children with bilateral hypoxic-ischemic brain injuries had cervical injuries.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
47. Hobbs CJ. Skull fracture and the diagnosis of abuse. *Arch Dis Child.* 1984;59(3):246-252.	Review/Other-Dx	89 children	To provide guidelines for the recognition of abuse in skull fracture from an analysis of 89 children, 29 of whom were abused.	Fracture characteristics found considerably more often in abused children were: multiple or complex configuration; depressed, wide, and growing fracture; involvement of more than a single cranial bone; non-parietal fracture; and associated ICI including subdural hematoma. No fractures measuring more than 5.0 mm on presentation were found after accidents, but 6 of these 'growing fractures' were found in abused children. Accidents usually resulted in single, narrow, linear fractures most commonly of the parietal, with no associated ICI.	4
48. Prabhu SP, Newton AW, Perez-Rossello JM, Kleinman PK. Three-dimensional skull models as a problem-solving tool in suspected child abuse. *Pediatr Radiol.* 2013;43(5):575-581.	Review/Other-Dx	73 children	To assess the value of 3-D skull models as a problem-solving tool in children younger than 2 years.	Of the 73 children, volume-rendered 3-D models were obtained in 26 (35.6%). 3-D models changed initial CT interpretation in 9 instances (34.6%). Findings thought to be fractures were confirmed as normal variants in 4 children. Depressed fractures were correctly shown to be ping-pong fractures in 2 cases. In 1 case, an uncertain finding was confirmed as a fracture, and an additional contralateral fracture was identified in 1 child. A fracture seen on skull radiographs but not seen on axial CT images was identified on the 3-D model in 1 case. Changes in interpretation led to modification in management in 5 children.	4
49. Chen CY, Chou TY, Zimmerman RA, Lee CC, Chen FH, Faro SH. Pericerebral fluid collection: differentiation of enlarged subarachnoid spaces from subdural collections with color Doppler US. *Radiology.* 1996;201(2):389-392.	Review/Other-Dx	18 infants	To determine if the cerebral cortical vain sign seen on MRIs can be used with color Doppler US to differentiate enlarged subarachnoid space from subdural collection.	Positive cortical vein sign was seen at US in 12 patients (group A): 9 with benign enlargement of subarachnoid spaces, 2 with brain atrophy, and 1 with meningococcal meningitis. The veins were displaced and embedded within the echogenic pia-arachnoid that surrounds the brain or were trapped in the subarachnoid spaces between the neo-membrane and cortical surface (group B, negative cortical vein sign) in 4 patients with meningitis, 2 victims of child abuse, and 1 patient with leukemia. Findings from subsequent MRI confirmed the color Doppler US findings.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
50. Amodio J, Spektor V, Pramanik B, Rivera R, Pinkney L, Fefferman N. Spontaneous development of bilateral subdural hematomas in an infant with benign infantile hydrocephalus: color Doppler assessment of vessels traversing extra-axial spaces. *Pediatr Radiol.* 2005;35(11):1113-1117.	Review/Other-Dx	1 infant	An infant with macrocrania, who initially demonstrated prominent extra-axial fluid collections on sonography of the brain, compatible with benign infantile hydrocephalus is evaluated.	No result stated in abstract.	4
51. Jaspan T, Narborough G, Punt JA, Lowe J. Cerebral contusional tears as a marker of child abuse--detection by cranial sonography. *Pediatr Radiol.* 1992;22(4):237-245.	Review/Other-Dx	6 infants	Series of infants subjected to child abuse is presented in whom contusional tears of subcortical white matter were detected during life by intracranial sonography. The sonographic appearances of this highly pathognomonic marker of shaking injury are described for the first time and their significance discussed.	The authors suggest that high resolution cranial sonography is an extremely valuable part of the diagnostic workup in cases of suspected nonaccidental injury.	4
52. Kemp AM, Jaspan T, Griffiths J, et al. Neuroimaging: what neuroradiological features distinguish abusive from non-abusive head trauma? A systematic review. *Arch Dis Child.* 2011;96(12):1103-1112.	Review/Other-Dx	18 studies	To investigate the optimal neuroradiological investigation strategy to identify inflicted brain injury.	Of the 320 studies reviewed, 18 met the inclusion criteria, reflecting data on 367 children with inflicted brain injury and 12 were published since 1998. When an MRI was conducted in addition to an abnormal early CT examination, additional information was found in 25% (95% CI, 18.3%-33.16%) of children. The additional findings included further subdural hematoma, subarachnoid hemorrhage, shearing injury, ischemia, and infarction; it also contributed to dating of injuries. DWI further enhanced the delineation of ischemic changes, and assisted in prognosis. Repeat CT studies varied in timing and quality, and none were compared to the addition of an early MRI/DWI.	4
53. Pinto PS, Meoded A, Poretti A, Tekes A, Huisman TA. The unique features of traumatic brain injury in children. review of the characteristics of the pediatric skull and brain, mechanisms of trauma, patterns of injury, complications, and their imaging findings--part 2. *J Neuroimaging.* 2012;22(2):e18-41.	Review/Other-Dx	N/A	To comprehensively review frequent primary and secondary brain injuries and to give a short overview of two special types of pediatric TBI: birth related and nonaccidental injuries.	High-end CT and/or MRI should be performed to guide and monitor treatment. In addition, anatomical and functional imaging data may better predict functional outcome.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
54. Hamilton M, Mrazik M, Johnson DW. Incidence of delayed intracranial hemorrhage in children after uncomplicated minor head injuries. *Pediatrics*. 2010;126(1):e33-39.	Review/Other-Dx	17,962 children	To determine the incidence of delayed diagnosis of intracranial hemorrhage in the general population and the proportion of children who presented to emergency departments with uncomplicated minor head injuries who received delayed diagnoses of intracranial hemorrhage.	17,962 children (95% CI, 17,412-18,511 children) with uncomplicated minor head injuries were evaluated at Calgary Health Region emergency departments. Two and 8 children were identified as having delayed diagnoses of intracranial hemorrhage with and without delayed deterioration in level of consciousness (GCS of <15), respectively. The proportions of children with uncomplicated minor head injuries with delayed diagnoses of intracranial hemorrhage with and without deterioration in level of consciousness were approximately 0.00% (0 of 17,962 children [upper limit of 95% CI, 0.02%]) and 0.03% (5 of 17,962 children [95% CI, 0.01%-0.07%]), respectively. On the basis of population data for the Calgary Health Region, the incidences of delayed diagnosis of intracranial hemorrhage with and without deterioration in level of consciousness were 0.14 and 0.57 cases per 100,000 children per year, respectively.	4
55. Hollingworth W, Vavilala MS, Jarvik JG, et al. The use of repeated head computed tomography in pediatric blunt head trauma: factors predicting new and worsening brain injury. *Pediatr Crit Care Med*. 2007;8(4):348-356; CEU quiz 357.	Review/Other-Dx	257 patients	To describe the prevalence of worsening brain injury on repeat CT, predictors of worsening CT findings, and the frequency of neurosurgical intervention after the repeat CT.	20% (50/257) of patients with mild head injury had worsening CT findings, and 3 patients (1%) had subsequent neurosurgical intervention. Patients with moderate and severe head injuries were more likely to have worsening CT findings (107/248; 43%) and to have neurosurgical intervention (15/248; 6%). In most surgical patients, repeat CT was preceded by rapid decline in neurologic status or elevated intracranial pressure. Stratification based on 4 clinical factors (initial head injury severity, any intraparenchymal finding on initial CT, normal findings on initial CT, coagulopathy) identified 100% of the surgical patients and 89% of patients with worsening brain injuries on the repeat CT.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
56. Stence NV, Fenton LZ, Goldenberg NA, Armstrong-Wells J, Bernard TJ. Craniocervical arterial dissection in children: diagnosis and treatment. *Curr Treat Options Neurol.* 2011;13(6):636-648.	Review/Other-Dx	N/A	Review diagnosis and treatment of craniocervical arterial dissection in children.	No results stated in abstract.	4
57. Sepelyak K, Gailloud P, Jordan LC. Athletics, minor trauma, and pediatric arterial ischemic stroke. *Eur J Pediatr.* 2010;169(5):557-562.	Review/Other-Dx	3 cases	To describe three cases of sports-related stroke in previously healthy school-age children and discuss acute and long-term stroke care.	These three cases are representative of sports-related arterial ischemic stroke, which is often associated with arterial dissection after neck trauma. Stroke mechanism is not always clear. When arterial dissection is strongly suspected based on clinical history, thorough vascular imaging with multiple modalities may be required to definitively exclude dissection. Screening for hypercoaguable state is also mandatory.	4
58. Jones TS, Burlew CC, Kornblith LZ, et al. Blunt cerebrovascular injuries in the child. *Am J Surg.* 2012;204(1):7-10.	Review/Other-Dx	45 patients	To describe the incidence, injury patterns, and stroke rates of pediatric patients sustaining blunt cerebrovascular injuries.	45 patients sustained blunt cerebrovascular injuries (60% male; mean age, 13 +/- .7 years; mean Injury Severity Score, 23 +/- 2). Three patients exsanguinated, and 10 presented with stroke; neurologic changes occurred 17 +/- 6 hours after injury (range, 1-72 hours). Screening indications were present in 30%. 32 asymptomatic patients were diagnosed. All but 1 received antithrombotic agents; 1 patient had neurologic deterioration despite heparinization. Comparing asymptomatic patients with those with stroke, there was a significant difference in age (15 vs 11 years).	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
59. Kopelman TR, Berardoni NE, O'Neill PJ, et al. Risk factors for blunt cerebrovascular injury in children: do they mimic those seen in adults? *J Trauma.* 2011;71(3):559-564; discussion 564.	Review/Other-Dx	128 patients	To determine whether adult criteria translate to the pediatric population. Eastern Association for the Surgery of Trauma guideline for the evaluation of blunt cerebrovascular injury states that pediatric trauma patients should be evaluated using the same criteria as the adult population.	1,209 pediatric trauma patients were admitted during the study period. While 128 patients met criteria on retrospective review for evaluation based on Eastern Association for the Surgery of Trauma criteria, only 52 patients (42%) received subsequent radiographic evaluation. In all, 14 carotid artery or vertebral artery injuries were identified in 11 patients (all admissions, 0.9% incidence; all screened, 21% incidence). Adult risk factors were present in 91% of patients diagnosed with an injury. Major thoracic injury was found in 67% of patients with carotid artery injuries. Cervical spine fracture was found in 100% of patients with vertebral artery injuries. Stroke occurred in 4 patients (36%). Stroke rate after admission for untreated patients was 38% (3/8) vs 0.0% in those treated (0/2). Mortality was 27% because of concomitant severe TBI.	4
60. Mortazavi MM, Verma K, Tubbs RS, Harrigan M. Pediatric traumatic carotid, vertebral and cerebral artery dissections: a review. *Childs Nerv Syst.* 2011;27(12):2045-2056.	Review/Other-Dx	26 case studies from 70 pediatric patients	Review article that highlight the fact that there is no level 1 evidence for the natural history of cerebral dissections or for the best treatment.	No results stated in abstract.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
61. Aoki Y, Inokuchi R, Gunshin M, Yahagi N, Suwa H. Diffusion tensor imaging studies of mild traumatic brain injury: a meta-analysis. *J Neurol Neurosurg Psychiatry*. 2012;83(9):870-876.	Review/Other-Dx	28 studies	To assess the possibility that diffusion tensor imaging can detect white matter damage in mild TBI patients via systematic review and meta-analysis.	A comprehensive literature search identified 28 diffusion tensor imaging studies, of which 13 independent diffusion tensor imaging studies of mild TBI patients were eligible for the meta-analysis. Random effect model demonstrated significant fractional anisotropy reduction in the corpus callosum (P=0.023, 95% CIs, -0.466 to -0.035, 280 mild TBIs and 244 controls) with no publication bias and minimum heterogeneity, and a significant increase in mean diffusivity (P=0.015, 95% CIs, 0.062 to 0.581, 154 mild TBIs and 100 controls). Meta-analyses of the subregions of the corpus callosum demonstrated in the splenium fractional anisotropy was significantly reduced (P=0.025, 95% CIs, -0.689 to -0.046) and mean diffusivity was significantly increased (P=0.013, 95% CIs, 0.113 to 0.950). Fractional anisotropy was marginally reduced in the midbody (P=0.099, 95% CIs, -0.404 to 0.034), and no significant change in fractional anisotropy (P=0.421, 95% CIs, -0.537 to 0.224) and mean diffusivity (P=0.264, 95% CIs, -0.120 to 0.438) in the genu of the corpus callosum.	4
62. Munson S, Schroth E, Ernst M. The role of functional neuroimaging in pediatric brain injury. *Pediatrics*. 2006;117(4):1372-1381.	Review/Other-Dx	N/A	To review empirical studies published in the last 10 years that used various functional neuroimaging techniques to assess pediatric patients with brain injury.	Overall, these studies have demonstrated the ability of functional neuroimaging to offer unique information concerning the diagnosis, clinical outcome, and recovery mechanisms after pediatric brain injury. Future research using functional neuroimaging is recommended to better understand the functional reorganization and neurodevelopmental consequences resulting from brain injury.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
63. Wilde EA, McCauley SR, Hunter JV, et al. Diffusion tensor imaging of acute mild traumatic brain injury in adolescents. *Neurology*. 2008;70(12):948-955.	Observational-Dx	10 adolescents with mild TBI and 10 controls	To determine if fractional anisotropy, apparent diffusion coefficient , and radial diffusivity were altered in the corpus callosum in the acute phase of mild TBI in adolescents with GCS scores of 15 and negative CT findings.	The mild TBI group demonstrated increased fractional anisotropy and decreased apparent diffusion coefficient and radial diffusivity, and more intense postconcussion symptoms and emotional distress compared to the control group. Increased fractional anisotropy and decreased radial diffusivity were correlated with severity of postconcussion symptoms in the mild TBI group, but not in the control group.	3
64. Worley G, Hoffman JM, Paine SS, et al. 18-Fluorodeoxyglucose positron emission tomography in children and adolescents with traumatic brain injury. *Dev Med Child Neurol*. 1995;37(3):213-220.	Observational-Dx	22 children and adolescents	Objectives of this study are: 1) to compare PET with assessments of clinical condition for prediction of outcome, (2) to compare PET and contemporaneous CT/MRI for prediction of outcome, (3) to compare PET done during rehabilitation with PET done after recovery, and (4) to determine in what specific circumstances PET may be useful in assessing children who have had TBI.	The PET score (obtained by adding the score of 15 brain regions: normal metabolism = 1; reduced = 0) was significantly associated with the clinical outcome measure. PET earlier than 12 weeks after head trauma correlated with outcome, but later PET did not. PET scores improved significantly between rehabilitation and outcome for the 11 subjects who had two PETs, but improvement was not associated with improvement in clinical condition. PET score did not add to the amount of variance explained in the last regression model for prediction of outcome when the results of contemporaneous CT/MRI and clinical condition were taken into account. The data suggest that routine PET during rehabilitation is no more useful than contemporaneous CT or MRI for prediction of outcome.	3

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
65. Goshen E, Zwas ST, Shahar E, Tadmor R. The role of 99Tcm-HMPAO brain SPET in paediatric traumatic brain injury. *Nucl Med Commun.* 1996;17(5):418-422.	Observational-Dx	28 patients	To correlate the results of single photon emission tomography studies with clinical status in children presenting with chronic sequella of TBI.	Neuro-single photon emission tomography with Tc-99m-HMPAO is more sensitive than morphological or electrophysiological tests in detecting functional lesions. In our group, 15/32 CT scans were normal, compared with 3/35 single photon emission tomography studies. Single photon emission tomography identified approximately 2.5 times more lesions than CT (86 vs 34). Single photon emission tomography was found to be particularly sensitive in detecting organic abnormalities in the basal ganglia and cerebellar regions, with a 3.6:1 detection rate in the basal ganglia and a 5:1 detection rate in the cerebellum compared with CT.	3
66. Ewing-Cobbs L, Prasad MR, Swank P, et al. Arrested development and disrupted callosal microstructure following pediatric traumatic brain injury: relation to neurobehavioral outcomes. *Neuroimage.* 2008;42(4):1305-1315.	Review/Other-Dx	41 children	To examine the impact of TBI on multiple diffusion tensor imaging metrics from well-defined corpus callosum regions and to characterize their relation to age and neuropsychological outcomes.	TBI was associated with significant reduction in fractional anisotropy and increased radial diffusivity in the posterior third of the corpus callosum and in the genu. The axial diffusivity did not differ by either age or group. Logistic regression analyses revealed that fractional anisotropy and radial diffusivity were equally sensitive to post-traumatic changes in 4 of 6 callosal regions; radial diffusivity was more sensitive for the rostral midbody and splenium. IQ, working memory, motor, and academic skills were correlated significantly with radial diffusion and/or fractional anisotropy from the isthmus and splenium only in the TBI group. Reduced size and microstructural changes in posterior callosal regions after TBI suggest arrested development, decreased organization, and disrupted myelination. Increased radial diffusivity was the most sensitive diffusion tensor imaging-based surrogate marker of the extent of neuronal damage following TBI; fractional anisotropy was most strongly correlated with neuropsychological outcomes.	4

Head Trauma–Child
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
67. Ashwal S, Babikian T, Gardner-Nichols J, Freier MC, Tong KA, Holshouser BA. Susceptibility-weighted imaging and proton magnetic resonance spectroscopy in assessment of outcome after pediatric traumatic brain injury. *Arch Phys Med Rehabil.* 2006;87(12 Suppl 2):S50-58.	Review/Other-Dx	N/A	To assess the role of MRI, specifically MR spectroscopy and SWI, in the evaluation of children with TBI.	The data suggest that more sensitive imaging techniques that provide early evidence of injury and that are better predictors of outcome are needed to identify children at risk for such deficits. Specifically, the number and volume of hemorrhagic DAI lesions as well as changes in spectral metabolites such as reduced N-acetylaspartate or elevations in choline-related compounds correlate with neurologic disability and impairments of global intelligence, memory, and attention.	4
68. Walz NC, Cecil KM, Wade SL, Michaud LJ. Late proton magnetic resonance spectroscopy following traumatic brain injury during early childhood: relationship with neurobehavioral outcomes. *J Neurotrauma.* 2008;25(2):94-103.	Review/Other-Dx	10 children and 10 controls	To extend previous research that demonstrates reduced neurometabolite concentrations during the chronic phase of pediatric TBI in children injured during early childhood. The authors hypothesized that young children with TBI in the chronic phase post-injury would have lower N-acetyl aspartate metabolite concentrations in gray and white matter in comparison to controls. The authors also hypothesized that metabolite levels would be correlated with acute TBI severity and neurobehavioral skills.	There was a trend for lower N-acetyl aspartate concentrations in the medial frontal gray matter for the TBI group. Late N-acetyl aspartate and Cr levels in the medial frontal gray matter and N-acetyl aspartate levels in the left frontal white matter were strongly positively correlated with initial GCS. Metabolite levels were correlated with some neurobehavioral measures differentially for children with TBI or orthopedic injury. Some neurometabolite levels differed between the TBI and orthopedic injury groups more than 1 year post-injury and were related to injury severity, as well as some neurobehavioral outcomes following TBI during early childhood.	4

Evidence Table Key

Study Quality Category Definitions

- *Category 1* The study is well-designed and accounts for common biases.
- *Category 2* The study is moderately well-designed and accounts for most common biases.
- *Category 3* There are important study design limitations.
- *Category 4* The study is not useful as primary evidence. The article may not be a clinical study or the study design is invalid, or conclusions are based on expert consensus. For example:
  a) the study does not meet the criteria for or is not a hypothesis-based clinical study (e.g., a book chapter or case report or case series description);
  b) the study may synthesize and draw conclusions about several studies such as a literature review article or book chapter but is not primary evidence;
  c) the study is an expert opinion or consensus document.

Dx = Diagnostic

Tx = Treatment

Abbreviations Key

AHT = Abusive head trauma

CI = Confidence interval

CT = Computed tomography

DAI = Diffuse axonal injury

DWI = Diffusion-weighted imaging

GCS = Glasgow Coma Scale

GOSE = Glasgow Outcome Scale

ICI = Intracranial injury

MRI = Magnetic resonance imaging

PET = Positron emission tomography

SWI = Susceptibility-weighted imaging

TBI = Traumatic brain injury

US = Ultrasound