

Testing for Abuse in Children With Sentinel Injuries

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abstract

OBJECTIVE: Child physical abuse is commonly missed, putting abused children at risk for repeated injury and death. Several so-called sentinel injuries have been suggested to be associated with high rates of abuse, and to imply the need for routine testing for other, occult traumatic injuries. Our objective was to determine rates of abuse evaluation and diagnosis among children evaluated at leading children's hospitals with these putative sentinel injuries.

METHODS: This is a retrospective secondary analysis of the Pediatric Health Information System database. We identified 30 355 children with putative sentinel injuries. We measured rates of abuse diagnosis and rates of testing commonly used to identify occult injuries.

RESULTS: Among all visits for children <24 months old to Pediatric Health Information System hospitals, the rate of abuse diagnosis was 0.17%. Rates of abuse diagnosis for children with at least 1 putative sentinel injury ranged from 3.5% for children <12 months old with burns to 56.1% for children <24 months with rib fractures. Rates of skeletal survey and other testing that can identify occult traumatic injury were highly variable between centers and for different injuries.

CONCLUSIONS: Several putative sentinel injuries are associated with high rates of physical abuse. Among eligible children with rib fracture(s), abdominal trauma, or intracranial hemorrhage, rates of abuse were more than 20%. Future work is warranted to test whether routine testing for abuse in these children can improve early recognition of abuse.

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Dr Lindberg conceptualized and designed the study, participated in data analysis, drafted the initial manuscript. Ms Beaty participated in study design and led the data analysis. Drs Juarez-Colunga and Wood participated in study design and data analysis. Dr Runyan participated in study conceptualization and design. Drs Juarez-Colunga, Wood, and Runyan, and Ms Beaty reviewed and revised the manuscript, and approved the final manuscript as submitted. Dr Lindberg has had access to all study data and takes responsibility for the study as a whole.

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WHAT'S KNOWN ON THIS SUBJECT: Several injuries have been suggested to be disproportionately associated with abuse in young children, but rates of abuse among children with these injuries are not currently known.

WHAT THIS STUDY ADDS: Abuse is diagnosed commonly in children with sentinel injuries, including the majority of children <24 months with rib fractures.

Child physical abuse is common, with more than 119 000 victims, 600 deaths, and \$124 billion in total costs annually in the United States.^{1–5} It is also commonly missed by health care providers. Approximately 30% of abusive head trauma and 20% of abusive fractures are missed initially, putting children at risk for ongoing abuse.^{6–8} Several diagnostic studies (eg, skeletal survey [SS], neuroimaging, hepatic transaminases, and retinal examination) can identify occult abusive injuries and improve abuse recognition and diagnosis.^{9–15} However, use of these studies has been shown to be widely variable, and to be affected by practice setting, race, and socioeconomic status.^{16,17} Twice as many children with high-risk injuries are recognized as abused in children's hospitals than in general hospitals,¹⁸ and abusive fractures are 7 times more likely to be missed in general emergency departments (EDs) than in pediatric EDs.⁷ Even among leading children's hospitals, testing of children with high-risk injuries ranges from 40% to 90%.¹⁹

In the absence of objective, validated measures of abuse likelihood, the decision to undertake screening often depends on an individual provider's gestalt about the likelihood of abuse. One source of testing variability may be the subjective nature of several factors that may affect this gestalt. Factors such as affect, eye contact, and the amount of detail in an offered history have been suggested to be important in estimating the likelihood of abuse, though they are difficult to measure objectively and their reliability, sensitivity, and specificity have not been reported.^{20,21}

An alternative, more objective approach would be to routinely screen those children who are found to have injuries most associated with abuse. Several such sentinel injuries have been suggested on the basis of case reports and retrospective analyses of cohorts of abused

children.^{22–24} However, these studies have not been able to estimate the likelihood of abuse in children with these injuries because they have not identified the denominator of children presenting with these injuries. One large analysis of the association between fractures and abuse was able to overcome this challenge, but was limited to children who were admitted to the hospital.²⁵

Our goal was to determine which putative sentinel injuries are most associated with physical abuse. We performed a secondary analysis of children who were seen in the ED or inpatient wards of leading children's hospitals by using the Pediatric Health Information System (PHIS) database. We determined rates of recognized abuse among children with putative sentinel injuries.

METHODS

Data Source

This was a retrospective analysis of data from the PHIS database for patients seen in the ED, observation, and/or inpatient setting from January 1, 2004, through December 31, 2011. We included data from the 18 institutions with continuous valid data submission throughout this period. PHIS is an administrative database that contains inpatient, ED, ambulatory surgery, and observation data from 43 leading not-for-profit, tertiary care pediatric hospitals in the United States. These hospitals are affiliated with the Children's Hospital Association (Shawnee Mission, KS), a business alliance of children's hospitals. Data quality and reliability are assured through a joint effort between the Children's Hospital Association and participating hospitals. The data warehouse function for PHIS is managed by Thomson Reuters (Ann Arbor, MI). No patient-specific clinical data exist in the database. This project was determined to be exempt from review

as human subjects research by the Colorado Multiple Institutional Review Board.

Study Population

From the published literature, we identified putative sentinel injuries and the ages at which children with each injury are thought to be at increased risk for abuse (Table 1). For example, although bruises are extremely common in older children, they are strongly associated with abuse in children <6 months old.^{26,27} Children with at least one candidate injury were identified on the basis of *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes. We excluded children with a previous diagnosis of physical abuse during the data abstraction period and children whose injuries were diagnosed after a motor vehicle collision (as determined by the presence of ICD-9-CM codes: E810–E845) because these patients are rarely thought to be victims of abuse.²⁸ We excluded visits with Medicare Severity-Diagnosis Related Group code 795 (normal newborn). Because children who were transferred from another center may have had testing completed before arrival to the PHIS center, and because they may represent a population with different likelihood of abuse, patients who were noted to have been transferred were excluded from the main study cohort and were analyzed separately.

We determined how frequently SS, neuroimaging (computed tomography [CT] or MRI), and hepatic transaminases were obtained for children with each putative sentinel injury, and how frequently abuse was diagnosed. Performance of testing was determined by using clinical transaction code (CTC) procedure codes (skeletal survey 427811, neuroimaging–head CT 417051; brain CT 411051; neuro/head MRI 417052; head arteriography MRI 471052; or brain MRI 411052, hepatic

TABLE 1 Putative Sentinel Injuries

Candidate Injuries	Age at Risk, mo	ICD-9-CM Codes	Source
Bruising	<6	920–924	Harper et al ²⁷ ; Sugar et al ²⁶
Burns	<6	940–949	DeGraw et al ³⁶ ; Hicks and Stolh ³⁷
Oropharyngeal injury	<6	873.6–873.7	Thackeray ²² ; Maguire ³⁸
Femur/humerus fracture	<12	812, 820–821	Leventhal et al ²⁵ ; Scherl ³⁹ ; Strait ⁴⁰
Radius/ulna/tibia/fibula fracture	<12	813, 823, 824	Leventhal et al ²⁵ ; John ⁴¹
Isolated skull fracture	<12	800–804 ^a	Deye et al ⁴² ; Wood ³³ ; Laskey ⁴³
Intracranial hemorrhage	<12	800–801, 803–804, 851–853 ^a	Wood ¹⁷ ; Trokel ¹⁸ ; Kemp ⁴⁴
Rib fracture(s)	<24	807.0, 807.1, 807.4	Rubin et al ¹² ; Maguire ⁴⁵
Abdominal trauma	<24	863–869	Lindberg et al ^{9,46} ; Trokel ²⁸
Genital injury	<24	922.4, 878	Carpenter ⁴⁷
Subconjunctival hemorrhage	<24	372.72	Sheets et al ²⁴ ; DeRidder ⁴⁸

^a ICD-9 codes that signify skull fracture with intracranial hemorrhage (eg, 804.2) were included in the group with intracranial hemorrhage, not with subjects who have isolated skull fractures.

transaminases–liver profile 310400; 14-test chem profile 310114; critical care panel 300171; other multichem panel 310129; general health profile 300140; aspartate aminotransferase (AST) 315060; or alanine aminotransferase (ALT) 315020). No participating center used codes for skeletal survey, unspecified technique 427800 or skeletal survey, other specified technique 427899. A diagnosis of abuse was defined by the assignment of any of the following ICD-9-CM codes, which have been used previously to identify recognized abuse from within the PHIS cohort (995.50, 995.54, 995.55, 995.59, E960–E967, E968.0–E968.3, and E968.5–E968.9).¹⁹

Rates of abuse testing and diagnose were computed by using descriptive

statistics. Correlation between rates of abuse diagnosis and rates of SS was computed by using linear regression. All analyses were performed by using SAS 9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

From 2004 to 2011, 18 participating hospitals in the PHIS database with continuously submitted data had 4 131 177 patient visits for children <24 months old, excluding normal newborn deliveries. Among all patient visits, 7062 (0.17%) were associated with a diagnosis of abuse. Rates of abuse diagnoses for all patient visits in children <24 months old for each hospital ranged from 0.04% to 0.46%.

After excluding injuries documented during visits transferred from

another facility (*n* = 2747), there were 34 565 putative sentinel injuries identified at 30 766 visits (0.7% of all visits) among 30 355 children <24 months old. These visits formed the main study cohort.

The number of patient visits with each putative sentinel injury and demographic characteristics of subjects is shown in Table 2. The large majority of subjects (89.8%) had only 1 putative sentinel injury identified. Two putative sentinel injuries were identified in 7.6% and 2.6% had 3 to 6 injuries identified. For the 4 100 411 patient visits in which no sentinel injury was identified, abuse was diagnosed in 1414 (0.03%).

Rates of abuse diagnosis and testing commonly used to identify occult injury for each sentinel injury are shown in Table 3. Rates of abuse diagnosis ranged from 3.5% for children <6 months old with burns to 56.1% for children <24 months old with rib fractures. Among all centers, 14 138 visits (46.0%) with identified putative sentinel injuries included SS; 21 094 (68.6%) included neuroimaging, and 7651 (24.9%) had hepatic transaminases obtained. Testing varied widely between centers for all injuries and all testing modalities (Table 3). Among infants with skull fractures, the rate of SS between centers ranged from just over 20% of patients, to as high as 74%.

TABLE 2 Demographic Characteristics of Subjects With Sentinel Injuries

Candidate Injury ^a	<i>n</i>	Age in Months, Median (Interquartile Range)	Boy, %	White, %	Hispanic, %
Age <6 mo					
Bruise(s)	7906	3 (1–4)	54.1	33.2	17.1
Burn(s)	1218	3 (1–4)	54.7	18.7	13.4
Oropharyngeal injury	295	3 (1–4)	60.3	27.5	13.2
Age <12 mo					
Femur/humerus fracture	4587	6 (3–8)	52.5	28.0	14.0
Radius/ulna/tibia/fibula fracture	3692	8 (5–10)	52.7	29.5	17.5
Isolated skull fracture ^b	6433	5 (2–8)	59.3	36.9	17.8
Intracranial hemorrhage	5829	3 (1–6)	58.8	32.9	16.0
Age <24 mo					
Rib fracture(s)	1633	3 (2–6)	60.4	27.9	13.0
Abdominal trauma	837	11 (3–18)	57.6	23.2	13.0
Genital injury	535	15 (7–19)	58.7	36.5	12.3
Subconjunctival hemorrhage	1600	7 (3–15)	51.8	25.5	18.8

^a Subjects identified as having been transferred from another health care facility excluded.

^b Isolated skull fracture implies that there was no ICD-9 code for intracranial hemorrhage. It does not preclude the identification of injuries in other body areas.

TABLE 3 Rates of Abuse Diagnosis and Testing for Children With Putative Sentinel Injuries

Candidate Injury	% With Abuse Diagnosis, Mean (Range)	% With Skeletal Survey, Mean (Range)	% With Neuroimaging, Mean (Range)	% With Hepatic Transaminases, Mean (Range)
Age <6 mo				
Bruise(s)	8.3 (1.1–21.3)	20.0 (5.4–30.8)	44.0 (19.9–60.1)	14.9 (2.5–24.0)
Burn(s)	3.5 (0–6.9)	13.1 (0–23.3)	15.7 (4.8–29.4)	15.9 (0–44.1)
Oropharyngeal injury	17.0 (0–41.7)	31.9 (11.1–62.5)	39.3 (11.1–62.5) ^a	26.1 (7.1–40.0)
Age <12 mo				
Femur/humerus fracture	18.9 (7.1–51.4)	59.8 (40.9–82.0)	63.8 (43.3–84.7)	35.2 (9.8–71.2)
Radius/ulna/tibia/fibula fracture	19.2 (3.5–49.3)	42.8 (25.0–78.9)	45.1 (25.5–78.9)	25.7 (6.0–64.8)
Isolated skull fracture	4.3 (0.3–11.8)	40.6 (21.5–74.3)	79.6 (66.6–95.4)	19.8 (1.3–47.8)
Intracranial hemorrhage	26.3 (10.7–42.9)	59.0 (42.3–81.6)	89.3 (75.8–96.9)	49.6 (15.9–71.4)
Age <24 mo				
Rib fracture(s)	56.1 (11.5–71.6)	81.5 (69.2–94.9)	90.6 (78.2–98.6)	73.1 (11.5–87.7)
Abdominal trauma	24.5 (0–47.4)	31.9 (18.2–57.9)	58.7 (36.4–75.7)	74.3 (35.8–91.8)
Genital injury	12.3 (0–21.4)	18.5 (0–40.0)	20.0 (0–45.0)	16.5 (39.5–89.5)
Subconjunctival hemorrhage	8.6 (0–22.0)	14.3 (5.9–36.6)	19.7 (10.9–38.2)	14.7 (0–35.4)

Rates are percentages after excluding visits noted to be transfers from another institution.

^a Ranges for SS and neuroimaging are identical because the 2 institutions with the highest and lowest rates of testing in this group obtained neuroimaging in all children who received SS.

The rate of abuse diagnosis for each putative sentinel injury correlated with the rate of SS completion ($R^2 = 0.679$) with high rates of SS generally associated with high rates of abuse diagnosis. However, children with fracture(s) of the skull, femur, or humerus were disproportionately more likely to have SS, whereas patients with subconjunctival hemorrhage, genital injury, or abdominal injury were disproportionately less likely, relative to the rate of abuse diagnosis (Fig 1).

Among 32 858 total patient visits, 2092 (6.4%) were noted to have been transferred from another institution. A large majority of visits (26 402 85.8%) was coded as having other or unknown source of admission. A diagnosis of abuse was more likely among children noted to have been transferred from another center: unadjusted odds ratio = 3.63 (95% confidence interval: 3.28–4.01). Odds of having a SS performed were also higher: unadjusted odds ratio = 2.67 (95% confidence interval: 2.44–2.92).

DISCUSSION

Among young children found to have putative sentinel injuries without a motor vehicle collision at leading children's hospitals, rates of diagnosed abuse were high. Rib

fractures were by far the most concerning for abuse, with intracranial hemorrhage and abdominal injury also associated with abuse in more than 20% of cases. Children with burns and isolated skull fractures had the lowest rates of abuse diagnoses, though rates were still high relative to the baseline risk for children without putative sentinel injuries.

The American Academy of Pediatrics considers the radiographic SS to be "mandatory" for children with concern for abuse; this recommendation is echoed by the American College of Radiology.^{29,30} In our population where all children were <24 months of age, the decision to obtain SS might be taken as 1 surrogate measure of whether there was a concern for abuse that rose to the level of evaluation. The observed correlation between rates of abuse diagnosis and rates of SS is consistent with the ideas that (1) SS is more likely to be ordered when concern for abuse is higher and (2) concern for abuse is likely to increase if SS identifies additional, occult fractures in a child with a sentinel injury. However, the likelihood of abuse does not account for all the variability in SS use, either between centers, or from injury to injury. These data suggest that SS use should be increased for

children with abdominal injury, subconjunctival hemorrhage, or genital injury.

Overall rates of abuse diagnosis were also highly variable (range, 0.04%–0.46%) between centers. We suggest several reasons for this variability. First, it is possible that true rates of abuse are actually highly variable between centers on the basis of characteristics of the population the hospital serves or on referral patterns. Alternatively, it is possible that the recognition of abuse differed between hospitals. Finally, it is possible that recognition of abuse was similar between centers, but ICD-9 coding of abuse suspicion differed systematically between centers.³¹ Systematic undercoding for abuse by some centers would result in underestimating the significance of putative sentinel injuries and overestimating the variability between centers.

Children who were noted to have been transferred from another institution were significantly more likely to undergo SS and to be diagnosed with abuse. This is consistent with the hypothesis that children with traumatic injuries are more likely to be transferred to the pediatric referral centers that participate in the PHIS database when

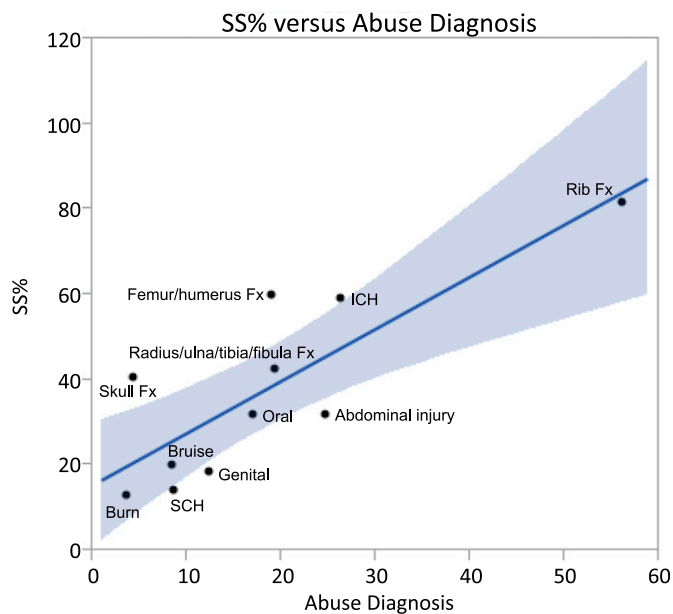


FIGURE 1

Rate of abuse diagnosis and SS completion for each putative sentinel injury. Skull fracture and femur or humerus fractures had higher rates of SS completion relative to rates of abuse diagnoses, whereas genital and abdominal injuries had lower rates. Fx, fracture; ICH, intracranial hemorrhage; SCH, subconjunctival hemorrhage.

there is some concern for abuse. It is also possible that abused children are more likely to present initially to nonpediatric centers, or that the difference could be explained by other characteristics of transferred children (age, injury type) that correlate with abuse likelihood. Children may also have had testing that we did not identify if they were transferred out from a PHIS center to another institution. Because all centers are tertiary referral centers, we suspect that the number of such subjects is small.

Our study is subject to several limitations. ICD-9 codes have been shown to have variable and limited sensitivity for abuse.^{31,32} Because a final determination of any traumatic injury's etiology may come after a child is discharged from the hospital, it is possible that many children ultimately determined to have been abused were not identified by our search. The relatively lower rate of abuse diagnosis in young infants with bruises is consistent with this possibility. Sugar et al²⁶ demonstrated that <1% of healthy

infants <6 months old had any bruising, and when such bruised infants are evaluated for abuse, rates of additional injuries and abuse diagnoses have been reported at 50%.²⁷ However, the rate of abuse that we identified in children with burns or isolated skull fractures seems more consistent with previous work.³³⁻³⁷ This limitation might be especially relevant for children without any identified putative sentinel injuries who might only be finally diagnosed as abused after hospital discharge. If this is true, rates of abuse would increase for children with and without putative sentinel injuries, but our estimate of the relative increase in abuse prevalence among children with putative sentinel injuries would be inflated.

Furthermore, these administrative data may have poor sensitivity to detect all diagnostic procedures that were performed in each subject. For example, among subjects coded as having intracranial hemorrhage, neuroimaging was identified in only 89.3%, whereas it would seem that

neuroimaging would be needed to establish the diagnosis for 100% of cases. This could be explained if ICD-9 codes for intracranial hemorrhage were incorrectly applied to children with subgaleal hematoma or other injuries that could be diagnosed without neuroimaging, or if we failed to identify children who were transferred from another institution after neuroimaging had been obtained. This latter possibility seems especially likely given the high rate of children coded as other or unknown for the source of admission. These limits of our administrative data imply that true rates of testing may be higher than our estimates, but would not affect the variability we identify between sites and injuries unless there is also systematic regional variability in the testing practices of referring hospitals. Because children with concern for abuse are more likely than other children with sentinel injuries to be transferred to PHIS centers, inaccuracies in coding transfers could artificially inflate the rates of abuse for children with putative sentinel injuries.

Although CTC procedure codes are relatively consistent for SS and neuroimaging, it is likely that there is more variability in coding for hepatic transaminases. Although some hospitals may include AST and ALT in a "14-test chem profile" (CTC code 310114), others may only include them in "critical care panel" (CTC code 300171) or another such panel. Further, it is possible that some hospitals obtained hepatic transaminases as part of a panel that was obtained to check other laboratory data, or from routine ordering, and not to test for additional abusive injuries. We attempted to include all CTC codes that might have included AST/ALT to use the maximum estimate of testing prevalence. If CTC codes were not accurate, and if this inaccuracy was systematically associated with different centers, our estimates of

the variability in ordering of hepatic transaminases would be inflated.

Although SS is primarily done for occult injury evaluation, neuroimaging and hepatic transaminase testing may be undertaken either to identify occult injuries or those with clear or subtle signs. We are not able to determine the reasons that testing was undertaken. If rates of clinically apparent injuries differed systematically between centers, this would account for some of the variability in testing that we identified.

Whereas our use of the term sentinel injury applied to children in whom abuse was diagnosed on the index visit, other authors have used the term to refer to children who are subsequently diagnosed with recurrent abuse on a future visit. Whether the risk of abuse is in the immediate, near, or long-term, we feel that the core attribute of a sentinel injury is that it should prompt the clinician to consider the possibility of physical abuse, and in most cases to undertake testing for additional occult injuries.

True sentinel injuries would present without other clinically apparent injuries or history of abuse. We were not able to determine the presenting injury for any given child, nor whether a child's sentinel injury was accompanied by other obvious signs of abuse, such as a history of witnessed assault. It is therefore possible that the putative sentinel injuries that are most likely to have been identified in the course of an abuse evaluation (eg, rib fractures)

would have inflated rates of abuse. However, for the large majority of patient visits, only a single putative sentinel injury was identified, suggesting at least that these injuries were not only the least noticeable injuries in children with obvious polytrauma. We therefore believe that the high rates of abuse among children with the listed injuries create a strong presumption that abuse should be carefully considered when these injuries are identified.

Similarly, because we are not able to identify the reason for presentation, children who present with clear evidence of a sentinel injury are grouped with children whose injuries were only identified after testing prompted for less specific complaints. It has been well-described that abused children frequently present with subtle signs and symptoms, and that the history may be incomplete or misleading.^{6,22,23} Therefore, although rates of abuse diagnoses were vanishingly low in patients without a putative sentinel injury, our results should not be interpreted to discourage abuse evaluations when sentinel injuries are not obvious.

Several methods could be used to increase testing and decrease variability for children with putative sentinel injuries. These and other data could be included in physician training and in the development of clinical guidelines and pathways that address abuse evaluations. In centers with access to subspecialty child abuse pediatricians, the presence of a putative sentinel injury could be considered an indication for

subspecialty consultation to determine the plan for occult injury testing. Finally, these data could form the basis for electronic clinical decision support prompting clinicians to consider occult injury testing for children with putative sentinel injuries.

CONCLUSIONS

Previous work has revealed that physical abuse is commonly missed. Our data reveal an overall high rate of diagnosed abuse, but tremendous variability in evaluation and diagnosis of abuse across hospitals and injury categories. Together, these facts suggest that increased, routine, or protocolized testing for children with these injuries can identify other children with abuse that might otherwise be missed. These results support future trials of protocolized evaluations for children with these putative sentinel injuries.

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ABBREVIATIONS

CT: computed tomography
ED: emergency department
ICD-9-CM: *International Classification of Diseases, Ninth Revision, Clinical Modification*
PHIS: Pediatric Health Information System
SS: skeletal survey

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