Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. Wintermark M, Sanelli PC, Anzai Y, Tsiouris AJ, Whitlow CT. Imaging evidence and recommendations for traumatic brain injury: conventional neuroimaging techniques. *J Am Coll Radiol.* 2015;12(2):e1-e14.	Review/Other-Dx	N/A	To suggest practical imaging recommendations for patients presenting with TBI across different practice settings and to simultaneously provide the rationale and background evidence supporting their use.	These recommendations should ultimately assist referring physicians faced with the task of ordering appropriate imaging tests in particular patients with TBI for whom they are providing care. These recommendations should also help radiologists advise their clinical colleagues on appropriate imaging utilization for patients with TBI.	4
2. Wintermark M, Sanelli PC, Anzai Y, Tsiouris AJ, Whitlow CT. Imaging evidence and recommendations for traumatic brain injury: advanced neuro- and neurovascular imaging techniques. *AJNR Am J Neuroradiol.* 2015;36(2):E1-E11.	Review/Other-Dx	N/A	To review advanced neuroimaging techniques in the evaluation of patients with TBI.	Advanced neuroimaging techniques, including MRI diffusion-tensor imaging, blood oxygen level–dependent fMRI, MRS, perfusion imaging, PET/SPECT, and magnetoencephalography, are of particular interest in identifying further injury in patients with TBI when conventional non-contrast CT and MRI findings are normal, as well as for prognostication in patients with persistent symptoms. These advanced neuroimaging techniques are currently under investigation in an attempt to optimize them and substantiate their clinical relevance in individual patients. However, the data currently available confine their use to the research arena for group comparisons, and there remains insufficient evidence at the time of this writing to conclude that these advanced techniques can be used for routine clinical use at the individual patient level.	4
3. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. *Lancet.* 1974;2(7872):81-84.	Review/Other-Dx	N/A	Clinical scale for evaluation of impaired consciousness and coma is reviewed.	The scale facilitates consultations between general and special units in cases of recent brain damage, and is useful also in defining the duration of prolonged coma.	4
4. American College of Radiology. ACR Appropriateness Criteria®: Head Trauma - Child. Available at: https://acsearch.acr.org/docs/3083021/Narrative/. Accessed September 20, 2015.	Review/Other-Dx	N/A	Evidence-based guidelines to assist referring physicians and other providers in making the most appropriate imaging or treatment decision for a specific clinical condition.	N/A	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
5. Wei SC, Ulmer S, Lev MH, Pomerantz SR, Gonzalez RG, Henson JW. Value of coronal reformations in the CT evaluation of acute head trauma. *AJNR Am J Neuroradiol*. 2010;31(2):334-339.	Observational-Dx	213 patients	Prospective study to evaluate whether coronal reformations improve detection of ICH in noncontrast cranial CT performed for head trauma.	Of 213 patients, 32 noncontrast cranial CT demonstrated ICH (a total of 104 foci). 15/104 (14%) ICHs (8 patients) were detected solely on coronal images. Locations included the floor of the anterior and middle cranial fossas, vertex, corpus callosum, falx, tentorium, and occipital convexity. Coronal reformations allowed exclusion of suspicious findings on axial images in 14 instances (7 patients). Coronal images aided interpretation in 29/104 (28%) findings. Coronal reformations improve the detection of ICH over axial images alone, especially for lesions that lie in the axial plane immediately adjacent to bony surfaces. The use of coronal reformations should be considered in the routine interpretation of head CT examinations performed for the evaluation of head trauma.	3
6. Zacharia TT, Nguyen DT. Subtle pathology detection with multidetector row coronal and sagittal CT reformations in acute head trauma. *Emerg Radiol.* 2010;17(2):97-102.	Observational-Dx	200 patients	To retrospectively analyze the advantages of coronal and sagittal reformations obtained with MDCT in patients with acute head trauma. Images analyzed by two independent, blinded readers.	CT imaging abnormalities were detected in 55/200 patients who were scanned for head trauma. Acute traumatic intracranial abnormality was detected on axial scans in 45 patients. Subtle findings were confirmed on coronal and sagittal CT reformations in 10 cases, and these were undetected initially on axial CT. Coronal and sagittal reformations confirmed subtle findings in 18.2% (10/55) of the cases (P=0.001). Indeterminate neuroimaging findings confirmed by coronal and sagittal CT head reformations include tentorial and interhemispheric fissure subdural hemorrhage, subarachnoid hemorrhage, and inferior frontal and temporal lobe contusions. Overall, coronal and sagittal reformations improved diagnostic confidence and interobserver agreement over axial images alone for visualization of normal structures and in the diagnosis of acute abnormality.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
7. 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 a more recent development, 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
8. Arfanakis K, Haughton VM, Carew JD, Rogers BP, Dempsey RJ, Meyerand ME. Diffusion tensor MR imaging in diffuse axonal injury. *AJNR Am J Neuroradiol.* 2002;23(5):794-802.	Observational-Dx	5 patients; 10 controls	To determine the role of diffusion tensor imaging in depiction of DAI. White matter regions that appeared normal on CT and other MRI were studied, including apparent diffusion coefficient maps.	Patients displayed significant reduction of diffusion anisotropy in several regions compared with the homologous ones in the contralateral hemisphere. Such differences were not observed in the control subjects. Significant reduction of diffusion anisotropy was also detected when diffusion tensor results from the patients were compared with those of the controls. This reduction was often less evident 1 month after injury. White matter regions with reduced anisotropy are detected in the first 24 hours after TBI. Therefore, diffusion tensor imaging may be a powerful technique for in vivo detection of DAI.	3
9. Ashikaga R, Araki Y, Ishida O. MRI of head injury using FLAIR. *Neuroradiology.* 1997;39(4):239-242.	Observational-Dx	56 patients	To examine the utility of fluid-attenuated inversion-recovery MRI in the investigation of head injury.	In all cases, the sensitivity of fluid-attenuated inversion-recovery images to equal or superior to that of conventional spin-echo images to the traumatic lesions. In 9 cases, central DAI of the fornix and corpus callosum could be seen only on sagittal fluid-attenuated inversion-recovery images.	2
10. Gentry LR, Godersky JC, Thompson B. MR imaging of head trauma: review of the distribution and radiopathologic features of traumatic lesions. *AJR Am J Roentgenol.* 1988;150(3):663-672.	Observational-Dx	40 patients	To determine the ability of MRI to prospectively identify and characterize the traumatic intraaxial lesions found in patients with closed head trauma by using a simple anatomic and topographic method of classification. MRI and CT were compared.	Primary intraaxial lesions were classified according to their distinctive topographical distribution within the brain and were of four main types: 1) DAI (48.2%), 2) cortical contusion (43.7%), 3) subcortical gray-matter injury (4.5%), and 4) primary brainstem injury (3.6%). MRI was found to be superior to CT and to be very effective in the detection of traumatic head lesions and some secondary forms of injury. While T2-weighted images were most useful for lesion detection, T1-weighted images proved to be most useful for anatomic localization and classification.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
11. Gentry LR, Thompson B, Godersky JC. Trauma to the corpus callosum: MR features. *AJNR Am J Neuroradiol.* 1988;9(6):1129-1138.	Observational-Dx	78 total patients	Prospective study where MRI is compared with CT for detection of corpus callosum lesions after trauma in patients with acute (n = 63) and chronic (n = 15) head injuries.	MRI was significantly (*P*<.001) more sensitive than CT in the detection of callosal injuries. MRI and CT visualized 100% and 27%, respectively, of the traumatic callosal lesions that were detected in the study population.	3
12. Mittl RL, Grossman RI, Hiehle JF, et al. Prevalence of MR evidence of diffuse axonal injury in patients with mild head injury and normal head CT findings. *AJNR Am J Neuroradiol.* 1994;15(8):1583-1589.	Observational-Dx	20 consecutive patients; 2 blinded readers	Prospective study to assess the prevalence of MRI evidence for DAI at 1.5 T in patients with normal head CT findings after mild head injury.	The readers agreed that abnormalities compatible with DAI were present in the white matter of 6 (30%) of 20 patients (95% CI, 12% to 54%). Both readers agreed that foci of high signal intensity were present on the T2-weighted spin-echo sequence in 3 (15%) of the 20 cases (95% CI, 3% to 38%) and that foci of hypointensity compatible with hemorrhagic shear injury were present on the T2-weighted sequence in 4 (20%) of the 20 patients (95% CI, 6% to 44%). Both types of abnormality were noted by the readers in one patient. MRI shows evidence of DAI in some patients with normal head CT findings after mild head injury. These lesions may represent the pathologic substrate underlying the postconcussion syndrome that occurs in many patients with moderate to severe head injury.	1
13. Haacke EM, Mittal S, Wu Z, Neelavalli J, Cheng YC. Susceptibility-weighted imaging: technical aspects and clinical applications, part 1. *AJNR Am J Neuroradiol.* 2009;30(1):19-30.	Review/Other-Dx	N/A	To present the technical background for SWI and discuss the concept of gradient-echo images and how local changes in susceptibility can be measured.	No results stated in abstract.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
14. Wang X, Wei XE, Li MH, et al. Microbleeds on susceptibility-weighted MRI in depressive and non-depressive patients after mild traumatic brain injury. *Neurol Sci.* 2014;35(10):1533-1539.	Review/Other-Dx	200 patients	To explore the relationship between abnormality on SWI and newly-developed depression after mTBI.	The difference in microbleed lesions on SWI was compared between the depressive and nondepressive groups. The depressive group had a higher rate of abnormality on SWI than did the non-depressive group (P<0.001). Among patients that had exhibited microbleed lesions, the number and volume of lesions were greater in the depressive group than the nondepressive group (both P<0.001). These differences in numbers and volume of lesions were found only at the frontal, parietal and temporal lobes (all P<0.001). Among patients that had exhibited microbleed lesions, the number and volume of lesions in other areas were not significantly different between the depressive and nondepressive groups (all P>0.05).	4
15. Fiser SM, Johnson SB, Fortune JB. Resource utilization in traumatic brain injury: the role of magnetic resonance imaging. *Am Surg.* 1998;64(11):1088-1093.	Observational-Dx	40 patients had 79 CT scans and 40 MRIs	Retrospective review to determine whether MRI influenced the acute diagnosis and management of TBI patients.	9 patients (22.5%) had injuries on CT scan but not on MRI; most commonly skull fractures or small subarachnoid hemorrhages. 24 patients (60%) had injuries on MRI but not on CT scan, most commonly corpus callosum shear injuries. There were 2 cases of child abuse and both had injuries of varying ages identified by MRI, but not CT. All injuries requiring a therapeutic intervention or change in management were identified by CT scan. MRI identified one patient with a traumatic ICA thrombosis. The performance of MRI resulted in additional charges of $75,640 or $3,152/patient identified with a new lesion. Although MRI identifies lesions not evident on CT scan, MRI does not alter management plans and is of limited value in the acute management of TBI. MRI may be of medicolegal benefit in cases of child abuse.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
16. Lang DA, Hadley DM, Teasdale GM, Macpherson P, Teasdale E. Gadolinium DTPA enhanced magnetic resonance imaging in acute head injury. *Acta Neurochir (Wien)*. 1991;109(1-2):5-11.	Review/Other-Dx	10 patients	To examine the effect of contrast enhancement on MRI in patients with a recent head injury.	Use of contrast did not increase the number of traumatic lesions identified and authors did not detect evidence of altered blood brain barrier permeability in any of the 7 patients, who had a total of 27 lesions, imaged between one and 4 days after injury. Enhancement was found in each of 3 patients imaged 6 or more days after injury. Findings suggest that traumatic cortical and intraparenchymal lesions are not associated with increased cerebrovascular permeability within the first 96 hours of a head injury.	4
17. Masters SJ, McClean PM, Arcarese JS, et al. Skull x-ray examinations after head trauma. Recommendations by a multidisciplinary panel and validation study. *N Engl J Med.* 1987;316(2):84-91.	Review/Other-Dx	7,035 patients	Multidisciplinary panel of medical experts was assembled to review the issue of skull radiography for head trauma. The panel identified two main groups of patients—those at high risk of intracranial injury and those at low risk of such injury—and developed a management strategy for imaging in the two groups. A prospective study of 7,035 patients with head trauma at 31 hospital emergency rooms was conducted to validate the management strategy.	No intracranial injuries were discovered in any of the low-risk patients. Therefore, no intracranial injury would have been missed by excluding skull radiography for low-risk patients, according to the protocol. Authors conclude that use of the management strategy is safe and that it would result in a large decrease in the use of skull radiography, with concomitant reductions in unnecessary exposure to radiation and savings of millions of dollars annually.	4
18. Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PM. Indications for computed tomography in patients with minor head injury. *N Engl J Med.* 2000;343(2):100-105.	Observational-Dx	1st phase – 520 consecutive patients; 2nd phase – 909 consecutive patients	Prospective study to derive and validate a set of clinical criteria that could be used to identify patients with MHI in whom CT could be forgone. The study was conducted in two phases at a large, inner-city, level 1 trauma center.	Of the 520 patients in the first phase, 36 (6.9%) had positive scans. All patients with positive CT scans had one or more of 7 findings: headache, vomiting, an age over 60 years, drug or alcohol intoxication, deficits in short-term memory, physical evidence of trauma above the clavicles, and seizure. Among the 909 patients in the second phase, 57 (6.3%) had positive scans. In this group of patients, the sensitivity of the 7 findings combined was 100% (95% CI, 95% to 100%). All patients with positive CT scans had at least one of the findings. For the evaluation of patients with MHI, the use of CT can be safely limited to those who have certain clinical findings.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
19. Stiell IG, Wells GA, Vandemheen K, et al. The Canadian CT Head Rule for patients with minor head injury. *Lancet.* 2001;357(9266):1391-1396.	Observational-Dx	3,121 consecutive patients	Prospective cohort multicenter study to develop a highly sensitive clinical decision rule for use of CT in patients with minor head injuries.	A CT head rule was derived which consists of 5 high-risk factors (failure to reach GCS (G of 15 within 2 h, suspected open skull fracture, any sign of basal skull fracture, vomiting >2 episodes, or age >65 years) and two additional medium-risk factors (amnesia before impact >30 min and dangerous mechanism of injury). The high-risk factors were 100% sensitive (95% CI, 92%–100%) for predicting need for neurological intervention, and would require only 32% of patients to undergo CT. The medium-risk factors were 98.4% sensitive (95% CI, 96%–99%) and 49.6% specific for predicting clinically important brain injury, and would require only 54% of patients to undergo CT.	3
20. Mower WR, Hoffman JR, Herbert M, Wolfson AB, Pollack CV, Jr., Zucker MI. Developing a decision instrument to guide computed tomographic imaging of blunt head injury patients. *J Trauma.* 2005;59(4):954-959.	Review/Other-Dx	N/A	To determine if clinical characteristics may be able to reliably identify patients who do not have intracranial injuries and consequently, do not require imaging.	Intracranial injuries were found in 917 of 13,728 enrolled patients (6.7%). Injuries were rare among patients under age 65 who had no evidence of skull fracture, scalp hematoma, neurologic deficit, abnormal alertness, abnormal behavior, coagulopathy, or persistent vomiting. These characteristics would have identified 901 injury cases (sensitivity 98.3% [CI: 97.2–99.0]), while classifying 1,752 patients (12.8%) as "low risk."	4
21. Haydel MJ. Clinical decision instruments for CT scanning in minor head injury. *Jama.* 2005;294(12):1551-1553.	Review/Other-Dx	N/A	Overview of clinical decision making issues related to CT scanning of MHI subjects.	Differences in outcome measures, physician acceptance, practice and medical-legal environments and judgment affect scanning decision making.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
22. Smits M, Dippel DW, de Haan GG, et al. External validation of the Canadian CT Head Rule and the New Orleans Criteria for CT scanning in patients with minor head injury. *Jama.* 2005;294(12):1519-1525.	Observational-Dx	3,181 consecutive patients	Prospective multicenter study to validate and compare the Canadian CT Head Rule (CCHR) to the New Orleans Criteria (NOR) in Dutch patients with head injuries.	Of 3,181 patients with a GCS score of 13 to 15, neurosurgical intervention was performed in 17 patients (0.5%); neurocranial traumatic CT findings were present in 312 patients (9.8%). Sensitivity for neurosurgical intervention was 100% for both the CCHR and the NOC. The NOC had a higher sensitivity for neurocranial traumatic findings and for clinically important findings (97.7%–99.4%) than did the CCHR (83.4%–87.2%). Specificities were very low for the NOC (3.0%–5.6%) and higher for the CCHR (37.2%–39.7%). The estimated potential reduction in CT scans for patients with MHI would be 3.0% for the adapted NOC and 37.3% for the adapted CCHR. CCHR is less sensitive for trauma or clinically relevant findings, but would identify all neurosurgical cases and reduce CT utilization.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
23. Stiell IG, Clement CM, Rowe BH, et al. Comparison of the Canadian CT Head Rule and the New Orleans Criteria in patients with minor head injury. *Jama.* 2005;294(12):1511-1518.	Observational-Dx	CCHR evaluated in 2,707 adults CCHR and NOC compared in a subgroup of 1,822 adults	Prospective multicenter cohort study to compare the clinical performance of CCHR to the NOR for detecting the need for neurosurgical intervention and clinically important brain injury.	Among 1,822 patients with GCS of 15, 8 (0.4%) required neurosurgical intervention and 97 (5.3%) had clinically important brain injury. The NOC and the CCHR both had 100% sensitivity but the CCHR was more specific (76.3% vs 12.1%, *P*<.001) for predicting need for neurosurgical intervention. For clinically important brain injury, the CCHR and the NOC had similar sensitivity (100% vs 100%; 95% CI, 96%–100%) but the CCHR was more specific (50.6% vs 12.7%, *P*<.001), and would result in lower CT rates (52.1% vs 88.0%, *P*<.001). The kappa values for physician interpretation of the rules, CCHR vs NOC, were 0.85 vs 0.47. Physicians misinterpreted the rules as not requiring imaging for 4.0% of patients according to CCHR and 5.5% according to NOC (*P*=.04). Among all 2,707 patients with a GCS of 13 to 15, the CCHR had sensitivities of 100% (95% CI, 91%–100%) for 41 patients requiring neurosurgical intervention and 100% (95% CI, 98%–100%) for 231 patients with clinically important brain injury. For patients with MHI and GCS score of 15, the CCHR and the NOC have equivalent high sensitivities for need for neurosurgical intervention and clinically important brain injury, but the CCHR has higher specificity for important clinical outcomes than does the NOC, and its use may result in reduced imaging rates.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
24. Smits M, Dippel DW, de Haan GG, et al. Minor head injury: guidelines for the use of CT--a multicenter validation study. *Radiology*. 2007;245(3):831-838.	Observational-Dx	3,181 patients	To prospectively and externally validate published national and international guidelines for the indications of CT in patients with a MHI.	Only the European Federation of Neurological Societies guidelines reached a sensitivity of 100% for all outcomes. Specificity was 0.0%–0.5%. The Dutch guidelines had the lowest sensitivity (76.5%) for neurosurgical interventions. The best specificities for traumatic CT findings and neurosurgical interventions were reached with the criteria proposed by the United Kingdom National Institute for Clinical Excellence (NICE) (46.1% and 43.6%, respectively), albeit at relatively low sensitivities (82.1% and 94.1%, respectively). The number of patients needed to scan ranged from 6 to 13 for traumatic CT findings and from 79 to 193 for neurosurgical interventions. All validated guidelines demonstrated a trade-off between sensitivity and specificity. The lowest number of patients needed to scan for either of the outcomes was reached with the NICE criteria.	3
25. Smits M, Dippel DW, Nederkoorn PJ, et al. Minor head injury: CT-based strategies for management--a cost-effectiveness analysis. *Radiology*. 2010;254(2):532-540.	Review/Other-Dx	3,181 patients	To compare the cost-effectiveness of using selective CT strategies with that of performing CT in all patients with MHI. Data from the multicenter CT in head injury patients Study involving 3,181 patients with MHI were used.	Study results showed that performing CT selectively according to the CCHR or the CT in head injury patients rule could lead to substantial U.S. cost savings ($120 million and $71 million, respectively), and the CCHR was the most cost-effective at reference-case analysis. When the prediction rule had lower than 97% sensitivity for the identification of patients who required neurosurgery, performing CT in all patients was cost-effective. The CT in head injury patients rule was most likely to be cost-effective. At value-of-information analysis, the expected value of perfect information was $7 billion, mainly because of uncertainty about long-term functional outcomes. Selecting patients with MHI for CT renders cost savings and may be cost-effective, provided the sensitivity for the identification of patients who require neurosurgery is extremely high. Uncertainty regarding long-term functional outcomes after MHI justifies the routine use of CT in all patients with these injuries.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
26. Tavender EJ, Bosch M, Green S, et al. Quality and consistency of guidelines for the management of mild traumatic brain injury in the emergency department. *Acad Emerg Med.* 2011;18(8):880-889.	Review/Other-Dx	6 clinical practice guidelines	To provide an overview of the recommendations and quality of evidence-based clinical practice guidelines for the emergency management of mTBI, with a view to informing best practice and improving the consistency of recommendations.	The search identified 18 potential clinical practice guidelines, of which 6 met the inclusion criteria. The included clinical practice guidelines varied in scope, target population, size, and guideline development processes. Four clinical practice guidelines were assessed as “strongly recommended.” The majority of clinical practice guidelines did not provide information about the level of stakeholder involvement (mean AGREE standardized domain score = 57%, range = 25% to 81%), nor did they address the organizational/cost implications of applying the recommendations or provide criteria for monitoring and review of recommendations in practice (mean AGREE standardized domain score = 46.6%, range = 19% to 94%). Recommendations were mostly consistent in terms of the use of the GCS score (adult and pediatric) to assess the level of consciousness, initial assessment criteria, the use of CT scanning as imaging investigation of choice, and the provision of patient information. The clinical practice guidelines defined mTBI in a variety of ways and described different rules to determine the need for CT scanning and therefore used different criteria to identify high-risk patients.	4
27. *Head Injury: Triage, Assessment, Investigation and Early Management of Head Injury in Infants, Children and Adults.* London: National Collaborating Centre for Acute Care (UK); 2007.	Review/Other-Dx	N/A	Updated guideline on the care of adults, children (aged 1–15 years) and infants (<1 year) who present with a suspected or confirmed traumatic head injury with or without other major trauma.	N/A	4
28. Jagoda AS, Bazarian JJ, Bruns JJ, Jr., et al. Clinical policy: neuroimaging and decisionmaking in adult mild traumatic brain injury in the acute setting. *Ann Emerg Med.* 2008;52(6):714-748.	Review/Other-Dx	N/A	To provide evidence-based recommendations on select issues in the management of adult patients with mTBI in the acute setting.	N/A	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
29. Kido DK, Cox C, Hamill RW, Rothenberg BM, Woolf PD. Traumatic brain injuries: predictive usefulness of CT. *Radiology*. 1992;182(3):777-781.	Observational-Dx	72 patients	CT scans from patients with TBI were reviewed to determine whether a specific type, location, or size of lesion correlated with changes in neurologic function (assessed with the GCS), patient outcome (assessed with the GOS), or catecholamine levels.	GOS changed as a function of lesions size (P=.00004) in the 48 patients with focal hemorrhages, regardless of whether the lesions were intra- or extraaxial, and in the 19 patients with normal CT scans. Patients with lesions larger than 4,100 mm^3 had a twofold greater risk of a poor outcome than patients with smaller lesions (100% vs 50%). Patients with normal CT scans were significantly more likely to have mild neurological dysfunction or none than patients with abnormal CT scans (P=.03), but lesion location, skull fracture, and pineal shift were not significant predictors of GCS or GOS scores. A positive relationship existed between lesion size and both plasma norepinephrine and epinephrine levels (P<.02); a significant relationship existed between lesion size and GCS score (P=.02).	2
30. Reinus WR, Zwemer FL, Jr., Fornoff JR. Prospective optimization of patient selection for emergency cranial computed tomography: univariate and multivariate analyses. *Invest Radiol.* 1996;31(2):101-108.	Observational-Dx	551 patients	To determine if the clinical variables that are important for selecting patients for emergency cranial CT are population dependent.	Of 551 patients having cranial CT, neurologic examination was positive in 340 and CT scan was positive in 122. The neurologic examination correlated strongly with the results of the CT scan (P<0.00001). In this patient population, the most important clinical predictors of 17 abnormal CT scans from the 211 patients without positive neurologic examinations were seizure and a history of neoplasm. Abnormal neurologic examination is the most important criterion available to select patients for emergency cranial CT.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
31. Shackford SR, Wald SL, Ross SE, et al. The clinical utility of computed tomographic scanning and neurologic examination in the management of patients with minor head injuries. *J Trauma.* 1992;33(3):385-394.	Observational-Dx	2,766 patients	To determine the value of CT and neurologic examination in the management of patients with minor injuries. Hypothesis that normal CT and MHI have negligible risk of neurosurgical deterioration.	A neurologic examination and a CT scan were performed on 2,166 patients; 933 patients had normal neurologic examinations and normal CT scans and none required craniotomy; 1,170 patients had normal CT scans and none required craniotomy; 2,112 patients had normal neurologic examinations and 59 required craniotomy. The sensitivity of the CT scan was 100%, with PPV of 10%, NPV of 100%, and specificity of 51%. The use of CT alone as a diagnostic modality would have saved 3,924 hospital days, including 814 ICU days, and $1,509,012 in hospital charges. CT scanning is essential in the management of patients with minor head injuries and if the neurologic examination is normal and the scan is negative patients can be safely discharged from the emergency room.	3
32. Reljic T, Mahony H, Djulbegovic B, et al. Value of repeat head computed tomography after traumatic brain injury: systematic review and meta-analysis. *J Neurotrauma.* 2014;31(1):78-98.	Meta-analysis	41 studies enrolling 10,501 patients	Systematic review and meta-analysis were performed to determine the value of repeat head CT after TBI.	Change in management following repeat CT was reported in 13 prospective and 28 retrospective studies and yielded a pooled proportion of 11.4% (95% CI, 5.9–18.4) and 9.6% (95% CI, 6.5–13.2), respectively. In a subgroup analysis of mTBI patients (GCS score 13 to 15), 5 prospective and 9 retrospective studies reported on change in management following repeat CT with the pooled proportion across prospective studies at 2.3% (95% CI, 0.3–6.3) and across retrospective studies at 3.9% (95% CI, 2.3–5.7), respectively. The evidence suggests that repeat CT in patients with TBI results in a change in management for only a minority of patients. Better designed studies are needed to address the issue of the value of repeat CT in the management of TBI.	M

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
33. Washington CW, Grubb RL, Jr. Are routine repeat imaging and intensive care unit admission necessary in mild traumatic brain injury? *J Neurosurg.* 2012;116(3):549-557.	Review/Other-Dx	321 patients	To determine if there exists a subpopulation of mTBI patients with an abnormal head CT scan that requires neither repeat brain imaging nor admission to an ICU.	321/1,101 reviewed cases that met inclusion criteria for the study. Only 4 patients (1%) suffered a neurological decline and 4 (1%) required nonemergent neurosurgical intervention. There was a medical decline in 18 of the patients (6%) as a result of a combination of events such as respiratory distress, myocardial infarction, and sepsis. Both patient age and the transfusion of blood products were significant predictors of medical decline. Overall patient mortality was 1%. Based on imaging data, the rate of injury progression was 6%. The only type of ICH found to have a significant rate of progression (53%) was a subfrontal/temporal intraparenchymal contusion. Other variables found to be significant predictors of progression on head CT scans were the use of anticoagulation, an age >65 years, and a volume of ICH >10 mL.	4
34. Cohen DB, Rinker C, Wilberger JE. Traumatic brain injury in anticoagulated patients. *J Trauma.* 2006;60(3):553-557.	Review/Other-Dx	77 patients with GCS scores of 13 to 15	To describe the effect of coumadin in elderly TBI patients.	For patients with GCS scores <8, average International Normalized Ratio was 6.0, with almost 50% having an initial value >5.0. Overall mortality was 91.5%. For the 77 patients with GCS scores of 13 to 15, average International Normalized Ratio was 4.4. Overall mortality for this group was 80.6%. A subset of patients deteriorated to a GCS score of <10 just hours after injury, despite most having normal initial CT scans. Mortality in this group was 84%.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
35. Manolakaki D, Velmahos GC, Spaniolas K, de Moya M, Alam HB. Early magnetic resonance imaging is unnecessary in patients with traumatic brain injury. *J Trauma.* 2009;66(4):1008-1012; discussion 1012-1004.	Observational-Dx	123 trauma patients	To evaluate the role of early MRI in the initial management of patients with TBI.	The authors identified 123 trauma patients who had MRI within 18 hours +/- 14.5 hours of CT (median: 12 hours). In 82 (67%) patients, the findings of CT and MRI were identical. In the remaining 41 patients there were discrepancies between CT and MRI: 35 patients had slight differences in the location or size of the lesions found and 6 had minor brain lesion detected by MRI and not CT. Compared with patients who had identical CT and MRI, those who showed differences in the 2 tests had higher severity of head injury, lower initial blood pressure, and a higher rate of intubation. Based on CT findings, 78 (63%) patients received TBI-related interventions: 8 craniotomies, 12 intracranial pressure monitoring catheters, 14 mannitol infusions, and 72 antiepileptic medications. There was no change in treatment because of MRI.	2
36. Yuh EL, Mukherjee P, Lingsma HF, et al. Magnetic resonance imaging improves 3-month outcome prediction in mild traumatic brain injury. *Ann Neurol.* 2013;73(2):224-235.	Observational-Dx	135 patients	To determine the clinical relevance, if any, of traumatic intracranial findings on early head CT and brain MRI to 3-month outcome in mTBI.	27% of mTBI patients with normal admission head CT had abnormal early brain MRI. CT evidence of subarachnoid hemorrhage was associated with a multivariate OR of 3.5 (P=0.01) for poorer 3-month outcome, after adjusting for demographic, clinical, and socioeconomic factors. One or more brain contusions on MRI, and ≥4 foci of hemorrhagic axonal injury on MRI, were each independently associated with poorer 3-month outcome, with multivariate ORs of 4.5 (P=0.01) and 3.2 (P=0.03), respectively, after adjusting for head CT findings and demographic, clinical, and socioeconomic factors.	2
37. 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	159 patients	Prospective cohort study in which patients with moderate to severe head injuries using MRI in the early phase were examined. The objective was to explore the occurrence of DAI and determine whether DAI was related to level of consciousness and patient outcome.	DAI was found in almost three-quarters of the patients with moderate and severe head injury who survived the acute phase. DAI influenced the level of consciousness, and only in patients with DAI was GCS score related to outcome. Finally, DAI was a negative prognostic sign only when located in the brainstem.	2

Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
38. Kampfl A, Schmutzhard E, Franz G, et al. Prediction of recovery from post-traumatic vegetative state with cerebral magnetic-resonance imaging. *Lancet.* 1998;351(9118):1763-1767.	Observational-Dx	80 patients; 3 blinded reviewers	To define the MRI signs of cerebral injury in patients in post-traumatic vegetative state. Authors also examined whether lesions in certain brain areas can predict that there will be nonrecovery from a post-traumatic vegetative state.	Cerebral MRI findings in the subacute stage after head injury can predict the outcome of the post-traumatic vegetative state. Corpus callosum and dorsolateral brainstem lesions are highly significant in predicting non-recovery.	2
39. Metting Z, Rodiger LA, De Keyser J, van der Naalt J. Structural and functional neuroimaging in mild-to-moderate head injury. *Lancet Neurol.* 2007;6(8):699-710.	Review/Other-Dx	N/A	Review structural and functional imaging techniques in patients with mild-to-moderate head injury.	Review outlines the advantages and limitations of CT and MRI, including different MRI sequences, SPECT, perfusion-weighted MRI, perfusion CT, PET, MRS, fMRI and magnetic encephalography in the contexts of the initial assessment and identification of brain abnormalities and the prediction of outcome.	4
40. Ichise M, Chung DG, Wang P, Wortzman G, Gray BG, Franks W. Technetium-99m-HMPAO SPECT, CT and MRI in the evaluation of patients with chronic traumatic brain injury: a correlation with neuropsychological performance. *J Nucl Med.* 1994;35(2):217-226.	Observational-Dx	29 patients (minor TBI, n=15 and major TBI, n=14); 17 controls	Purposes of study were: 1) to compare Tc-99m-HMPAO SPECT with CT and MRI in chronic TBI patients and 2) to correlate both functional and structural neuroimaging measurements of brain damage with neuropsychological performance.	19 (66%) patients showed 42 abnormalities on SPECT images, whereas 13 (45%) and 10 (34%) patients showed 29 abnormalities on MRI and 24 abnormalities on CT. SPECT detected relatively more abnormalities than CT or MRI in the minor TBI subgroup. The TBI group showed impairment on 11 tests for memory, attention and executive function. Of these, the anterior-posterior ratio correlated with six tests, whereas the ventricle-to-brain ratio, a known structural index of a poor neuropsychological outcome, correlated with only two tests. In evaluating chronic TBI patients, HMPAO SPECT, as a complement to CT or MRI, may play a useful role by demonstrating brain dysfunction in morphologically intact brain regions and providing objective evidence for some of the impaired neuropsychological performance.	2

Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
41. Jacobs A, Put E, Ingels M, Bossuyt A. Prospective evaluation of technetium-99m-HMPAO SPECT in mild and moderate traumatic brain injury. *J Nucl Med.* 1994;35(6):942-947.	Observational-Dx	67 total patients; 42 - first subgroup of moderate trauma; 25 - second subgroup of mild trauma	Prospectively evaluate the contribution of Tc-99m-HMPAO SPECT in patients who have sustained acute, mild or moderate head trauma. All 67 patients underwent an initial SPECT within 4 weeks after a closed cranial trauma.	For the group as a whole (moderate trauma + mild trauma), the following results could be derived: in 32/33 initial SPECT negative cases, clinical symptoms had resolved; PPV of initial SPECT was only 20/34 (59%); the sensitivity for the repeat SPECT was 19/20 (95%). Results show that: 1) SPECT alterations correlate well with the severity of the trauma; 2) a negative initial SPECT study is a reliable predictor of a favorable clinical outcome; 3) in cases with a positive initial SPECT, a follow-up consisting of a combination of SPECT and clinical data is necessary; 4) in patients suffering from postconclusive symptoms, SPECT offers an instrument to objective sequelae.	2
42. Kinuya K, Kakuda K, Nobata K, et al. Role of brain perfusion single-photon emission tomography in traumatic head injury. *Nucl Med Commun.* 2004;25(4):333-337.	Observational-Dx	35 patients	To examine the role of brain perfusion SPECT in traumatic head injury. Results were compared with those of X-ray, CT and MRI.	CT and MRI detected brain contusions in 7 patients, subarachnoid hemorrhage in one patient and both in 9 patients. In 16 of the 17 subjects (94%), SPECT with Tc-99m-HMPAO revealed CT/MRI-negative abnormalities. SPECT afforded additional information in 26 patients (74%). CT possesses an advantage with respect to the detection of hemorrhagic lesions. MRI provides more precise information regarding contusions and axonal injury. Frequently, SPECT may be the only examination to reveal perfusion abnormalities which are related to symptoms in the absence of other objective findings, such as post-traumatic amnesia, vertigo or personality change.	3

Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
43. Peskind ER, Petrie EC, Cross DJ, et al. Cerebrocerebellar hypometabolism associated with repetitive blast exposure mild traumatic brain injury in 12 Iraq war Veterans with persistent post-concussive symptoms. *Neuroimage.* 2011;54 Suppl 1:S76-82.	Review/Other-Dx	12 Iraq war Veterans with mTBI and 12 controls	To determine the extent to which persistent post-concussive symptoms reported by Iraq combat Veterans with repeated episodes of mTBI from explosive blasts represent structural or functional brain damage or an epiphenomenon of comorbid depression or post-traumatic stress disorder.	Compared to controls, Veterans with mTBI (with or without post-traumatic stress disorder) exhibited decreased cerebral metabolic rate of glucose in the cerebellum, vermis, pons, and medial temporal lobe. They also exhibited subtle impairments in verbal fluency, cognitive processing speed, attention, and working memory, similar to those reported in the literature for patients with cerebellar lesions. These FDG-PET imaging findings suggest that regional brain hypometabolism may constitute a neurobiological substrate for chronic post-concussive symptoms in Iraq combat Veterans with repetitive blast-trauma mTBI.	4
44. Garnett MR, Blamire AM, Corkill RG, et al. Abnormal cerebral blood volume in regions of contused and normal appearing brain following traumatic brain injury using perfusion magnetic resonance imaging. *J Neurotrauma.* 2001;18(6):585-593.	Observational-Dx	18 patients	Conventional and perfusion MRI was used in patients, on average 10 days following injury, to assess possible subacute hemodynamic disturbances following TBI.	TBI is a heterogeneous insult causing a variety of pathology, not all of which is visible using conventional imaging methods. Regions of both normal appearing and contused brain may have an abnormal regional cerebral blood volume and alterations in regional cerebral blood volume may play a role in determining the clinical outcome of patients.	3
45. Metting Z, Rodiger LA, Stewart RE, Oudkerk M, De Keyser J, van der Naalt J. Perfusion computed tomography in the acute phase of mild head injury: regional dysfunction and prognostic value. *Ann Neurol.* 2009;66(6):809-816.	Observational-Dx	76 patients; 25 healthy control subjects	To perform perfusion CT imaging in the acute phase of mild head injury in patients without intracranial abnormalities on the noncontrast CT, to assess whether these patients had cerebral perfusion abnormalities. Also, the relation between perfusion CT parameters and severity of head injury and outcome was evaluated.	In patients with a decreased GCS score, a significant decrease of cerebral blood flow and cerebral blood volume was detected in the frontal and occipital gray matter. In logistic regression analyses, decreased cerebral blood flow and cerebral blood volume in the frontal lobes predicted worse outcome according to the extended GOS score. CT perfusion parameters did not predict return to work. In the acute phase of mild head injury, disturbed cerebral perfusion is seen in patients with normal noncontrast CT correlating with severity of injury and outcome.	3

Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
46. Huisman TA, Schwamm LH, Schaefer PW, et al. Diffusion tensor imaging as potential biomarker of white matter injury in diffuse axonal injury. *AJNR Am J Neuroradiol*. 2004;25(3):370-376.	Observational-Dx	20 patients	To determine if changes in anisotropic diffusion in TBI correlate with acute GCS and/or Rankin scores at discharge.	Apparent diffusion coefficient values were significantly reduced within the splenium (Delta18%, P=.001). Fractional anisotropy values were significantly reduced in the internal capsule (Delta14%; P<.001) and splenium (Delta16%; P=.002). Fractional anisotropy values were significantly correlated with GCS (r = 0.65–0.74; P<.001) and Rankin (r = 0.68–0.71; P<.001) scores for the internal capsule and splenium. The correlation between fractional anisotropy and clinical markers was better than for the corresponding apparent diffusion coefficient values. No correlation was found between apparent diffusion coefficient of the internal capsule and GCS/Rankin scores.	3
47. Mayer AR, Ling J, Mannell MV, et al. A prospective diffusion tensor imaging study in mild traumatic brain injury. *Neurology*. 2010;74(8):643-650.	Observational-Dx	22 patients with semi-acute mTBI, 21 matched healthy controls. 32 healthy controls from independent sample	To investigate white matter integrity and compare the accuracy of traditional anatomic scans, neuropsychological testing, and diffusion tensor imaging for objectively classifying mTBI patients from controls.	mTBI patients did not differ from controls on clinical imaging scans or neuropsychological performance, although effect sizes were consistent with literature values. In contrast, mTBI patients demonstrated significantly greater fractional anisotropy as a result of reduced radial diffusivity in the corpus callosum and several left hemisphere tracts. Diffusion tensor imaging measures were more accurate than traditional clinical measures in classifying patients from controls. Longitudinal data provided preliminary evidence of partial normalization of diffusion tensor imaging values in several white matter tracts.	3
48. Jantzen KJ. Functional magnetic resonance imaging of mild traumatic brain injury. *J Head Trauma Rehabil.* 2010;25(4):256-266.	Review/Other-Dx	N/A	To review the recent fMRI literature relevant to the study of mTBI. The pathophysiology of mTBI and the neural basis of the blood oxygen level-dependent fMRI response are also considered with particular focus on important issues for using fMRI to investigate mTBI.	fMRI offers potential for understanding the neural and functional basis of mTBI and the relationship to behavioral and somatic symptoms.	4

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EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
49. Jantzen KJ, Anderson B, Steinberg FL, Kelso JA. A prospective functional MR imaging study of mild traumatic brain injury in college football players. *AJNR Am J Neuroradiol.* 2004;25(5):738-745.	Observational-Dx	8 college football players; 4 with concussion and 4 without concussion (controls)	Prospective, functional neuroimaging approach was used to assess sports-related concussion in which imaging was performed before injury so that brain changes resulting from concussion could be better understood. Four players who had a concussion repeated baseline procedures within 1 week of injury. The remaining control players were retested at the end of the season.	Specific neural signatures of concussion were detected in individual players by comparing postconcussion results to preconcussion baseline values. The validity of these indicators was confirmed by comparing them with the same measures in noninjured control subjects. When compared with control subjects, concussed players had marked within-subject increases in the amplitude and extent of blood oxygen level-dependent activity during a finger-sequencing task. Effects were observed primarily in the parietal and lateral frontal and cerebellar regions. Differences in neural functioning were observed in the absence of observed deficits in behavioral performance, suggesting that this approach may increase sensitivity to concussion compared with neuropsychological evaluation alone. The proposed prospective neuroimaging approach may have great potential for understanding mTBI and identifying mechanisms underlying recovery.	3
50. Shutter L, Tong KA, Lee A, Holshouser BA. Prognostic role of proton magnetic resonance spectroscopy in acute traumatic brain injury. *J Head Trauma Rehabil.* 2006;21(4):334-349.	Review/Other-Dx	N/A	To review the technology of MRS, discuss its role in patient assessment after TBI, and present a summary of published and ongoing research.	No results stated in abstract.	4
51. Govindaraju V, Gauger GE, Manley GT, Ebel A, Meeker M, Maudsley AA. Volumetric proton spectroscopic imaging of mild traumatic brain injury. *AJNR Am J Neuroradiol.* 2004;25(5):730-737.	Observational-Dx	14 patients with mild closed head injury; 13 control subjects	To obtain spectroscopic measurements over a large brain region to improve sensitivity for the characterization of the degree of injury. An additional aim was to evaluate the relationship of the MR spectroscopic findings with clinical outcomes 6 months after injury.	Significant changes ($P<.05$) were found for some, but not all, brain regions for the average values from all mTBI subjects, with reduced NAA/total creatine, increased choline/ creatine, and reduced NAA/choline. Global NAA/choline obtained from the sum of all sampled regions in 2 subjects was significantly reduced. Metabolite ratios were not significantly correlated with GCS score at admission or GOS score at 6 months after injury, although they were weakly correlated with GOS score at discharge.	3

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EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
52. Bromberg WJ, Collier BC, Diebel LN, et al. Blunt cerebrovascular injury practice management guidelines: the Eastern Association for the Surgery of Trauma. *J Trauma.* 2010;68(2):471-477.	Review/Other-Dx	68 articles	EBM guideline for the screening, diagnosis, and treatment of BCVI by the Eastern Association for the Surgery of Trauma organization Practice Management Guidelines committee.	The East Practice Management Guidelines Committee suggests guidelines that should be safe and efficacious for the screening, diagnosis, and treatment of BCVI. Risk factors for screening are identified, screening modalities are reviewed indicating that although angiography remains the gold standard, multi-planar (≥8 slice) CTA may be equivalent, and treatment algorithms are evaluated. It is noted that change in the diagnosis and management of this injury constellation is rapid due to technological advancement and the difficulties inherent in performing randomized prospective trials in this patient population.	4
53. Biffl WL, Egglin T, Benedetto B, Gibbs F, Cioffi WG. Sixteen-slice computed tomographic angiography is a reliable noninvasive screening test for clinically significant blunt cerebrovascular injuries. *J Trauma.* 2006;60(4):745-751; discussion 751-742.	Observational-Dx	331 patients	Prospective study to determine ability of CTA to detect clinically significant blunt cerebrovascular injuries.	CTA detected all clinically significant injuries (in 18 patients) during this study period. Liberal screening with 16-slice CTA is appropriate and is likely to miss very few significant injuries. A multicenter trial will help to clarify risk factors and the accuracy of noninvasive diagnostic modalities.	2
54. Eastman AL, Chason DP, Perez CL, McAnulty AL, Minei JP. Computed tomographic angiography for the diagnosis of blunt cervical vascular injury: is it ready for primetime? *J Trauma.* 2006;60(5):925-929; discussion 929.	Observational-Dx	162 patients	To determine the sensitivity of CTA for the diagnosis of BCVI. The authors hypothesized that advances in CT technology have improved the diagnostic sensitivity of CTA at least to that of invasive catheter angiography.	Over 11 months, 162 patients were at risk for BCVI. In all, 146 patients received both CTA and CA. 46 BCVIs were identified among 43 patients. In 45/46 cases (98%), the results of CTA and catheter angiography were concordant. There was a single false-negative CTA in a patient with a grade I vertebral artery injury. The remaining 103 patients had normal CTAs confirmed by a normal catheter angiography. The overall sensitivity, specificity, PPV, NPV, and accuracy of CTA for the diagnosis of BCVI were 97.7%, 100%, 100%, 99.3%, and 99.3%, respectively.	3

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EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
55. Patterson BO, Holt PJ, Cleanthis M, Tai N, Carrell T, Loosemore TM. Imaging vascular trauma. *Br J Surg.* 2012;99(4):494-505.	Review/Other-Dx	58 articles	To define optimal first-line imaging in patients with suspected vascular injury in different anatomical regions.	Of 1,511 titles identified, 58 articles were incorporated in the systematic review. Most described the use of CTA. The application of duplex US, MRI/angiography and transesophageal echocardiography was described, but significant drawbacks were highlighted for each. CTA displayed acceptable sensitivity and specificity for diagnosing vascular trauma in blunt and penetrating vascular injury within the neck and extremity, as well as for blunt aortic injury.	4
56. Delgado Almandoz JE, Kelly HR, Schaefer PW, Lev MH, Gonzalez RG, Romero JM. Prevalence of traumatic dural venous sinus thrombosis in high-risk acute blunt head trauma patients evaluated with multidetector CT venography. *Radiology.* 2010;255(2):570-577.	Review/Other-Dx	195 patients	To determine the prevalence of trauma-related dural venous sinus thrombosis in high-risk patients with blunt head trauma who are examined with MDCT venography.	MDCT venography depicted thrombosis of 98 dural sinuses or jugular bulbs in 57 (40.7%) of the 140 patients with skull fractures extending to a dural sinus or jugular bulb. 54 (55%) of the 98 sinuses or bulbs had occlusive thrombosis. dural venous sinus thrombosis was seen in only those patients with skull fractures extending to a dural sinus or jugular bulb. Among the skull fractures extending to the transverse sinus, sigmoid sinus, or jugular bulb, those of the petrous temporal bone had a higher risk (50%, 36/72 fractures) of traumatic dural venous sinus thrombosis than did those of the occipital bone (34% risk [32/93 fractures]) (*P*=.044). However, among the skull fractures extending to the superior sagittal sinus, those of the occipital bone had a higher risk (67% [8/12 fractures]) of traumatic dural venous sinus thrombosis than did those of the parietal (39% risk [11/28 fractures]) and frontal (24% risk [4/17 fractures]) bones (*P*=.065). 4 (7%) patients with traumatic dural venous sinus thrombosis had associated hemorrhagic venous infarctions, all secondary to occlusive dural venous sinus thrombosis.	4

Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
57. Khandelwal N, Agarwal A, Kochhar R, et al. Comparison of CT venography with MR venography in cerebral sinovenous thrombosis. *AJR Am J Roentgenol.* 2006;187(6):1637-1643.	Observational-Dx	50 patients	To compare cerebral CT venography with MR venography and determine the reliability of CT venography in the diagnosis of cerebral sinovenous thrombosis.	Of these 50 patients, 30 patients were diagnosed as having cerebral sinovenous thrombosis on both CT venography and MR venography. The total numbers of sinuses involved were 81 and 77 (CT venography and MR venography). When MR venography was used as the gold standard, CT venography was found to have both a sensitivity and a specificity of 75%–100%, depending on the sinus and vein involved.	2
58. Bousser MG, Ferro JM. Cerebral venous thrombosis: an update. *Lancet Neurol.* 2007;6(2):162-170.	Review/Other-Dx	N/A	A review on cerebral venous thrombosis.	MRI with T1, T2, fluid-attenuated inversion recovery, and T2* sequences combined with MR angiography are the best diagnostic methods.	4
59. Baugnon KL, Hudgins PA. Skull base fractures and their complications. *Neuroimaging Clin N Am.* 2014;24(3):439-465, vii-viii.	Review/Other-Dx	N/A	To review skull base anatomy; morphology of the common fracture patterns within the anterior, central, and posterior skull base; associated complications; imaging findings; and possible pitfalls in imaging of skull base trauma.	Transverse middle cranial fossa fractures extending through the carotid canal are at increased risk for vascular injury, and should prompt screening with vascular studies, such as CTA. Thin-section multiplanar CT reformations, as well as 3-D reconstructions, are helpful in the detection of subtle skull base fractures.	4
60. Yilmazlar S, Arslan E, Kocaeli H, et al. Cerebrospinal fluid leakage complicating skull base fractures: analysis of 81 cases. *Neurosurg Rev.* 2006;29(1):64-71.	Review/Other-Tx	81 patients	To evaluate the results of conservative and surgical management options for traumatic CSF leakage complicating skull base fractures.	The factors that had a critical influence on outcome in this series were level of consciousness on admission and presence of additional intracranial pathology associated with CSF leakage within cases of traumatic CSF fistulae due to skull base fractures. Treatment decisions should be dictated by the severity of neurological decline during the emergency period and the presence/absence of associated intracranial lesions. The timing for surgery and CSF drainage procedures must be decided with great care and with a clear strategy. The authors offer a treatment algorithm.	4

Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
61. Stone JA, Castillo M, Neelon B, Mukherji SK. Evaluation of CSF leaks: high-resolution CT compared with contrast-enhanced CT and radionuclide cisternography. *AJNR Am J Neuroradiol.* 1999;20(4):706-712.	Observational-Dx	42 patients	To evaluate the use of screening noncontrast high-resolution CT in identifying the presence and site of CSF rhinorrhea and otorrhea and compare it with contrast-enhanced CT cisternography and radionuclide cisternography.	High-resolution CT showed bone defects in 30/42 patients (71%) with CSF leak. High-resolution, radionuclide cisternography and CT cisternography did not show bone defects or CSF leak for 12 patients (29%) who had clinical evidence of CSF leak. Among the 30 patients with bone defects, 20 (66%) had positive results of their radionuclide cisternography and/or CT cisternography. For the 21 patients who underwent surgical exploration and repair, intraoperative findings correlated with the defects revealed by high-resolution CT in all cases. High-resolution CT identified significantly more patients with CSF leak than did radionuclide cisternography and CT cisternography, with a moderate degree of agreement.	3
62. Zapalac JS, Marple BF, Schwade ND. Skull base cerebrospinal fluid fistulas: a comprehensive diagnostic algorithm. *Otolaryngol Head Neck Surg.* 2002;126(6):669-676.	Observational-Dx	52 patients	To assess the efficacy of current diagnostic modalities in the management of skull base CSF fistulas.	beta2-Transferrin analysis of collected specimen was the most efficacious means of confirming a CSF leak. High-resolution CT was the most informative radiographic study, yielding a sensitivity and an accuracy of 87%. MR cisternography, yielding a sensitivity and an accuracy of 78%, was instrumental in localizing the site of leak for a few cases but was most commonly corroborative. Using a graduated diagnostic approach, successful repair was attained in 88% of cases after 1 attempt and 98% after 1 or 2 attempts.	3
63. Rice DH. Cerebrospinal fluid rhinorrhea: diagnosis and treatment. *Curr Opin Otolaryngol Head Neck Surg.* 2003;11(1):19-22.	Review/Other-Dx	N/A	To review the diagnosis and treatment of CSF rhinorrhea.	No results stated in abstract.	4

Head Trauma
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
64. Bell RB, Dierks EJ, Homer L, Potter BE. Management of cerebrospinal fluid leak associated with craniomaxillofacial trauma. *J Oral Maxillofac Surg.* 2004;62(6):676-68.	Review/Other-Dx	735 patients	To determine the incidence of persistent CSF rhinorrhea and otorrhea and assess the clinical outcomes of patients presenting to a level 1 trauma center with posttraumatic CSF leaks who were managed by both surgical and nonsurgical means.	34 patients (incidence, 4.6%) were identified with CSF leak presenting as otorrhea (n = 25 [75.8%]) or rhinorrhea (n = 9 [26.5%]), which was diagnosed by clinical, laboratory, or radiographic examination (average age, 28.2 years; age range, 2 to 80 years; 23 males and 11 females). All patients in this study experienced successful resolution of CSF otorrhea or rhinorrhea by using a variable combination of observation, CSF diversion, and extracranial repair. There were no complications or cases of meningitis. 28 patients (84.6%) experienced uncomplicated resolution of the leak without treatment in 2 to 10 days. Persistent CSF leak, defined by drainage >7 days after injury, was identified in 6 patients (incidence, 0.8%), all except 1 who underwent CSF diversion via a lumbar drain for a period of 5 to 10 days. 2 of these patients were treated successfully; the remaining 4 patients required surgical procedures.	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.
- M = Meta-analysis

Dx = Diagnostic

Tx = Treatment

Abbreviations Key

BCVI = Blunt cerebrovascular injury

CI = Confidence interval

CSF = Cerebrospinal fluid

CT = Computed tomography

CTA = Computed tomography angiography

DAI = Diffuse axonal injury

fMRI = Functional magnetic resonance imaging

GCS = Glasgow Coma Scale

GOS = Glasgow Outcome Scale

HMPAO = Hexamethyl-propylamine-oxime

ICA = Internal carotid artery

ICH = Intracranial hemorrhage

MDCT = Multidetector computed tomography

MHI = Minor head injury

MRI = Magnetic resonance imaging

MRS = Magnetic resonance spectroscopy

mTBI = Mild traumatic brain injury

NAA = N-acetylaspartate

NPV = Negative predictive value

OR = Odds ratio

PET = Positron emission tomography

PPV = Positive predictive value

SPECT = Single-photon-emission computed tomography

SWI = Susceptibility-weighted imaging

TBI = Traumatic brain injury

TCD = Transcranial Doppler