Additional Injuries in Young Infants with Concern for Abuse and Apparently Isolated Bruises

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Objective 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.

Study design This was a prospectively planned secondary analysis of an observational study of children <10 years (120 months) of age evaluated for possible physical abuse by 20 US child abuse teams. This analysis included infants <6 months of age with apparently isolated bruising who underwent diagnostic testing for additional injuries or bleeding disorders.

Results 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. Skeletal surveys 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 one 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.

Conclusions Infants younger than 6 months of age with bruising prompting subspecialty consultation for abuse have a high risk of additional serious injuries. Routine medical evaluation for young infants with bruises and concern for physical abuse should include physical examination, skeletal survey, neuroimaging, and abdominal injury screening. *(J Pediatr 2014;■:■-■).*

Young infants (<6 months old) are disproportionately subject to child maltreatment and have rates of serious physical abuse[1] and abusive head trauma[2] more than twice the rate of children between 1 and 3 years of age. Despite the recognition that these infants are at high risk for serious injury, physical abuse frequently is still missed, resulting in additional injuries[3] and/or death.[4,5] Currently, diagnostic testing for additional occult injuries concerning for abuse may be based on clinician gestalt or the presence of social risk factors (eg, history of domestic violence, caregiver substance abuse, or previous involvement with child protective services). This may result in disproportionate child abuse evaluations according to race and socioeconomic status.[4,6-9] An approach based on routine evaluation for additional injuries in infants with initial physical findings indicative of a high risk for abuse might increase the rates of abuse detection while decreasing testing variability. Likewise, routine evaluation for medical conditions that may mimic abuse (eg, bleeding disorders) may increase detection of such conditions while decreasing inappropriate diagnoses of abuse.

Since the work of Ambrose Tardieu, physicians have recognized that bruises are rare in healthy infants who have not yet begun to crawl, or "cruise."[10-13] Any bruising in infants younger than 6 months of age has been considered a "red flag" for abuse, as has bruising to the torso, ear, and neck in infants and toddlers.[14-16] In a recent analysis of infants with abusive head trauma and serious physical abuse, more than 25% had previous injury reported by caregivers, including bruising and/or oral injury.[17] Bruises identified in infants often raise concerns for bleeding disorders and/or inflicted injury. Testing for occult injury, including hepatic transaminases,[18,19] skeletal surveys (SS),[20] and neuroimaging,[21,22] may identify and prevent additional abusive injury and/or death. Furthermore, testing children with bruising for bleeding disorders also has been recommended to identify conditions that mimic physical abuse.[23]

CAP	Child abuse physician
CT	Computed tomography
ExSTRA	Examining Siblings To Recognize Abuse
PT	Prothrombin time
PTT	Partial thromboplastin time
SS	Skeletal survey

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Although the low prevalence of bruising in healthy young infants has been reported in several prospective studies, the prevalence of additional serious injuries or bleeding disorders in bruised infants is currently unknown.[10,11,13] Our objectives were: (1) to determine the rate at which diagnostic testing for occult injury is performed in infants presenting with apparently isolated bruising; and (2) to determine the prevalence of additional serious injuries and bleeding disorders in a large population of infants <6 months of age who underwent subspecialty evaluation for abuse.

Methods

This was a prospectively planned secondary analysis of data from the Examining Siblings To Recognize Abuse (ExSTRA) research network, the methods of which have been described previously.[24] To summarize, the ExSTRA research network was a prospective, observational study by 20 US child abuse teams that included all children younger than 10 years of age who underwent subspecialty evaluation for concerns of physical abuse between January 15, 2010, and April 30, 2011. Although the primary analysis of the ExSTRA network involved household contacts such as siblings and children who shared a daycare with the index child, this analysis includes data only from index children. Although participating centers endorsed a common screening protocol for contacts of abused children as part of the parent study, no such protocol was in place for index children, the subjects for this analysis. All testing for index children was undertaken at the discretion of the clinical team. All participating centers and the data coordinating center obtained approval for the parent study with waiver of informed consent from their local institutional review board. This secondary analysis of deidentified data was determined to be exempt from review.

For enrolled subjects, the responsible child abuse physician (CAP) recorded the characteristics of any identified cutaneous injury, the results of any testing, and the ultimate estimate of the likelihood of abuse at the time of disposition. The perceived likelihood of abuse was recorded with the use of a previously published 7-point scale where a rating of 7, "Definite Inflicted Injury," represents the greatest perceived likelihood of abuse and a rating of 1, "Definitely Not Inflicted Injury," the least.[25] Scores of 6, "Substantial Evidence of Inflicted Injury," or 7, "Definite Inflicted Injury," were considered to represent a high perceived likelihood of abuse and scores of 1, "Definitely Not Inflicted Injury," and 2, "No Concern for Inflicted Injury," were considered to represent a low perceived likelihood of abuse.

For this secondary analysis, index subjects from the ExSTRA study who were younger than 6 months old and who were coded as having bruises were the eligible subjects. Eligible subjects were selected for further analysis to identify those who presented for care because of apparently isolated bruising. These subjects became the study group for this secondary analysis. To determine whether a subject presented for apparently isolated bruising, 3 independent reviewers (N.H., K.F., and N.S.) who were blinded to the results of diagnostic testing reviewed data from the history and physical examinations of all eligible subjects. Subjects were not considered to have apparently isolated bruising if there were other concerning physical examination findings unrelated to bruises (eg, altered mental status, decreased limb use, oral bleeding) or a history of assault. Children with a history of a fall were not excluded, because this history may be provided in cases of both accidental trauma and abuse.[26,27] Scalp swelling or bruising was not considered to be an additional concerning finding on physical examination. Disagreement on inclusion or exclusion of subjects was resolved by consensus.

Data were entered prospectively during the parent study into a secure, web-based data entry form (Quickbase; Intuit, Waltham, Massachusetts). CAPs recorded the presence of cutaneous injuries, including patterned injuries, burns, lacerations, and bruises, as well as the number and location of bruises. Clearly patterned injury was defined as an injury for which the CAP could reasonably determine the implement that caused the bruises (eg, slap mark, loop mark, belt pattern). For each diagnostic study, including coagulation screening, the responsible CAP coded whether testing identified a new injury or mimic, identified a known injury, was nonspecific, or was normal. Identified injuries were defined as "new injuries" if they had not been demonstrated on previous study, including physical examination.

Descriptive statistics were used to describe the proportion of subjects with diagnostic testing performed, and the proportion of these tests that identified additional serious injuries or bleeding disorders. Fleiss kappa was used to determine initial inter-rater agreement between the 3 raters who determined the presence of apparently isolated bruising.[28]

Results

The ExSTRA research network abstracted data for 2890 index children, the demographics of which have been published elsewhere.[24] Of the initial cohort, 33.9% (980/2890) were <6 months of age. Of these, 25.9% (254/980) had bruises and underwent blinded review to determine whether the abuse evaluation was undertaken for apparently isolated bruising. Independent blinded review resulted in initial agreement of 86.2% (219/254) between reviewers (kappa = 0.72) a level generally thought to represent substantial agreement.[29] After resolution of disagreement by consensus, 57.5% (146/254) were determined to have presented apparently for isolated bruising.

Demographics, level of concern for abuse, and characteristics of the study cohort are shown in **Table I**. Clearly patterned injuries were identified in 30 subjects. This included 3 subjects with a pattern considered benign by the CAP (dog bite mark, abrasions, and an imprint of the child's ear against their head). The remaining subjects included subjects with the following patterns: hand (5), grip marks (2), finger marks (1), bite marks (7), belt buckle (1), and 11 with no implement listed by the CAP.

Table I. Characteristics of the study cohort (n = 146)

Male, n (%)	89 (61.0)
Age in months, mean (SD)	3.0 (1.5)
Clearly patterned injury, n (%)	30 (20.5)
Ultimate level of concern for abuse, n (%)*	
1 – Definitely not inflicted injury	6 (4.1)
2 – No concern for inflicted injury	17 (11.6)
3 – Mildly concerning for inflicted injury	14 (9.6)
4 – Intermediately concerning for inflicted injury	16 (11.0)
5 – Very concerning for inflicted injury	20 (13.7)
6 – Substantial evidence of inflicted injury	33 (22.6)
7 – Definite inflicted injury	40 (27.4)
Number of bruises	
1	50 (34.2)
2-5	76 (52.0)
6-10	12 (8.2)
>10	8 (5.5)
Location†	
Face/head	110 (75.3)
Trunk	46 (31.5)
Extremities	39 (26.7)
Abdominal injury	4 (2.7)
Traumatic brain injury	28 (19.2)
Number of fractures, n (%)	
0	84 (57.5)
1	26 (17.8)
2	14 (9.5)
3-5	8 (5.5)
6-10	9 (6.2)
>10	5 (3.4)

*According to a 7-point scale of perceived abuse likelihood.
†Results do not sum because some subjects had bruises in multiple locations.

Among subjects with a single bruise, 28% (14/50) had a high perceived likelihood of abuse, and 26% (13/50) had a low perceived likelihood of abuse. Rates of diagnostic testing performed for occult injury in the study cohort relative to the overall parent cohort of all children who had consultation for concern of physical abuse are shown in Table II.

Overall, 50.0% (73/146) of all subjects had additional injuries identified by diagnostic testing, and 50.0% (73/146) had a high perceived likelihood of abuse (43 had both a high perceived likelihood of abuse and additional injury identified; Table III). Reports to Child Protective Services were initiated in 86.3% (63/73) of those with additional injuries and in 93.2% (68/73) of the subjects without additional injuries on diagnostic testing.

Neuroimaging

Computed tomography (CT) and/or magnetic resonance imaging of the brain were completed in 91.1% (133/146) of subjects, of whom 27.4% (40/133) had a new injury identified. Injuries in subjects included skull fracture (20), subdural hematoma (18), subarachnoid hemorrhage (17), cerebral contusion (7), subgaleal hemorrhage or soft-tissue swelling (5), epidural hemorrhage (3), cerebral edema (2), and intra-ventricular hemorrhage (1). The number of injuries identified is greater than the number of subjects with injuries because some subjects had multiple injuries. Only 2 subjects had isolated soft-tissue swelling. Among subjects with new injury on neuroimaging, 90.0% (36/40) also had face or head bruising. Subjects with face or head bruising were significantly more likely to have new injury identified by neuroimaging than those whose bruises were elsewhere (OR 3.89, 95% CI, 1.19-14.09).

SS and Dedicated Films

Among the 146 subjects, SS was performed in 93.8% (137/146) with new fractures identified in 23.3% (34/137). Overall (Table I), including SS and other imaging modalities, 42.5% (62/146) of subjects had fractures identified, with multiple fractures identified in 58.1% (36/62). Although the majority of fractures were identified on SS, fractures were identified by dedicated films obtained before SS in 7 subjects (2 humerus, 2 skull, and 1 each femur, rib, and finger). Of these, 3 children were imaged because the history was of a fall onto the extremity; 2 children had skull radiographs performed before CT because of bruising to the head; and 2 had dedicated imaging because of symptoms that had been present before the presentation with bruising.

Including both neuroimaging and dedicated radiographs, skull fractures were identified in 28 subjects, of whom 35.7% (10/28) had isolated scalp swelling (without additional bruising on physical examination). These 10 subjects included 2 with multiple skull fractures identified. Only 7 subjects with skull fractures had a history of a trauma. The remaining 18 subjects with skull fractures had multiple bruises in 8, multiple fractures in 7, and an abdominal injury identified in 1. No infant in this cohort had a single fracture identified by isolated bruising overlying the site of injury.

Abdominal Injury

Hepatic transaminases were obtained in 63.0% (92/146) of subjects and were increased greater than 80 IU/L in 14.

Table II. Rates of diagnostic testing and injury identification

Screening study	Total, n = 2890, n (%)	0-6 months, n = 980, n (%)	Study cohort, n = 146, n (%)
SS obtained	2049 (70.9)	909 (95.3)	137 (93.8)
SS shows new injury	471 (16.3)	253 (25.8)	34 (23.3)
Neuroimaging obtained	1692 (58.5)	857 (87.4)	133 (91.1)
Neuroimaging shows new injury	727 (25.2)	368 (37.6)	40 (27.4)
Hepatic transaminases obtained	1538 (53.2)	708 (72.2)	92 (63.0)
Abdominal CT obtained	292 (10.1)	105 (10.7)	15 (10.3)
Abdominal imaging shows new injury	73 (2.5)	22 (2.2)	4 (2.7)

Percentages of injuries identified are calculated using the number of subjects as the denominator with the assumption that studies that were not ordered would be negative.
New injuries represent injuries not identified on previous studies or physical examination.

Table III. Results according to bruise characteristics in the study cohort

Characteristics for study cohort, total = 146 infants	Any new injury identified, total = 73 infants, n (%)	Any coagulation screening, total = 103 infants, n (%)	High level of concern for abuse,* total = 73 infants, n (%)
Number of bruises			
1, n = 50	30 (60.0)	23 (46.0)	14 (28.0)
2-5, n = 76	32 (42.1)	60 (78.9)	43 (56.6)
6-10, n = 12	7 (58.3)	12 (100.0)	9 (75.0)
>10, n = 8	4 (50.0)	8 (100.0)	7 (87.5)
Location†			
Face/head, n = 110	59 (53.6)	75 (68.2)	59 (53.6)
Trunk, n = 46	22 (47.8)	43 (93.5)	27 (58.7)
Extremities, n = 39	21 (53.8)	33 (84.6)	26 (66.7)
Patterned bruises, n = 30	9 (30.0)	24 (80.0)	20 (66.7)

*High level of concern for abuse was defined as a rating of 6 (Substantial Evidence of Inflicted Injury) or 7 (Definite Inflicted Injury) on a 7-point scale.[23]
†Results do not sum because some subjects had bruises in multiple locations.

Abdominal CT was performed in 10.3% (15/146) of whom 12 had increased levels of hepatic transaminase, and 4 had abdominal bruising. New abdominal injury was identified in 2.7% (4/146) of subjects. All 4 injuries were liver lacerations and/or contusions.

Bleeding Disorders

Diagnostic testing for bleeding disorders was completed in 70.5% (103/146) of subjects (Table IV). Testing was significantly more likely to be ordered for subjects with 2 or more bruises than for subjects with a single bruise (83.3% vs 46.0%, OR 5.87, 95% CI, 2.53-13.74). Of those tested, 86.4% (89/103) had studies that included prothrombin time (PT)/international normalized ratio and partial thromboplastin time (PTT). Platelet counts were reported in 89 subjects as well. Additional studies, such as fibrinogen, thrombin time, von Willebrand factor antigen, factor levels (8 and 9), and platelet-function analysis, were obtained in less than 20% of infants tested. No infant in the study group had testing performed for Factor 13 deficiency. Bleeding disorder testing was interpreted by CAPs as normal in 76.7% (79/103) of subjects and nonspecific in 22.3% (23/103). No bleeding disorders were identified. However, one subject had abnormal studies as a result of taking warfarin for congenital heart disease.

Table IV. Diagnostic testing for bleeding disorders in the study cohort

Study reported	Total = 103 infants, n (%)
Platelet count	89 (86.4)
PT/INR	89 (86.4)
PTT	90 (87.4)
Thrombin time	9 (8.7)
Fibrinogen	18 (17.5)
Factor 8	17 (16.5)
Factor 9	4 (3.9)
von Willebrand antigen	19 (17.5)
PFA-100	14 (13.6)
PIVKA	1 (0.7)

INR, international normalized ratio; *PFA-100*, platelet function analysis; *PIVKA*, protein induced by vitamin K absence.
Results do not sum to 103 because some subjects had testing performed in multiple categories.

Discussion

These data demonstrate that infants younger than 6 months of age who are evaluated for physical abuse because of apparently isolated bruises, including infants with a single bruise, frequently undergo additional testing and have additional injuries identified. In our study cohort, one-half of the infants had additional serious injuries identified on diagnostic testing. There was no significant association between the number or location of bruises and the presence of additional serious injuries. Even among infants with a single bruise, 60% had additional injuries identified. One in four infants had additional injuries identified on neuroimaging. Although new injuries on neuroimaging were more likely to occur in infants with face or head bruising, 10% had injuries identified when bruises were elsewhere on the body. Bruising in any premobile infant should be considered a "red flag" for abuse with high risk for additional serious brain, skeletal, and visceral injuries. The implementation of clinical guidelines with routine diagnostic testing may prevent more serious physical injury as well as reduce screening disparities.[30]

SS are recommended by the American Academy of Pediatrics in all children younger than 2 years of age with concerns for child physical abuse.[31] Screening for occult injury with the use of SS has varied greatly across institutions, including children's hospitals with child abuse programs.[32] In this cohort where all children were evaluated by a CAP, compliance with SS recommendations was high (95% of all infants younger than 6 months of age and 94.0% of our study cohort). Identification of additional SS occurred in more than 25% of our study cohort infants, which complements published literature.[20,33,34]

Although the presence of occult intracranial injury in neurologically asymptomatic young infants is supported by 2 published studies,[21,22] recommendations for neuroimaging are not as consistent as those for SS. The American Academy of Pediatrics states "careful consideration of symptoms, signs, history, and judicious use of other ancillary tests should guide the clinician in determining the need for imaging" noting that the "absence of neurologic symptoms should not exclude the need for imaging."[31]

Reluctance to order neuroimaging studies may be secondary to concerns for radiation exposure with CT and/or sedation for magnetic resonance imaging.[35] Neuroimaging was obtained in more than 90% of our study cohort with new injury identified in more than 25%. Our data also support previous work demonstrating that, although routine neuroimaging is appropriate for all subjects younger than 6 months of age with bruising concerning for abuse, subjects with bruising to the face or head were at especially increased risk.[22]

Diagnostic testing, such as pancreatic and liver enzymes, are considered "helpful in screening children for abdominal trauma."[31] Large multicenter studies have demonstrated the utility of hepatic transaminases (aspartate aminotransferase and alanine aminotransferase) in identifying abdominal injury in children with physical abuse concerns. Abdominal CT is recommended in children with aspartate aminotransferase or alanine aminotransferase >80[18,19] or with an abnormal findings on examination (eg, abdominal bruising, tenderness, or distention). In our cohort, diagnostic testing for abdominal injury was not performed as frequently as neuroimaging or surveys, and injuries were identified in only 2.7%. Nevertheless, rates of injury identification in imaged infants were greater than among children presenting with known trauma.[36] This finding supports continued aggressive evaluation for abdominal injuries in young, bruised infants.

We are not able to measure the forensic significance of each bruise or additional identified injury. Indeed, neither the perceived likelihood of abuse, nor the decision to report to children's services, was completely predicted by the identification of additional injuries. Fifteen subjects with additional injuries identified were ultimately thought to have a low perceived likelihood of abuse and even more subjects without additional injuries identified were reported to child protective services, which suggests that some of the additional identified injuries were not thought to be highly concerning for abuse and that some bruises were themselves considered extremely concerning for abuse. However, we believe that the high proportion of cases in which additional injuries were identified in children ultimately thought to have been abused supports the high rate of testing shown in this group.

Children with bleeding disorders can present primarily with bruising suspicious for physical abuse. Testing for bleeding disorders is recommended in children with bleeding and/or nonpatterned bruising in the absence of skeletal and abdominal trauma.[23,37] One recommended testing regimen for an infant with isolated bruising, published after our data were collected, includes a complete blood counter, PT/PTT, Factor 8, Factor 9, and testing for von Willebrand disease.[23] The majority of subjects in this cohort who were evaluated for bleeding disorders had only a platelet count (complete blood count), PT/international normalized ratio, or PTT performed. Testing for bleeding disorders was conducted according to recently published guidelines in less than 3% of study cohort subjects. It is possible that CAPs thought that a bleeding disorder was unlikely in cases in which additional serious injuries such as fractures were identified, or that CAPs did not pursue testing for bleeding disorders when bruises were mild and concern for abuse was low. Although CAPs believed the performed testing in this study cohort was reassuring, a larger number of infants would be necessary to evaluate the benefits of diagnostic testing for bleeding disorders in this population. Until additional data are available, testing for bleeding disorders should be performed with the use of available published guidelines.[23]

Our study is subject to several limitations. First, the cohort is subject to selection bias because it includes only infants who were referred for subspecialty evaluation with physical abuse concerns. Medical providers who had a low level of concern for abuse may not have referred infants with apparently isolated bruising for subspecialty evaluation. However, we doubt that medical providers could have identified a cohort whose risk was so much lower as to negate the utility of screening. In published studies of well infants and children, bruised infants are quite rare at 0.6% of 366 infants under 6 months of age[11] and 1.2% of 246 infants younger than 9 months of age.[10] Our study infants, evaluated for apparently isolated bruising, had additional injuries identified in 50% on diagnostic testing. In this same ExSTRA cohort in another published secondary analysis, the prevalence of additional serious injury among infants with apparently isolated skull fractures was only 5.6%, suggesting that bruises in children younger than 6 month of age are dramatically more concerning for abuse than skull fractures.[38] The high prevalence of additional serious injuries in our study, equally high in infants with a single bruise, suggests that infants younger than 6 months of age would benefit from comprehensive evaluation.

Second, this was an observational study and the indications for completing diagnostic testing for occult injury and bleeding disorders varied between centers and CAPs. Because some subjects were not screened, it is possible that CAPs consciously or unconsciously used other unmeasured factors (such as evidence of underlying medical disease, social risk factors, or parental behavior) than those reported here (bruising characteristics) to determine the need for additional studies. Furthermore, because subjects who were not evaluated were counted as not having an injury or bleeding disorder, the rates we report should be considered a minimum prevalence. The true prevalence would be greater if any children who were not tested had occult injuries or a bleeding disorder.

Finally, because it was not possible to standardize physical examinations among CAPs or referring physicians, it is possible that subjects may have had bruises that were not noted, and other children may have been inappropriately excluded from the cohort.

Infants under 6 months of age who are referred for subspecialty abuse evaluation for apparently isolated bruises are at high risk for additional serious injuries. In this cohort, 50% of infants meeting these criteria were ultimately thought to have a high level of concern for abuse. Routine medical evaluation for young infants with bruises and concern for

physical abuse should include physical examination, skeletal survey, neuroimaging, and abdominal injury screening. ■

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Appendix

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