

Suspected Physical Abuse — Child  
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. U.S. Department of Health and Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children’s Bureau. (2015). Child maltreatment 2013. Available at: <a href="http://www.acf.hhs.gov/programs/cb/research-data-technology/statistics-research/child-maltreatment">http://www.acf.hhs.gov/programs/cb/research-data-technology/statistics-research/child-maltreatment</a>	Review/Other-Dx	N/A	Present national data about child abuse and neglect known to child protective agencies in the United States during Federal fiscal year 2009.	N/A	4
2. Gilbert R, Kemp A, Thoburn J, et al. Recognising and responding to child maltreatment. <i>Lancet</i> . 2009;373(9658):167-180.	Review/Other-Dx	N/A	Review patterns of recognition and response to child maltreatment and assess ways to improve process.	Authors suggest that professionals dealing with children have complementary roles in the recognition and response to child maltreatment.	4
3. Hobbs CJ, Bilo RA. Nonaccidental trauma: clinical aspects and epidemiology of child abuse. <i>Pediatr Radiol</i> . 2009;39(5):457-460.	Review/Other-Dx	N/A	Review clinical aspects and epidemiology of child abuse in nonaccidental injuries.	Knowledge of the differential diagnosis of unexplained or apparent injury is necessary for accurate diagnosis.	4
4. Mok JY. Non-accidental injury in children--an update. <i>Injury</i> . 2008;39(9):978-985.	Review/Other-Dx	N/A	Review physical abuse of children with emphasis on fractures.	Fracture detection rate will be increased by high quality radiographs and interpretation by a skilled pediatric radiologist.	4
5. Dwek JR. The radiographic approach to child abuse. <i>Clin Orthop Relat Res</i> . 2011;469(3):776-789.	Review/Other-Dx	44 articles	To detail the radiographic imaging of the more characteristic highly specific injuries and discuss the major issues that relate to some moderate- to low-specificity injuries. And to discuss several mimics of abuse with which the orthopedic surgeon should be familiar and should recognize.	Injuries that are highly specific for the diagnosis of abuse include metaphyseal corner fractures, posteromedial rib fractures, and sternal, scapular, and spinous process fractures. Lesions of moderate specificity include, among other injuries, multiple fractures of various ages and epiphyseal separations. Long-bone fractures and clavicular fractures, while common, are of low specificity. In addition to the appropriate accurate diagnosis of these injuries, several diseases and syndromes may mimic abuse due to the similarity in the radiographic picture.	4
6. Merten DF, Carpenter BL. Radiologic imaging of inflicted injury in the child abuse syndrome. <i>Pediatr Clin North Am</i> . 1990;37(4):815-837.	Review/Other-Dx	N/A	Review radiologic imaging of injuries in child abuse.	Awareness of patterns of injuries in abused infants and children may serve to identify potential victims of abuse and stimulate more thorough clinical and radiologic investigation.	4
7. Servaes S, Brown SD, Choudhary AK, et al. The etiology and significance of fractures in infants and young children: a critical multidisciplinary review. <i>Pediatr Radiol</i> . 2016;46(5):591-600.	Review/Other-Dx	N/A	To address significant misconceptions regarding the etiology of fractures in infants and young children in cases of suspected child abuse.	No abstract available.	4

\* See Last Page for Key

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8. Becker JC, Liersch R, Tautz C, Schlueter B, Andler W. Shaken baby syndrome: report on four pairs of twins. <i>Child Abuse Negl.</i> 1998;22(9):931-937.	Review/Other-Dx	4 pairs of twins	To describe incidence of shaken baby syndrome in 4 pairs of twins.	5 children were severely affected and 2 died. In 1 family, both of the twins repeatedly suffered injury from being shaken.	4
9. Lindberg DM, Shapiro RA, Laskey AL, Pallin DJ, Blood EA, Berger RP. Prevalence of abusive injuries in siblings and household contacts of physically abused children. <i>Pediatrics.</i> 2012;130(2):193-201.	Observational-Dx	134 contacts	To determine the prevalence of abusive injuries identified by a common screening protocol among contacts of physically abused children.	Protocol-indicated SS identified at least 1 abusive fracture in 16/134 contacts (11.9%, 95% CI, 7.5–18.5) <24 months of age. None of these fractures had associated findings on physical examination. No injuries were identified by neuroimaging in 19/25 eligible contacts (0.0%, 95% CI, 0.0–13.7). Twins were at substantially increased risk of fracture relative to nontwin contacts (OR 20.1, 95% CI, 5.8–69.9).	3
10. Quigley AJ, Stafrace S. Skeletal survey normal variants, artefacts and commonly misinterpreted findings not to be confused with non-accidental injury. <i>Pediatr Radiol.</i> 2014;44(1):82-93; quiz 79-81.	Review/Other-Dx	N/A	To present a pictorial essay to aid the reporting radiologists in the differentiation between normal variants or artifacts and true traumatic injury.	N/A	4
11. van Rijn RR, Sieswerda-Hoogendoorn T. Educational paper: imaging child abuse: the bare bones. <i>Eur J Pediatr.</i> 2012;171(2):215-224.	Review/Other-Dx	N/A	To discuss the radiological workup in case of suspected child abuse and the main radiological findings indicative of child abuse.	N/A	4
12. Hansen KK, Prince JS, Nixon GW. Oblique chest views as a routine part of skeletal surveys performed for possible physical abuse--is this practice worthwhile? <i>Child Abuse Negl.</i> 2008;32(1):155-159.	Observational-Dx	22 patients	Retrospective study to evaluate the value of oblique chest views in the diagnosis of rib fractures when used as a routine part of the SS performed for possible physical abuse.	In 12/22 cases, interpretation of the 4-view chest series was different than interpretation of the 2-view chest series. 4-view chest series adds information to that obtained from the 2-view chest series and increases the accuracy of diagnosing rib fractures in cases of possible physical abuse. Addition of oblique chest views to the routine protocol for SSSs performed for possible physical abuse is recommended.	3

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13. Marine MB, Corea D, Steenburg SD, et al. Is the new ACR-SPR practice guideline for addition of oblique views of the ribs to the skeletal survey for child abuse justified? <i>AJR Am J Roentgenol.</i> 2014;202(4):868-871.	Observational-Dx	212 patients	To determine whether adding oblique bilateral rib radiography to the SS for child abuse significantly increases detection of the number of rib fractures.	We identified 212 patients (106 with 1 or more fractures and 106 without). The sensitivity and specificity of the 2-view series were 81% and 91%, respectively. Sensitivity and specificity for detection of posterior rib fractures were 74% and 92%, respectively. There was good agreement between observers for detection of rib fractures in both series (average kappa values of 0.70 and 0.78 for 2-views and 4-views, respectively). Confidence significantly increased for 4-views.	3
14. Barsness KA, Cha ES, Bensard DD, et al. The positive predictive value of rib fractures as an indicator of nonaccidental trauma in children. <i>J Trauma.</i> 2003;54(6):1107-1110.	Observational-Dx	78 children (336 fractures)	Review medical records and imaging of children over a 6-year period to evaluate rib fractures to determine; the PPV of a rib fracture in defining NAT; and the frequency of rib fractures as the only skeletal manifestation of NAT.	For children <3 years, the PPV of a rib fracture as indicator of NAT was 95%. Rib fractures were the only skeletal manifestations of NAT in 29%.	3
15. Cadzow SP, Armstrong KL. Rib fractures in infants: red alert! The clinical features, investigations and child protection outcomes. <i>J Paediatr Child Health.</i> 2000;36(4):322-326.	Review/Other-Dx	18 infants	To examine clinical features, investigation methods and outcomes of infants with rib fractures.	Rib fractures were attributed to child abuse in 15 of 18 infants identified. The initial presentation in the abused infants was most often as a result of intracranial pathology and limb fractures. In 4 cases the rib fractures were incidental findings when abuse had not been suspected. BS revealed 8 previously undetected rib injuries in 4 cases. In 3 cases of abuse, the rib fractures were an isolated finding. 3 of the infants with inflicted rib injuries were discharged home. In 1 such infant a significant re-injury occurred. 3 returned home with implicated adults no longer in residence, and 9 spent a mean period of 12 months in foster care.	4
16. American College of Radiology. ACR-SPR Practice Parameter for Skeletal Surveys in Children. Available at: <a href="http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Skeletal_Surveys.pdf">http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Skeletal_Surveys.pdf</a> .	Review/Other-Dx	N/A	To assist practitioners in providing appropriate radiologic care for patients.	No results stated in abstract.	4

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17. Karmazyn B, Lewis ME, Jennings SG, Hibbard RA, Hicks RA. The prevalence of uncommon fractures on skeletal surveys performed to evaluate for suspected abuse in 930 children: should practice guidelines change? <i>AJR Am J Roentgenol.</i> 2011;197(1):W159-163.	Review/Other-Dx	930 children	To evaluate the prevalence and site of fractures detected on SSs performed for suspected child abuse at a tertiary children's hospital and to determine whether any survey images may be eliminated without affecting clinical care or the ability to make a diagnosis.	930 children (515 boys and 415 girls) with a median age of 6 months met the entry criteria for the study. Fractures were detected in 317 children (34%), of whom 166 (18%) had multiple fractures. The most common sites for fractures were the long bones (21%), ribs (10%), skull (7%), and clavicle (2%). 10 children (1%) had fractures in the spine (n = 3), pelvis (n = 1), hands (n = 6), and feet (n = 2). All 10 children had other signs of physical abuse.	4
18. Barber I, Perez-Rossello JM, Wilson CR, Silvera MV, Kleinman PK. Prevalence and relevance of pediatric spinal fractures in suspected child abuse. <i>Pediatr Radiol.</i> 2013;43(11):1507-1515.	Review/Other-Dx	751 children	To establish the prevalence of spinal fractures detected on SSs performed for suspected child abuse and their association with intracranial injury.	14 children had a total of 22 definite spinal fractures. This constituted 1.9% (14/751) of the total cohort, and 9.7% (14/145) of children with a positive SS. Advanced imaging confirmed the fractures in 13 of the 14 children and demonstrated 12 additional spinal fractures. In 5 cases, spinal fractures were the only positive skeletal findings. In 71% (10/14) of the children, the spinal fractures were accompanied by intracranial injury. Children with spinal fractures were at significantly greater risk for intracranial injury than those without spinal injury ( $P < 0.05$ ).	4
19. Jha P, Stein-Wexler R, Coulter K, Seibert A, Li CS, Wootton-Gorges SL. Optimizing bone surveys performed for suspected non-accidental trauma with attention to maximizing diagnostic yield while minimizing radiation exposure: utility of pelvic and lateral radiographs. <i>Pediatr Radiol.</i> 2013;43(6):668-672.	Review/Other-Dx	530 children	To determine whether pelvic and lateral spinal radiographs should routinely be performed during initial bone surveys for suspected NAT.	Of the 530 children, 223 (42.1%) had rib and extremity fractures suspicious for NAT. No fractures were identified solely on pelvic radiographs. Only 1 child (<0.2%) had vertebral compression deformities identified on a lateral spinal radiograph. This infant had rib and extremity fractures and was clinically paraplegic. MRI confirmed the vertebral body fractures.	4
20. Kleinman PK, Morris NB, Makris J, Moles RL, Kleinman PL. Yield of radiographic skeletal surveys for detection of hand, foot, and spine fractures in suspected child abuse. <i>AJR Am J Roentgenol.</i> 2013;200(3):641-644.	Observational-Dx	365 studies	To assess the prevalence of fractures of the spine, hands, and feet in cases of suspected child abuse on ACR-standardized SSs acquired near the end of the film-screen era.	20 of 365 studies (5.5%) yielded fractures involving the spine, hands, or feet. Of all positive SSs, 8.9% (20/225) had fractures involving the spine, hands, or feet. Of all patients with more than 1 fracture on SS, 20.4% (20/98) had fractures involving these regions.	4

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21. Phillips KL, Bastin ST, Davies-Payne D, et al. Radiographic skeletal survey for non-accidental injury: systematic review and development of a national New Zealand protocol. <i>J Med Imaging Radiat Oncol.</i> 2015;59(1):54-65.	Review/Other-Dx	30 documents	To undertake a systematic review of the evidence supporting SS protocols to design a protocol that could be implemented across New Zealand.	We identified 2 guidelines for SS, 13 other protocols and 15 articles providing evidence for inclusion of specific images in a SS. The guidelines scored poorly on critical appraisal of several aspects of their methods. We found no studies that validate any of the protocols or compare their performance. Evidence supporting inclusion in a SS is limited to ribs, spine, pelvis, hands and feet, and long bone views. Our final protocol is a standardized, 2-tiered protocol consisting of between 17 and 22 views.	4
22. Harper NS, Eddleman S, Lindberg DM. The utility of follow-up skeletal surveys in child abuse. <i>Pediatrics.</i> 2013;131(3):e672-678.	Observational-Dx	796 children	To determine the proportion of follow-up SSs that identified new information in a large, multicenter population of children with concerns of physical abuse.	Among 2890 children enrolled in the Examining Siblings To Recognize Abuse research network, 2049 underwent SS and 796 (38.8%) had follow-up SSs. A total of 174 (21.5%) subjects had new information identified by follow-up SSs, including 124 (15.6%) with at least 1 new fracture and 55 (6.9%) with reassuring findings compared with the initial SS. Among cases with new fractures, the estimated likelihood of abuse increased in 41 (33%) cases, and 51 cases (41%) remained at the maximum likelihood of abuse.	4
23. Section on Radiology; American Academy of Pediatrics. Diagnostic imaging of child abuse. <i>Pediatrics.</i> 2009;123(5):1430-1435.	Review/Other-Dx	N/A	Review role of diagnostic imaging in cases of child abuse.	Imaging helps to identify the extent of physical injury when abuse is present and clarifies all imaging findings that point to alternative diagnoses. High-quality technologies, clinical and pathologic alterations that occur in abused children are all important factors in diagnosis.	4
24. Hansen KK, Keeshin BR, Flaherty E, et al. Sensitivity of the limited view follow-up skeletal survey. <i>Pediatrics.</i> 2014;134(2):242-248.	Observational-Dx	534 study subjects	To determine if a large multicenter study would support the results of our previous single-center study. Our hypothesis was that there would be no clinically significant difference in results from a limited view SS2 protocol that omits the spine and pelvis views (when no spine or pelvis fractures or questioned fractures are present on SS1) compared with a traditional SS2 protocol for radiographic evaluation of suspected physical abuse.	We identified 534 study subjects. 5 subjects had newly identified spine fractures, and no subjects had newly identified pelvis fractures on traditional SS2 studies. Only 1 subject with a newly identified spine fracture would have been missed with the limited view SS2 protocol used in this study (0.2% [95% CI: <0.005–1.0]). None of the newly identified fractures changed the abuse-related diagnosis.	4

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25. Sonik A, Stein-Wexler R, Rogers KK, Coulter KP, Wootton-Gorges SL. Follow-up skeletal surveys for suspected non-accidental trauma: can a more limited survey be performed without compromising diagnostic information? <i>Child Abuse Negl.</i> 2010;34(10):804-806.	Observational-Dx	22 cases	To evaluate if certain radiographs can be excluded at follow-up SS without compromising the clinical efficacy.	A total of 36 fractures were found on the initial bone survey in 16/22 patients (73%). 6 patients had no fractures detected at initial survey. Follow-up bone surveys demonstrated an additional 3 fractures (2 extremities and 1 rib) in 3/22 cases (14%); 1 was in a patient whose initial survey was negative. No additional fractures in the skull, spine, pelvis, feet, or hands were detected in any case. In combination with patients reported in the literature (194 patients total) no new fracture of the skull, spine, pelvis, or hands was detected at follow-up survey. The skull, spine and pelvis radiographs are the highest dose-exposure studies of the SS.	3
26. Zimmerman S, Makoroff K, Care M, Thomas A, Shapiro R. Utility of follow-up skeletal surveys in suspected child physical abuse evaluations. <i>Child Abuse Negl.</i> 2005;29(10):1075-1083.	Observational-Dx	48 children	Prospective study to evaluate the value of a follow-up SS in suspected child physical abuse evaluations.	Follow-up SS yielded additional information in 22/48 patients (46%). It identified additional fractures or clarified tentative findings in children who were suspected victims of physical child abuse. The follow-up SS is recommended.	4
27. Prosser I, Maguire S, Harrison SK, Mann M, Sibert JR, Kemp AM. How old is this fracture? Radiologic dating of fractures in children: a systematic review. <i>AJR Am J Roentgenol.</i> 2005;184(4):1282-1286.	Review/Other-Dx	3 articles	To conduct a systematic review of the literature to define the evidence for radiologic dating of fractures in children in the context of child protection.	Radiologic dating of fractures is an inexact science. Most radiologists date fractures on the basis of their personal clinical experience, and the literature provides little consistent data to act as a resource. There is an urgent need for research to validate the criteria used in the radiologic dating of fractures in children younger than 5 years.	4
28. Bainbridge JK, Huey BM, Harrison SK. Should bone scintigraphy be used as a routine adjunct to skeletal survey in the imaging of non-accidental injury? A 10 year review of reports in a single centre. <i>Clin Radiol.</i> 2015;70(8):e83-89.	Observational-Dx	166 patients	To retrospectively analyses the BS and SS data to evaluate the role and limitations of BS in the diagnosis of nonaccidental injury.	166 patients had both SS and BS. The findings were congruent in 74% of cases. BS added confidence to the SS findings in 8% and revealed a new abnormality in 4% of patients. BS demonstrated false-positive and -negative rates of 2% and 13%, respectively. Occult bony injury was detected in 12% of the 237 patients imaged.	3

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29. Kemp AM, Butler A, Morris S, et al. Which radiological investigations should be performed to identify fractures in suspected child abuse? <i>Clin Radiol.</i> 2006;61(9):723-736.	Meta-analysis	34 studies;2 reviewers	Meta-analysis to determine which radiological investigations should be performed to identify fractures in suspected child abuse.	Diagnostic imaging of the skeleton is necessary for children under 2-years old, where physical abuse is suspected. The following options would increase diagnostic yield if evaluated prospectively: SSs that includes oblique views, SSs and BS, a SS with repeat SS or selected images 2 weeks later or a BS plus skull radiography and coned views of metaphyses and epiphyses.	M
30. Conway JJ, Collins M, Tanz RR, et al. The role of bone scintigraphy in detecting child abuse. <i>Semin Nucl Med.</i> 1993;23(4):321-333.	Review/Other-Dx	N/A	Review role of bone scan in detecting child abuse.	Major advantages of bone scan are increased sensitivity (25% to 50%) in detecting evidence of soft-tissue and bone trauma in child abuse. Radionuclide scintigraphy is a complementary rather than competitive imaging modality to radiography evaluation in the diagnosis and management of physical child abuse.	4
31. Jaudes PK. Comparison of radiography and radionuclide bone scanning in the detection of child abuse. <i>Pediatrics.</i> 1984;73(2):166-168.	Observational-Dx	110 children	To compare radiographic surveys or radionuclide bone scans to detect child abuse.	110 children were evaluated with either radiographic surveys or bone scans, and 50 children had both roentgenograms and bone scans. In 40% of the children there was at least 1 fracture whereas 20% had between 2 and 7 fractures. Among the children who received both SSs and bone scans, 41 fractures were detected: SS detected 52% and bone scan detected 88% of those fractures. Children with fractures were more likely to be placed in foster homes than to be returned to the original environment. The presence of single vs multiple fractures did not alter the probability of foster placement.	3
32. Mandelstam SA, Cook D, Fitzgerald M, Ditchfield MR. Complementary use of radiological skeletal survey and bone scintigraphy in detection of bony injuries in suspected child abuse. <i>Arch Dis Child.</i> 2003;88(5):387-390; discussion 387-390.	Observational-Dx	124 bone injuries in 30 children	Retrospective review to compare the effectiveness of radiological SS and BS for the detection of bony injuries in suspected child abuse cases.	64/124 injuries were identified on bone scan and 77 on SS. SS and BS are complementary studies in the evaluation of nonaccidental injury, and should both be performed in cases of suspected child abuse.	3
33. Hedlund GL, Frasier LD. Neuroimaging of abusive head trauma. <i>Forensic Sci Med Pathol.</i> 2009;5(4):280-290.	Review/Other-Dx	N/A	To review pertinent neuroimaging modalities currently utilized in the diagnosis of AHT, describing clinical indications and a collaborative approach to this process.	No results stated in abstract.	4

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34. Langford S, Panigrahy A, Narayanan S, et al. Multiplanar reconstructed CT images increased depiction of intracranial hemorrhages in pediatric head trauma. <i>Neuroradiology</i> . 2015;57(12):1263-1268.	Observational-Dx	215 cases	To evaluate unenhanced head CTs in pediatric trauma patients to investigate the various benefits of multiplanar reconstructed images in this age group.	Multiplanar reconstructed images improved the detection of hemorrhage in 14 cases (6.5 %, $P < 0.01$ ) and incidental findings in 5 cases (2.3 %, $P < 0.05$ ) as well as helped prove artifacts in 5 cases (2.3 %, $P < 0.05$ ).	4
35. Prabhu SP, Newton AW, Perez-Rossello JM, Kleinman PK. Three-dimensional skull models as a problem-solving tool in suspected child abuse. <i>Pediatr Radiol</i> . 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
36. 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. <i>Clin Radiol</i> . 2009;64(5):473-483.	Review/Other-Dx	18 studies; 367 children	Systematic review to examine the optimal neuroradiological investigation strategy to identify inflicted brain injury.	Combining MRI with an abnormal early CT revealed additional information in 25% (95% CI: 18.3%–33.16%) of children. Optimal imaging strategy involves initial CT, followed by early MRI and diffusion-weighted imaging if early CT examination is abnormal, or there are ongoing clinical concerns.	4
37. Williams VL, Hogg JP. Magnetic resonance imaging of chronic subdural hematoma. <i>Neurosurg Clin N Am</i> . 2000;11(3):491-498.	Review/Other-Dx	N/A	To highlights the unique ability of MRI in evaluating the evolution of the subdural hematoma.	No results stated in abstract.	4
38. Vezina G. Assessment of the nature and age of subdural collections in nonaccidental head injury with CT and MRI. <i>Pediatr Radiol</i> . 2009;39(6):586-590.	Review/Other-Dx	N/A	No abstract available.	No abstract available.	4
39. Adamsbaum C, Rambaud C. Abusive head trauma: don't overlook bridging vein thrombosis. <i>Pediatr Radiol</i> . 2012;42(11):1298-1300.	Review/Other-Dx	N/A	No abstract available.	No abstract available.	4



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40. Choudhary AK, Bradford R, Dias MS, Thamburaj K, Boal DK. Venous injury in abusive head trauma. <i>Pediatr Radiol.</i> 2015;45(12):1803-1813.	Observational-Dx	45 children	To define the incidence and characteristics of venous and sinus abnormalities in AHT.	A total of 45 children were included. The median age was 3 months (range 15 days to 31 months) and 28 were boys (62%). Clinical findings included retinal hemorrhage in 71% and extracranial fractures in 55%. CT or MRI demonstrated subdural hemorrhage in 41 (91%); none had subdural effusions. In 31 cases (69%) MR venography demonstrated mass effect on the venous sinuses or cortical draining veins, with either displacement or partial or complete effacement of the venous structures from an adjacent subdural hematoma or brain swelling. We also describe the lollipop sign, which represents direct trauma to the cortical bridging veins and was present in 20/45 (44%) children.	2
41. Beavers AJ, Stagner AM, Allbery SM, Lyden ER, Hejkal TW, Haney SB. MR detection of retinal hemorrhages: correlation with graded ophthalmologic exam. <i>Pediatr Radiol.</i> 2015;45(9):1363-1371.	Observational-Dx	77 children	To determine the value of standard brain protocol MRI in detecting retinal hemorrhage and to determine whether there is any correlation with MR detection of retinal hemorrhage and the dilated fundoscopic exam grade of hemorrhage.	There was a statistically significant difference in the median grade of retinal hemorrhage examination between children who had retinal hemorrhage detected on MRI and children who did not have retinal hemorrhage detected on MRI ( $P=0.02$ ). When examination grade was categorized as low-grade (1-4), moderate-grade (5-8) or high-grade (>8) hemorrhage, there was a statistically significant association between exam grade and diagnosis based on MRI ( $P=0.008$ ). For example, only 14% of children with low-grade retinal hemorrhages were identified on MRI compared to 76% of children with high-grade hemorrhages. MR detection of retinal hemorrhage demonstrated a sensitivity of 61%, specificity of 100%, PPV of 100% and NPV of 63%. Retinal hemorrhage was best seen on the gradient recalled echo sequences.	3

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42. Zuccoli G, Panigrahy A, Haldipur A, et al. Susceptibility weighted imaging depicts retinal hemorrhages in abusive head trauma. <i>Neuroradiology</i> . 2013;55(7):889-893.	Observational-Dx	28 patients	To evaluate the capability of MRI susceptibility weighted images in depicting retinal hemorrhages in AHT compared to the gold standard dilated fundus exam.	Of the 21 subjects with retinal hemorrhages on dilated fundus exam, 13 (62%) were identified by using a standard susceptibility weighted images sequence performed as part of brain MRI protocols. Of the 15 patients who also underwent an orbits susceptibility weighted images protocol, 12 (80%) were positive for retinal hemorrhages. None of the 7 patients without retinal hemorrhages on dilated fundus exam had retinal hemorrhages on either standard or high-resolution susceptibility weighted images. Compared with dilated fundus exam, the MRI standard protocol showed a sensitivity of 75% which increased to 83% for the orbits susceptibility weighted images protocol.	3
43. Choudhary AK, Bradford RK, Dias MS, Moore GJ, Boal DK. Spinal subdural hemorrhage in abusive head trauma: a retrospective study. <i>Radiology</i> . 2012;262(1):216-223.	Review/Other-Dx	252 children	To compare the relative incidence, distribution, and radiologic characteristics of spinal subdural hemorrhage after AHT vs that after accidental trauma in children.	In the AHT cohort, 67 (26.5%) of 252 children had evaluable spinal imaging results. Of these, 38 (56%) of 67 children had undergone thoracolumbar imaging, and 24 (63%) of 38 had thoracolumbar subdural hemorrhage. Spinal imaging was performed in this cohort 0.3–141 hours after injury (mean, 23 hours +/- 27 [standard deviation]), with 65 (97%) of 67 cases having undergone imaging within 52 hours of injury. In the second cohort with accidental injury, only 1 (1%) of 70 children had spinal subdural hemorrhage at presentation; this patient had displaced occipital fracture. The comparison of incidences of spinal subdural hemorrhage in AHT vs those in accidental trauma was statistically significant ( $P<.001$ ).	4

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44. 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. <i>Pediatr Radiol.</i> 2014;44(7):839-848.	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. 1 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
45. Koumellis P, McConachie NS, Jaspan T. Spinal subdural haematomas in children with non-accidental head injury. <i>Arch Dis Child.</i> 2009;94(3):216-219.	Review/Other-Dx	18 infants	To examine the incidence of spinal pathology in infants with nonaccidental head injury.	There was a high incidence (8/18 cases, 44%) of subdural collections in the spine. They were all clinically occult and in 6 cases large. All 8 cases were associated with subdural hematomas in the supratentorial and infratentorial compartment. The signal characteristics were analyzed and compared with those of the intracranial collections. 1 had a small epidural hematoma. Other depicted abnormalities and appearances at follow-up were also reviewed.	4

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46. Wootton-Gorges SL, Stein-Wexler R, Walton JW, Rosas AJ, Coulter KP, Rogers KK. Comparison of computed tomography and chest radiography in the detection of rib fractures in abused infants. <i>Child Abuse Negl.</i> 2008;32(6):659-663.	Observational-Dx	12 abused infants	To compare CT and chest radiography in the evaluation of rib fractures in abused infants.	The mean patient age was 2.5 months (1.2–5.6), with 7 females and 5 males. While 131 fractures were visualized by CT, only 79 were seen by chest radiography ( $P<.001$ ). 1 patient had fractures only seen by CT. There were significantly ( $P<.05$ ) more early subacute (24 vs 4), subacute (47 vs 26), and old fractures (4 vs 0) seen by CT than by chest radiography. Anterior (42 vs 11), anterolateral (21 vs 12), posterolateral (9 vs 3) and posterior (39 vs 24) fractures were better seen by CT than by chest radiography ( $P<.01$ ). Bilateral fractures were detected more often by CT (11) than by chest radiography (6).	2
47. Sanchez TR, Lee JS, Coulter KP, Seibert JA, Stein-Wexler R. CT of the chest in suspected child abuse using submillisievert radiation dose. <i>Pediatr Radiol.</i> 2015;45(7):1072-1076.	Observational-Dx	4 children	To determine if CT of the chest in suspected child abuse using submillisievert radiation dose is more useful in the evaluation of high specificity fractures of NAT when the 4-view chest radiographs are negative.	We retrospectively identified 4 children (3 boys, 1 girl; age range 1–4 months) admitted between January 2013 and February 2014 with high suspicion for NAT from unexplained fractures of the long bones; these children all had CT of the chest when no rib fractures were evident on the SS. The absorbed radiation dose estimates for organs and tissue from the 4-view chest radiographs and subsequent CT were determined using Monte Carlo photon transport software, and the effective dose was calculated using published tissue-weighting factors. In 2 children, CT showed multiple fractures of the ribs, scapula and vertebral body that were not evident on the initial SS. The average effective dose for a 4-view chest radiograph across the 4 children was 0.29 mSv and the average effective dose for the chest CT was 0.56 mSv. Therefore the effective dose of a chest CT is on average less than twice that of a 4-view chest radiograph.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
48. Alkadhi H, Wildermuth S, Marincek B, Boehm T. Accuracy and time efficiency for the detection of thoracic cage fractures: volume rendering compared with transverse computed tomography images. <i>J Comput Assist Tomogr.</i> 2004;28(3):378-385.	Observational-Dx	50 patients	To compare accuracy and time efficiency of volume rendering compared to transverse images on MDCT to identify thoracic cage fractures. Patients with acute blunt chest trauma.	30/50 patients had 178 rib fractures. Mean sensitivity, specificity and accuracy for their detection were similar for transverse (96%, 100% and 99%) and volume rendering (98%, 100% and 100%) images. The time to read volume rendering images (106 seconds) was significantly reduced compared to the time needed for transverse image reading (167 seconds).	2
49. Sheybani EF, Gonzalez-Araiza G, Kousari YM, Hulett RL, Menias CO. Pediatric nonaccidental abdominal trauma: what the radiologist should know. <i>Radiographics.</i> 2014;34(1):139-153.	Review/Other-Dx	N/A	To review injury patterns and their imaging appearances, especially abdominal injury in NAT.	No results stated in abstract.	4
50. Harper NS, Feldman KW, Sugar NF, Anderst JD, Lindberg DM. Additional injuries in young infants with concern for abuse and apparently isolated bruises. <i>J Pediatr.</i> 2014;165(2):383-388 e381.	Review/Other-Dx	2890 children	To determine the prevalence of additional injuries or bleeding disorders in a large population of young infants evaluated for abuse because of apparently isolated bruising.	Among 2890 children, 33.9% (980/2890) were <6 months old, and 25.9% (254/980) of these had bruises identified. Within this group, 57.5% (146/254) had apparently isolated bruises at presentation. SSS identified new injury in 23.3% (34/146), neuroimaging identified new injury in 27.4% (40/146), and abdominal injury was identified in 2.7% (4/146). Overall, 50% (73/146) had at least 1 additional serious injury. Although testing for bleeding disorders was performed in 70.5% (103/146), no bleeding disorders were identified. Ultimately, 50% (73/146) had a high perceived likelihood of abuse.	4
51. Lindberg DM, Berger RP, Reynolds MS, Alwan RM, Harper NS. Yield of skeletal survey by age in children referred to abuse specialists. <i>J Pediatr.</i> 2014;164(6):1268-1273 e1261.	Observational-Dx	2609 children	To determine rates of SS completion and injury identification as a function of age among children who underwent subspecialty evaluation for concerns of physical abuse.	Among 2609 subjects, 2036 (78%) had SS and 458 (18%) had at least 1 new fracture identified. For all age groups up to 36 months, SS was obtained in >50% of subjects, but rates decreased to <35% for subjects >36 months. New fracture identification rates for SS were similar between children 24–36 months of age (10.3%, 95% CI, 7.2–14.2) and children 12–24 months of age (12.0%, 95% CI, 9.2–15.3)	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
52. Wood JN, Fakeye O, Feudtner C, Mondestin V, Localio R, Rubin DM. Development of guidelines for skeletal survey in young children with fractures. <i>Pediatrics</i> . 2014;134(1):45-53.	Review/Other-Dx	N/A	To develop guidelines for performing initial SS in children <24 months old with fractures, based on available evidence and collective judgment of experts from diverse pediatric specialties.	Panelists agreed that SS is “appropriate” for 191 (80%) of 240 scenarios rated and “necessary” for 175 (92%) of the appropriate scenarios. SS is necessary if a fracture is attributed to abuse, domestic violence, or being hit by a toy. With few exceptions, SS is necessary in children without a history of trauma. In children <12 months old, SS is necessary regardless of the fracture type or reported history, with rare exceptions. In children 12 to 23 months old, the necessity of obtaining SS is dependent on fracture type.	4
53. Barber I, Perez-Rossello JM, Wilson CR, Kleinman PK. The yield of high-detail radiographic skeletal surveys in suspected infant abuse. <i>Pediatr Radiol</i> . 2015;45(1):69-80.	Observational-Dx	567 infants	To determine the diagnostic yield of high-detail radiographic SSs in suspected infant abuse.	In 313/567 infants (55%), 1029 definite fractures were found. 21% (119/567) of the patients had a positive SS with a total of 789 (77%) unsuspected fractures. Long-bone fractures were the most common injuries, present in 145 children (26%). The skull was the site of fracture in 138 infants (24%); rib cage in 77 (14%), clavicle in 24 (4.2%) and uncommon fractures (including spine, scapula, hands and feet and pelvis) were noted in 26 infants (4.6%). Of the 425 infants with neuroimaging, 154 (36%) had intracranial injury. No significant correlation between positive SS and associated intracranial injury was found. Scapular fractures and complex skull fractures showed a statistically significant correlation with intracranial injury ( $P=0.029$ , $P=0.007$ , respectively).	4
54. Duffy SO, Squires J, Fromkin JB, Berger RP. Use of skeletal surveys to evaluate for physical abuse: analysis of 703 consecutive skeletal surveys. <i>Pediatrics</i> . 2011;127(1):e47-52.	Observational-Dx	703 SS	To assess the use of the SS to evaluate for physical abuse in a large consecutive sample, to identify characteristics of children most likely to have unsuspected fractures, and to determine how often SS results influenced directly the decision to make a diagnosis of abuse.	Of the 703 SSs, 10.8% yielded positive results. Children <6 months of age, children with an apparent life-threatening event or seizure, and children with suspected AHT had the highest rates of positive SS results. Of children with positive SS results, 79% had $\geq 1$ healing fracture.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
55. Kleinman PK, Perez-Rossello JM, Newton AW, Feldman HA, Kleinman PL. Prevalence of the classic metaphyseal lesion in infants at low versus high risk for abuse. <i>AJR Am J Roentgenol</i> . 2011;197(4):1005-1008.	Review/Other-Dx	42 infants	To determine the relative likelihood of encountering a classic metaphyseal lesion in infants at low and high risk for abuse	There were 42 low-risk infants (age range, 0.4–12 months; mean age, 4.4 months) and 18 high-risk infants (age range, 0.8–10.3 months; mean age, 4.6 months). At least 1 classic metaphyseal lesion was identified in 9 infants (50%) in the high-risk category. No classic metaphyseal lesions were identified in the low-risk group. The relative prevalence of classic metaphyseal lesions in the low-risk group (0/42) vs that in the high-risk group (9/18) was statistically significant ( $P<0.0001$ ; 95% CI, 0%–8% to 29%–76%).	4
56. Leventhal JM, Thomas SA, Rosenfield NS, Markowitz RI. Fractures in young children. Distinguishing child abuse from unintentional injuries. <i>Am J Dis Child</i> . 1993;147(1):87-92.	Review/Other-Dx	215 children 253 fractures	Case series to determine features of fractures in young children that are useful in distinguishing child abuse from unintentional injuries.	Fractures considered likely due to abuse were: 1) Fractures in children whose caretakers reported either a change in the child's behavior, but no accidental event, or a minor fall, but the injury was more severe than expected; 2) Fractures of the radius/ulna, tibia/fibula, or femur in children <1 year of age; 3) Midshaft or metaphyseal fractures of the humerus.	4
57. Shrader MW, Bernat NM, Segal LS. Suspected nonaccidental trauma and femoral shaft fractures in children. <i>Orthopedics</i> . 2011;34(5):360.	Review/Other-Dx	137 patients	To analyze femoral shaft fractures at a major pediatric level I trauma center in a large metropolitan area over a 5-year period to determine the incidence of suspected NAT and the risk factors associated with that diagnosis.	Over the 5-year study period, 137 patients presented to our institution with a femoral shaft fracture. Mean patient age at the time of injury was 2.2 years (range, 1 month to 4 years). Overall, 43 patients with a mean age of 1.8 years were determined to have injuries suspicious of NAT and were referred to Child Protective Services, giving an overall incidence of 31%. Age younger than 1 year was a highly significant risk factor for suspected NAT. Of the 20 children younger than 1 year, 18 (90%) were referred to Child Protective Services, comprising 42% of those children suspicious of NAT.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
58. Lloyd DA, Carty H, Patterson M, Butcher CK, Roe D. Predictive value of skull radiography for intracranial injury in children with blunt head injury. <i>Lancet</i> . 1997;349(9055):821-824.	Observational-Dx	883 children; CT done in 156 children	Prospectively study head-injured children to assess the value of skull radiography.	Radiographs showed 162 fractures. 107/156 children had a skull fracture. 23 children had intracranial injuries on CT. The presence of neurological abnormalities had sensitivity of 91% (21/23) and NPV of 97%. The corresponding values for skull fracture on radiography were 65% (15/23) and 83%. Skull radiograph not reliable to detect intracranial injury. A neurological abnormality is predictor of intracranial injury.	3
59. Quayle KS, Jaffe DM, Kuppermann N, et al. Diagnostic testing for acute head injury in children: when are head computed tomography and skull radiographs indicated? <i>Pediatrics</i> . 1997;99(5):E11.	Observational-Dx	322 children	Prospective cohort study to provide information relevant to the choice of imaging modalities in children with acute head trauma.	Intracranial injury occurred in 27 children (8%), while 50 (16%) had skull fractures. Intracranial injury may occur with few or subtle signs and symptoms in children <1 year.	3
60. Laskey AL, Holsti M, Runyan DK, Socolar RR. Occult head trauma in young suspected victims of physical abuse. <i>J Pediatr</i> . 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 SS and no clinical signs of intracranial injury. 75% of patients had CT or MRI; 69% had formal evaluation for retinal hemorrhages. 29% had evidence of intracranial injury without neurologic symptoms. Age <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 intracranial injury.	4



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EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
61. Rubin DM, Christian CW, Bilaniuk LT, Zazyczny KA, Durbin DR. Occult head injury in high-risk abused children. <i>Pediatrics</i> . 2003;111(6 Pt 1):1382-1386.	Review/Other-Dx	65 patients	To estimate the prevalence of occult head injury in a high-risk sample of abused children with normal neurologic examinations and to describe characteristics of this population.	Of the 65 patients, 51 (78.5%) had a head CT or MRI in addition to SS. 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 intracranial injury (53%). All except 3 of the head-injured patients had at least a skull fracture or intracranial injury. SS 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
62. Wilson PM, Chua M, Care M, Greiner MV, Keeshin B, Bennett B. Utility of head computed tomography in children with a single extremity fracture. <i>J Pediatr</i> . 2014;164(6):1274-1279.	Observational-Dx	320 children	To determine the clinical and forensic utility of head CT in children <2 years of age with an acute isolated extremity fracture and an otherwise-negative SS.	Of the 320 children evaluated, 37% received neuroimaging, 95.7% of which had no signs of skull fracture or intracranial trauma. 5 children (4.3%) with head imaging had traumatic findings but no children in the study had clinically significant head injury. 3 of these children had previous concerns for NAT and findings on head CT that were forensically significant. There was a greater rate of head imaging in children in the younger age groups and those with proximal extremity fractures ( $P<.05$ ).	4
63. Rennie L, Court-Brown CM, Mok JY, Beattie TF. The epidemiology of fractures in children. <i>Injury</i> . 2007;38(8):913-922.	Review/Other-Dx	108,987 children	To analyze all pediatric fractures presenting to hospital in Edinburgh, Scotland in 2000 to ascertain their incidence, demonstrate which fractures were most common and investigate the causes of fracture in different age groups. And to examine the fracture distribution curves of all fractures to see if there was a reproducible set of curves, which would encompass all fractures.	Analysis of pediatric fractures shows that there are 6 basic fracture distribution curves with 6 fractures showing a bimodal distribution but most having a unimodal distribution affecting younger or older children. The incidence of fractures increases with age with falls from below bed height (<1m) being the commonest cause of fracture. The majority of fractures in children involve the upper limb. Lower limb fractures are mainly caused by twisting injuries and road traffic accidents.	4

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EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
64. Kellogg ND. Evaluation of suspected child physical abuse. <i>Pediatrics</i> . 2007;119(6):1232-1241.	Review/Other-Dx	N/A	Review clinical guidance in the evaluation of suspected physical abuse in children. Medical assessment is outlined with respect to obtaining a history, physical examination, and appropriate ancillary testing.	Role of physicians include reporting suspected abuse; assessing the consistency of the explanation, the child's developmental capabilities, and the characteristics of the injury or injuries. Accurate and timely diagnosis can ensure appropriate evaluation, investigation, and outcomes.	4
65. Keenan HT, Runyan DK, Marshall SW, Nocera MA, Merten DF, Sinal SH. A population-based study of inflicted traumatic brain injury in young children. <i>JAMA</i> . 2003;290(5):621-626.	Review/Other-Dx	152 cases	To determine the incidence of serious or fatal inflicted traumatic brain injury in a defined U.S. population of approximately 230 000 children aged 2 years or younger.	A total of 152 cases of serious or fatal traumatic brain injury were identified, with 80 (53%) incurring inflicted traumatic brain injury. The incidence of inflicted traumatic brain injury in the first 2 years of life was 17.0 (95% CI, 13.3–20.7) per 100,000 person-years. Infants had a higher incidence than children in the second year of life (29.7 [95% CI, 22.9–36.7] vs 3.8 [95% CI, 1.3–6.4] per 100,000 person-years). Boys had a higher incidence than girls (21.0 [95% CI, 15.1–26.6] vs 13.0 [95% CI, 8.4–17.7] per 100,000 person-years). Relative to the general population, children who incurred an increased risk of inflicted injury were born to young mothers ( $\leq 21$ years), non-European American, or products of multiple births.	4
66. Kemp AM, Jaspan T, Griffiths J, et al. Neuroimaging: what neuroradiological features distinguish abusive from non-abusive head trauma? A systematic review. <i>Arch Dis Child</i> . 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. Diffuse-weighted imaging 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/diffuse-weighted imaging.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
67. Cramer JA, Rassner UA, Hedlund GL. Limitations of T2*-Gradient Recalled-Echo and Susceptibility-Weighted Imaging in Characterizing Chronic Subdural Hemorrhage in Infant Survivors of Abusive Head Trauma. <i>AJNR Am J Neuroradiol.</i> 2016.	Review/Other-Dx	N/A	To present 5 cases of chronic subdural hemorrhages in infants, demonstrating intensity near or greater than that of cerebrospinal fluid with variable amounts of hemosiderin staining along the neomembranes. To review the physiology and MRI physics behind the appearance of a chronic subdural hemorrhage, highlighting that the absence of a BBB can allow hemosiderin to be completely removed from the subdural compartment. To stress the importance of reviewing all multiplanar sequences for the presence of neomembranes, which can be quite subtle in the absence of hemosiderin staining and are critical for making the diagnosis of chronic subdural hemorrhage.	No results stated in abstract.	4
68. Sieswerda-Hoogendoorn T, Postema FA, Verbaan D, Majoie CB, van Rijn RR. Age determination of subdural hematomas with CT and MRI: a systematic review. <i>Eur J Radiol.</i> 2014;83(7):1257-1268.	Review/Other-Dx	22 studies	To systematically review the literature on dating subdural hematomas on CT and MRI scans.	We included 22 studies describing 973 subdural hematomas on CT and 4 studies describing 83 subdural hematomas on MRI. Data from 17 studies (413 subdural hematomas) could be pooled. There were significant differences between time intervals for the different densities on CT ( $P<0.001$ ). Time interval differed significantly between children and adults for iso- and hypodensity ( $P=0.000$ ) and hyperdensity ( $P=0.046$ ). Time interval did not differ significantly between abused and nonabused children. On MRI, time intervals for different signal intensities on T1 and T2 did not differ significantly ( $P=0.108$ and $P=0.194$ , respectively).	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
69. Larimer EL, Fallon SC, Westfall J, Frost M, Wesson DE, Naik-Mathuria BJ. The importance of surgeon involvement in the evaluation of non-accidental trauma patients. <i>J Pediatr Surg.</i> 2013;48(6):1357-1362.	Review/Other-Dx	267 patients	To evaluate the necessity of primary surgical evaluation and admission to the trauma service for children presenting with NAT.	We identified 267 NAT patients presenting with 473 acute injuries. Injuries in NAT patients were more severe than in AT patients, and Injury Severity Scores, ICU admission rates, and mortality were all significantly ( $P<0.001$ ) higher. The majority suffered from polytrauma. Multiple areas of injury were seen in patients with closed head injuries (72%), extremity fractures (51%), rib fractures (82%), and abdominal/thoracic trauma (80%). Despite these complex injury patterns, only 56% received surgical consults, resulting in potential delays in diagnosis, as 24% of abdominal CT scans were obtained >12 hours after hospitalization.	4
70. Trokel M, DiScala C, Terrin NC, Sege RD. Blunt abdominal injury in the young pediatric patient: child abuse and patient outcomes. <i>Child Maltreat.</i> 2004;9(1):111-117.	Review/Other-Dx	927 children	Extract cases from National Pediatric Trauma Registry to evaluate injury causes and patient outcomes in young children (0–4 years) with abdominal injuries.	3 most common mechanisms of abdominal injury were motor vehicles (61.27%), child abuse (15.75%), and falls (13.59%). Patient outcomes were more severe in abused children. Child abuse, compared to falls, is independently associated with a 6-fold increase in in-hospital mortality.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
71. Trokel M, Discala C, Terrin NC, Sege RD. Patient and injury characteristics in abusive abdominal injuries. <i>Pediatr Emerg Care.</i> 2006;22(10):700-704.	Review/Other-Dx	664 cases	To identify patient and injury characteristics associated with suspected child abuse in the setting of blunt abdominal trauma.	664 cases were analyzed. The median age of patients was 2.6 years; 11.4% were undernourished. The 3 most common mechanisms of injury were suspected child abuse (40.5%), fall (36.6%), and struck-not child abuse (9.7%). Hepatic injury (46.1%) was the most common intra-abdominal injury, followed by splenic (26%), hollow viscous (17.9%), and pancreatic (8.6%) injuries. 84% of deaths were related to suspected child abuse. There was a greater proportion of children with suspected child abuse in every patient and injury characteristics studied than all other mechanisms combined. In a regression model including age, undernourishment, pancreatic injury, hollow viscous injury, traumatic brain injury, and mortality, all variables were significantly associated with suspected abuse. Hollow viscous injury had the highest (OR, 9.5; confidence limits, 5.7, 15.8), whereas traumatic brain injury had the lowest (OR, 3.6; confidence limits, 2.4, 5.6).	4
72. Ledbetter DJ, Hatch EI, Jr., Feldman KW, Fligner CL, Tapper D. Diagnostic and surgical implications of child abuse. <i>Arch Surg.</i> 1988;123(9):1101-1105.	Review/Other-Dx	156 children	To review children <13 years with blunt abdominal injuries, and compare those injured in accidents (89%) with those injured by child abuse (11%).	Abused children were younger (mean age, 2 1/2 years) and all presented late to medical attention with a history that was inconsistent with their physical findings. Only 65% of abused children had physical or roentgenographic signs of prior abuse, while 35% had no signs of prior abuse. Physicians should suspect child abuse when children have unexplained injuries (especially young children with hollow viscus injuries).	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
73. Hilmes MA, Hernanz-Schulman M, Greeley CS, Piercey LM, Yu C, Kan JH. CT identification of abdominal injuries in abused pre-school-age children. <i>Pediatr Radiol.</i> 2011;41(5):643-651.	Review/Other-Dx	84 children	Retrospective review of a child abuse registry was performed to describe abdominopelvic injuries in abused pre-school-age children as identified on CT.	Of 84 children, 35 (41.7%) had abdominal injuries. Abdominal injuries included liver (15), bowel (13), mesentery (4), spleen (6), kidneys (7), pancreas (4) and adrenal glands (3). Of these children, 26% (9/35) required surgical intervention for bowel, mesenteric and pancreatic injuries. Another 9/35 children died, not as a result of abdominal injuries but as a direct result of inflicted intracranial injuries. Data indicate that abdominal injuries in abused children present in a pattern similar to that of children with accidental abdominal trauma, underscoring the need for vigilance and correlative historical and clinical data to identify victims of abuse. Mortality in abused children with intra-abdominal injury was frequently related to concomitant head injury.	4
74. Lindberg D, Makoroff K, Harper N, et al. Utility of hepatic transaminases to recognize abuse in children. <i>Pediatrics.</i> 2009;124(2):509-516.	Observational-Dx	1,272 patients with transaminase testing; 54 identified with abdominal injuries	To determine the sensitivity and specificity of routine transaminase testing in young children who underwent consultation for physical abuse.	Area under the curve for the highest level of either transaminase was 0.85. Using a threshold level of 80 IU/L for either aspartate aminotransferase or alanine aminotransferase yielded a sensitivity of 77% and a specificity of 82% (positive likelihood ratio: 4.3; negative likelihood ratio: 0.3). Of injuries with elevated transaminase levels, 14 (26%) were clinically occult, lacking abdominal bruising, tenderness, and distention. Several clinical findings used to predict abdominal injury had high specificity but low sensitivity. In the population of children with concern for physical abuse, abdominal injury is an important cause of morbidity and mortality, but it is not so common as to warrant universal imaging. Abdominal imaging should be considered for potentially abused children when either the aspartate aminotransferase or alanine aminotransferase level is >80 IU/L or with abdominal bruising, distention, or tenderness.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
75. Trout AT, Strouse PJ, Mohr BA, Khalatbari S, Myles JD. Abdominal and pelvic CT in cases of suspected abuse: can clinical and laboratory findings guide its use? <i>Pediatr Radiol.</i> 2011;41(1):92-98.	Observational-Dx	68 children	Retrospective review was performed to identify clinical or laboratory criteria that may predict intra-abdominal injury and guide the use of abdominal and pelvic CT in this population.	CTs were positive in 16% of patients (11/68). Hypoactive/absent bowel sounds ( $P=0.01$ , specificity=?94.7%) and aspartate aminotransferase/alanine aminotransferase values greater than twice normal ( $P=0.004$ and $P=0.003$ respectively, NPV=?93.6%) were significantly associated with positive CTs. Multiple abnormal physical exam or laboratory findings were also significantly associated with positive CTs ( $P=0.03$ and $P=0.002$ respectively, specificity=?91.3% and NPV=?93.6% respectively). CTs of the abdomen and pelvis are infrequently positive in cases of suspected abuse. To reduce radiation exposure, CTs should only be ordered if there are findings indicating that they may be positive.	3
76. Roaten JB, Partrick DA, Bensard DD, et al. Visceral injuries in nonaccidental trauma: spectrum of injury and outcomes. <i>Am J Surg.</i> 2005;190(6):827-829.	Review/Other-Dx	3705 patients	To characterize visceral injuries associated with NAT and the management and outcomes of children with these injuries.	NAT accounted for 7% ( $n = 265/3705$ ) of all trauma admissions during the period of study. Visceral injuries were diagnosed in 9% ( $n = 24/265$ ) of NAT patients. Compared with the remaining NAT population, children with visceral injuries were similar in age and sex but had higher injury severity scores (21 vs 17, $P<.05$ ). There was a high coincidence of thoracic trauma and nonburn integumental injuries in abdominally injured NAT patients. Children with visceral injuries were more likely to undergo emergent operations (46% [11/24] vs 5% [15/241], $P<.0001$ ) than those without. However, there was no difference in intensive care unit stay, hospital stay, or overall mortality for children with visceral injuries compared with those without.	4
77. Lonergan GJ, Baker AM, Morey MK, Boos SC. From the archives of the AFIP. Child abuse: radiologic-pathologic correlation. <i>Radiographics.</i> 2003;23(4):811-845.	Review/Other-Dx	N/A	Review injury patterns and imaging features in abused children.	For skull injuries, radiography is best for detecting fractures, but CT and MRI best depict intracranial injury.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
<p>78. Maguire SA, Upadhyaya M, Evans A, et al. A systematic review of abusive visceral injuries in childhood--their range and recognition. <i>Child Abuse Negl.</i> 2013;37(7):430-445.</p>	<p>Review/Other-Dx</p>	<p>88 studies</p>	<p>To define what abusive visceral injuries occur, including their clinical features and the value of screening tests for abdominal injury among abused children.</p>	<p>Of 88 included studies (64 addressing abdominal injuries), only 5 were comparative. Every organ in the body has been injured, intra-thoracic injuries were commoner in those aged &lt;5 years. Children with abusive abdominal injuries were younger (2.5–3.7 years vs 7.6–10.3 years) than accidentally injured children. Duodenal injuries were commonly recorded in abused children, particularly involving the third or fourth part, and were not reported in accidentally injured children &lt;4 years old. Liver and pancreatic injuries were frequently recorded, with potential pancreatic pseudocyst formation. Abdominal bruising was absent in up to 80% of those with abdominal injuries, and co-existent injuries included fractures, burns and head injury. Post mortem studies revealed that a number of the children had sustained previous, unrecognized, abdominal injuries. The mortality from abusive abdominal injuries was significantly higher than accidental injuries (53% vs 21%). Only 3 studies addressed screening for abdominal injury among abused children, and were unsuitable for meta-analysis due to lack of standardized investigations, in particular those with ‘negative’ screening tests were not consistently investigated.</p>	<p>4</p>



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EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
79. Holmes JF, Gladman A, Chang CH. Performance of abdominal ultrasonography in pediatric blunt trauma patients: a meta-analysis. <i>J Pediatr Surg.</i> 2007;42(9):1588-1594.	Meta-analysis	25 articles	To obtain the best estimates of the test performance of abdominal US for identifying children with intraabdominal injuries.	25 articles met the inclusion criteria, and 3838 children evaluated with abdominal US were included. Abdominal US had the following test characteristics for identifying children with hemoperitoneum: sensitivity, 80% (95% CI, 76%-84%); specificity, 96% (95% CI, 95%-97%); positive likelihood ratio, 22.9 (95% CI, 17.2-30.5); and negative likelihood ratio, 0.2 (95% CI, 0.16-0.25). Using the most methodologically rigorous studies, however, yielded the following test characteristics of abdominal US for identifying children with hemoperitoneum: sensitivity, 66% (95% CI, 56%-75%); specificity, 95% (95% CI, 93%-97%); positive likelihood ratio, 14.5 (95% CI, 9.5-22.1); and negative likelihood ratio, 0.36 (95% CI, 0.27-0.47).	M
80. Menichini G, Sessa B, Trinci M, Galluzzo M, Miele V. Accuracy of contrast-enhanced ultrasound (CEUS) in the identification and characterization of traumatic solid organ lesions in children: a retrospective comparison with baseline US and CE-MDCT. <i>Radiol Med.</i> 2015;120(11):989-1001.	Observational-Dx	73 children	To assess the sensibility and feasibility of CEUS in the assessment of low-energy abdominal trauma compared to baseline US in pediatric patients, using contrast-enhanced MDCT as the reference standard.	6/73 patients were negative at US, CEUS, and MDCT for the presence of organ injuries. In the remaining 67 patients, US depicted 26/67 parenchymal lesions. CEUS identified 67/67 patients (67/67) with parenchymal lesions: 21 lesions of the liver (28.8%), 26 lesions of the spleen (35.6%), 7 lesions of right kidney (9.6%), 13 lesions of left kidney. MDCT confirmed all parenchymal lesions (67/67). Thus, the diagnostic performance of CEUS was better than that of US, as sensitivity, specificity, PPV, NPV, and accuracy were 100%, 100%, 100%, 100%, and 100% for CEUS and 38.8%, 100%, 100%, 12.8%, and 44% for US. In some patients CEUS identified also prognostic factors as parenchymal active bleeding in 8 cases, partial devascularization in 1 case; no cases of vascular bleeding, no cases of urinoma. MDCT confirmed all parenchymal lesions. Parenchymal active bleeding was identified in 16 cases, vascular bleeding in 2 cases, urinoma in 2 cases, partial devascularization in 1 case.	3

**Suspected Physical Abuse — Child  
EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
81. Anderst JD. Chylothorax and child abuse. <i>Pediatr Crit Care Med.</i> 2007;8(4):394-396.	Review/Other-Dx	1	To report an unusual presentation of child abuse in a critical care setting.	Child abuse can present with unusual findings, and the diagnosis is not always apparent. In this and previous case reports of child abuse presenting as chylothorax, the diagnosis of abusive injury was not initially made by the managing clinicians. When abusive injury is in the differential diagnosis of a child's condition, a thorough and complete investigation-including SS, eye exam by an ophthalmologist, cranial neuroimaging, and consultation with child abuse physicians and child protective services-may be indicated.	4
82. Bennett BL, Chua MS, Care M, Kachelmeyer A, Mahabee-Gittens M. Retrospective review to determine the utility of follow-up skeletal surveys in child abuse evaluations when the initial skeletal survey is normal. <i>BMC Res Notes.</i> 2011;4:354.	Observational-Dx	47 children	To evaluate the utility of a follow-up SS in suspected child physical abuse evaluations when the initial SS is normal.	47 children had a negative initial SS and were included for analysis. The mean age was 6.9 months (SD 5.7); the mean number of days between SSs was 18.7 (SD 10.1) 4 children (8.5%) had signs of healing bone trauma on a follow-up SS. 3 of these children (75%) had healing rib fractures and 1 child had a healing proximal humerus fracture. The findings on the follow-up SS yielded forensically important information in all 4 cases and strengthened the diagnosis of NAT.	3
83. Kleinman PK, Nimkin K, Spevak MR, et al. Follow-up skeletal surveys in suspected child abuse. <i>AJR Am J Roentgenol.</i> 1996;167(4):893-896.	Observational-Dx	23 infants and toddlers	To assess the additional yield of a repeat SS in identifying and dating skeletal injury for cases in which child abuse was strongly suspected.	Follow-up SS yielded additional information regarding skeletal injury in 14 (61%) of 23 cases. Follow-up study increased the number of definite fractures detected from 70 to 89 (27%) ( $P=.005$ ). In 13/70 fractures previously detected, the follow-up SS also provided important information about the age of those injuries.	3
84. Harlan SR, Nixon GW, Campbell KA, Hansen K, Prince JS. Follow-up skeletal surveys for nonaccidental trauma: can a more limited survey be performed? <i>Pediatr Radiol.</i> 2009;39(9):962-968.	Observational-Dx	101 children	To determine whether a more limited follow-up survey could yield the same radiologic data as a full follow-up survey.	In the 101 children 244 fractures were identified on the initial osseous survey. Follow-up surveys demonstrated new information in 38 children (37.6%). A 15-view limited follow-up survey identified all additional information seen on the complete follow-up survey.	3

**Suspected Physical Abuse — Child  
EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
85. Islam O, Soboleski D, Symons S, Davidson LK, Ashworth MA, Babyn P. Development and duration of radiographic signs of bone healing in children. <i>AJR Am J Roentgenol.</i> 2000;175(1):75-78.	Review/Other-Dx	141 patients	To establish a timetable for expected radiographic changes visible during bone healing in otherwise healthy children.	<p>Scelerosis at the fracture margins was evident in 85% of fractures 5 weeks after injury. Widening of the fracture gap was observed in 62% of fractures at 6 weeks. Periosteal reaction was evident on all images by 4 weeks, and after 7 weeks, periosteal reaction was separable from cortex in only 10% of fractures. Fracture callus had a density equal to or greater than that of adjacent cortex 10 weeks after injury in 90% of fractures.</p>	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

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Dx = Diagnostic

Tx = Treatment

## Abbreviations Key

AHT = Abusive head trauma

BS = Bone scintigraphy

CEUS = Contrast-enhanced ultrasound

CI = Confidence interval

CT = Computed tomography

MDCT = Multidetector computed tomography

MRI = Magnetic resonance imaging

NAT = Nonaccidental trauma

NPV = Negative predictive value

OR = Odds ratio

PPV = Positive predictive value

SS = Skeletal survey

US = Ultrasound