ARTICLE

Skeletal Surveys in Infants With Isolated Skull Fractures

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What's Known on This Subject

Skeletal surveys are performed frequently for infants with skull fractures and no significant intracranial injuries to screen for occult fractures resulting from inflicted trauma; however, the risk of occult fractures in this population is not known.

What This Study Adds

For infants with simple or complex skull fractures but no significant intracranial injuries or suspicious clinical findings, skeletal surveys are unlikely to reveal additional injuries and may not be warranted.

ABSTRACT

OBJECTIVE. The goal was to describe the utility of skeletal surveys and factors associated with both skeletal survey use and referral to child protective services for infants with skull fractures in the absence of significant intracranial injury.

METHODS. A retrospective chart review was performed for infants who were evaluated at a tertiary children's hospital because of an isolated, non–motor vehicle-related, skull fracture between 1997 and 2006. Logistic regression analyses were used to test for associations of demographic factors, clinical findings that raised suspicion for abuse (absence of trauma history, changing history, delay in care, previous child protective services involvement, and other cutaneous injuries), and fracture type (simple versus complex) with the primary outcomes of skeletal survey use and reports to child protective services.

RESULTS. Among the 341 infants in the study, 31% had clinical findings that raised suspicion for abuse and 42% had complex skull fractures. Skeletal surveys were obtained for 141 infants (41%) and detected additional fractures for only 2 (1.4%) of those 141 infants. Child protective services reports were made for 52 (15%) of the 341 children. Both infants with positive skeletal survey findings had other clinical findings that raised suspicion for abuse, and they were among those reported. With controlling for race and age, Medicaid-eligible/uninsured infants were more likely than privately insured infants to receive skeletal surveys and child protective services reports in the presence of a complex skull fracture or clinical findings that raised suspicion for abuse.

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Key Words
child abuse, craniocerebral trauma, fractures, radiography, skull fractures

Abbreviations
CPS— child protective services
ICH—intracranial hemorrhage
SES—socioeconomic status
ICD-9—*International Classification of Diseases, Ninth Revision*
CI— confidence interval

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CONCLUSION. Skeletal surveys were ordered frequently for infants with isolated skull fractures, but they rarely added additional information, beyond the history and physical findings, to support a report to child protective services. *Pediatrics* 2009;123:e247–e252

INFLICTED TRAUMA, WHICH is a common cause of head injury in young children, is associated with significant morbidity and death. Between 17% and 33% of infants and toddlers who are admitted to the hospital with head injuries are victims of abuse.[1–3] Because of this high rate of abuse, clinicians routinely perform skeletal surveys to identify occult fractures in these children. The American Academy of Pediatrics recommends the performance of skeletal surveys in the evaluation of children <2 years of age with injuries resulting from suspected abuse,[4] with the recognition that up to one third of such children would have occult fractures detected.[1,3,5,6] Identification of occult fractures on the skeletal survey for an infant with head trauma may support the diagnosis of inflicted trauma and the decision to make a report to child protective services (CPS).

Although the concern regarding inflicted injury is generally high among infants with neurotrauma, the likelihood of abuse decreases when the reported mechanism of injury is plausible and the injuries are less severe. A particular group of children for whom the need for abuse evaluations remains uncertain is infants who present with isolated skull fractures in the absence of significant intracranial injury. Although one fourth of infants with inflicted trauma have skull fractures,[7,8] skull fractures also are known to result from accidental household trauma.[3,9] Two studies suggested that the likelihood of abuse among infants presenting with isolated skull fractures is lower than that among infants with skull fractures and intracranial injuries; in those studies, 19% to 48% of the young children with intracranial injuries were victims of abuse but, among infants with isolated skull fractures, confirmed abuse was absent in 1 study and only 11% in the other.[2,10] Both studies had small sample sizes, however, and neither reported whether all infants underwent skeletal surveys. Therefore, it is not clear whether the guidelines for performing a skeletal survey among infants with head injury should be applied to infants with skull fractures and no significant intracranial injury, particularly if there is a plausible history to explain the injury and there are no additional concerns.

In assessing the risk of abuse for an infant presenting with a skull fracture, clinicians may rely on the presence of clinical findings suggesting abuse and the fracture type. Previous research attempted to distinguish inflicted from accidental skull fractures on the basis of the type of fracture, with conflicting results.[9,11,12] Clinical findings that are commonly thought to raise suspicion for abuse include a lack of history of trauma, changing history,[13] conflicting histories, history that is inconsistent with the injury, delays in presentation for medical care, and the presence of other injuries on examination.[14] The utility of these "red flags" in assessment of the risk of occult fractures resulting from abuse in this particular population, however, has not been studied. Finally, in the absence of clear clinical evidence to guide them in deciding whether to order a skeletal survey, physicians may rely on nonscientific factors. Previous research suggested that characteristics such as race and socioeconomic status (SES) may influence physicians' decisions to evaluate for abuse.[15,16]

Lacking clarity on the underlying risk for inflicted injury and occult fractures in infants with isolated skull fractures, we identified the largest retrospective cohort of infants with isolated skull fractures, in an attempt (1) to describe the clinical characteristics of infants presenting with isolated skull fractures, (2) to describe the use of skeletal surveys and CPS referrals among this population, and (3) to identify the factors associated with the likelihood of skeletal survey use and reports to CPS in this population. Our hypothesis was that, although the likelihood of additional injuries might have been low, many children were receiving significant evaluations for inflicted injuries that might not have been warranted.

METHODS

A retrospective study was performed with infants <1 year of age who were evaluated at a large tertiary children's hospital between January 1, 1997, and December 31, 2006. Study subjects were identified by searching the hospital inpatient and emergency department electronic database for infants assigned an *International Classification of Diseases, Ninth Revision* (ICD-9) code for a skull fracture (ICD-9 codes 800–804) and then reviewing each case individually to ensure that the subjects met our inclusion and exclusion criteria. A validation of our search methods was performed with a subset of infants by performing an additional search of electronic radiology records for head images with skull fractures between January 1, 2003, and December 31, 2006. That validation (data not shown) demonstrated that we had selected the most inclusive ICD-9 codes to ensure complete coverage of targeted subjects.

Because we were interested in a target population of healthy infants sustaining isolated skull fractures as a result of household trauma, there were several exclusion criteria. First, the skull fracture had to be the primary injury and not an injury detected incidentally during the evaluation of other injuries. Second, injuries had to be reported as resulting from household trauma, which excluded cases in which external-cause-of-injury codes or chart abstraction revealed a history of a motor vehicle crash or in which the injury was detected before the infant's discharge from the hospital after birth. Finally, fractures occurring in the setting of metabolic bone disease, those resulting from penetrating trauma, those including the orbital rim, and those associated with significant intracranial injury were excluded. Although we excluded infants with significant intracranial injury, we did include infants with the common finding of minor intracranial hemorrhage (ICH), defined as small foci of extraaxial hemorrhage beneath or opposite the fracture. Injuries that were deemed significant intracranial injuries included intraparenchymal hemorrhage of any size, moderate/large extraaxial hemorrhage, and any injuries associated with mass effect, midline shift, cerebral edema, or change in mental status.

The primary outcomes of the study were use of a skeletal survey to evaluate an infant for inflicted injury and CPS referral for further evaluation of suspected abuse or neglect. Skeletal survey findings were confirmed through review of radiology reports and physician notes. Although referrals for CPS evaluations were documented, the results of those investigations were not available.

Predictor variables were divided into 3 categories, that is, family demographic features, clinical findings suggesting abuse (ie, red flags), and skull fracture type. Demographic variables included age, race, gender, and insurance status (private insurance versus Medicaid/uninsured). A single composite variable to denote red flags included cases with an absence of history of trauma to explain the skull fracture, those with a history of injuries or other injuries on physical examination (scars, bruises, burns, or bony deformities), those in which the caregiver reported previous CPS involvement, those with changing or conflicting histories of trauma, and those with a delay in seeking medical care of >72 hours. One team member (Dr Adams) reviewed the medical charts for the presence of red flags. We checked for potential misclassification of red flags by having a second investigator review a subset (10%) of the charts; there was high interrelater reliability ($\kappa = 0.92$). We considered including a history of trauma inconsistent with the injury as a red flag. All of the infants, however, had a history of blunt head trauma or no history of trauma. Therefore, none of the infants had a history of trauma that was clearly inconsistent with the injury. The history of trauma was categorized as a short fall (≤3 feet), a long fall (≥3 feet), or other trauma. Because of previous research suggesting that falls down steps are less severe than vertical free falls and the severity of the injury does not increase with the number of steps,[17] falls down ≤10 stairs without a vertical fall of >3 feet were classified as short falls. Nonfall mechanisms of blunt trauma, including collisions with objects, were classified as other trauma. Skull fractures were categorized as simple (single linear) or complex (bilateral, multiple, diastatic, depressed, or stellate, or any fracture associated with minor ICH).

Data analysis was conducted by using Stata 10.0 (Stata, College Station, TX). Data were described with frequencies for categorical variables and means and ranges for continuous variables. Bivariate χ^2 analyses were used to identify associations between categorical predictor variables. Because of sample size limitations, an aggregate clinical risk score with 3 levels was created, to maximize the power to examine important clinical subgroups. These subgroups included infants with simple skull fractures and no red flags, those with complex skull fractures and no red flags, and those with red flags, regardless of the type of skull fracture. Bivariate χ^2 analyses were used to assess unadjusted associations between the 2 outcome measures (skeletal survey ordering and CPS reporting) and the predictor variables. Predictor variables were included in multivariate logistic regression models if bivariate χ^2 or t test analyses (for age-related differences) indicated a trend association with the outcomes ($P < .2$) or if clinical experience warranted their inclusion (eg, age). Final models included insurance status, age, race, and clinical subgroup. Tests for interaction were conducted between the clinical subgroups and race and between clinical subgroups and insurance status, because of literature findings demonstrating important demographic differences in child abuse evaluations.[15,16,18] The outputs of the regression models were standardized as estimated probabilities of skeletal survey use or CPS referral, as opposed to odds ratios, because the baseline prevalence of the outcomes was high enough to render odds ratios less meaningful. The Children's Hospital of Philadelphia internal review board approved the study protocol.

RESULTS

Population Characteristics

Of the 508 infants with non–motor vehicle-related skull fractures who were identified with ICD-9 and external-cause-of-injury codes, 167 infants were excluded. The most likely reasons for exclusion were significant intracranial injury ($n = 125$) and identification of the skull fracture during evaluation of other primary injuries ($n = 24$).

Of the 341 infants included in the study, 52% were white ($n = 179$), 36% black ($n = 123$), and 11% other race ($n = 39$). Fifty-two percent ($n = 179$) had private insurance, and 48% ($n = 162$) had Medicaid/no insurance (Table 1). Black infants were more likely than white infants to have Medicaid/no insurance (80% vs 24%; $P < .001$). Ages ranged from 2 days to 361 days, with a median of 164 days (5.5 months). The majority of fractures were reported to have resulted from falls (46% from short falls and 36% from high falls), but 13% of infants presented without a history of trauma. Of the 144 complicated fractures identified, 18% were bilateral,

TABLE 1 Association of Demographic Characteristics, Clinical Findings, and Clinical Subgroup With Skeletal Survey Receipt and CPS Referral

	Skeletal Survey Obtained, %	P	Referred to CPS, %	P
Race				
White (52%)	36	.043	11	.007
Black (36%)	48		22	
Insurance status				
Private insurance (52%)	34	.002	10	.005
Medicaid/uninsured (48%)	50		21	
Age				
0–3 mo (31%)	40	.96	13	.75
3–9 mo (48%)	42		16	
9–12 mo (21%)	42		17	
Skull fracture type				
Simple (58%)[a]	39	.32	16	.77
Complex (42%)[b]	44		15	
Any red flag for abuse[c]				
No (70%)	28	<.001	5	<.001
Yes (31%)	71		38	
Lack of history of trauma				
No (87%)	33	<.001	9	<.001
Yes (13%)	96		52	
Changing or conflicting histories				
No (97%)	40	.001	14	<.001
Yes (3%)	91		64	
Previous CPS report				
No (96%)	39	<.001	14	.046
Yes (4%)	100		33	
Delay in presentation for care of >72 h				
No (82%)	39	.049	13	.013
Yes (18%)	52		25	
Other injuries noted in examination				
No (98%)	40	.007	14	<.001
Yes (2%)	88		63	
Clinical subgroups				
Simple fracture and no red flags (39%)	25	<.001	4	<.001
Complex fracture and no red flags (30%)	33		7	
Any fracture type with red flag (31%)	71		39	

The proportions of the population with the characteristics are indicated in parentheses. Columns display the frequency of skeletal survey receipt and CPS referral among patients with those characteristics, with the level of significance in bivariate analyses.

[a] Single linear fractures without ICH were classified as simple.

[b] Complex skull fractures included multiple, bilateral, depressed, stellate, or diastatic fractures and fractures associated with minor ICH. Minor ICH included small foci of extraaxial hemorrhage underneath or opposite the fracture that were not associated with mass effect, midline shift, cerebral edema, or change in mental status. Patients with significant ICH were excluded from the study.

[c] Red flags included the following: no history of trauma, other injuries noted in the physical examination, caregiver report of previous CPS involvement, changing or conflicting history of trauma, and a delay in seeking medical care of >72 hours.

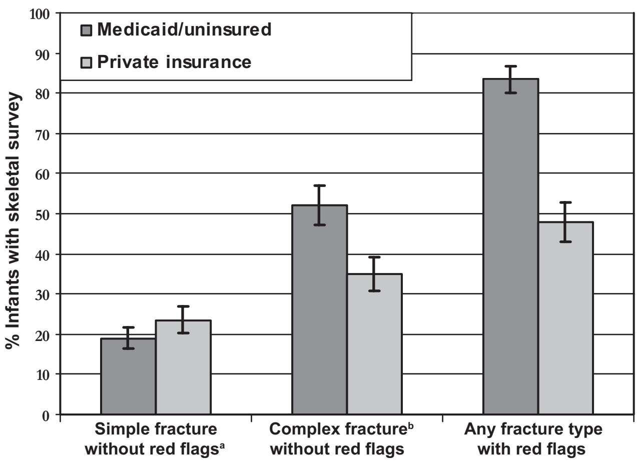

FIGURE 1
Adjusted probability of skeletal survey performance according to clinical subgroup and insurance status of the family. Results were generated through standardization of a logistic regression model, controlling for race and age ($P = .013$ for interaction of clinical subgroups and insurance status). [a] Red flags included the following: no history of trauma, other injuries noted in the physical examination, caregiver report of previous CPS involvement, changing or conflicting history of trauma, and a delay in seeking medical care of >72 hours. [b] Complex skull fractures included multiple or bilateral, depressed, stellate, or diastatic fractures and those associated with minor ICH. Minor ICH included small foci of extraaxial hemorrhage underneath or opposite the fracture that were not associated with mass effect, midline shift, cerebral edema, or change in mental status. Patients with significant ICH were excluded from the study.

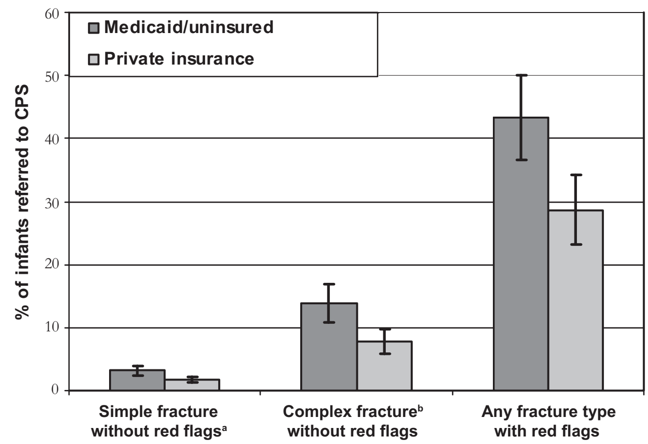

FIGURE 2
Adjusted probability of CPS referral according to clinical subgroup and insurance status of the family. Results were generated through standardization of a logistic regression model, controlling for race and age ($P < .001$ for clinical subgroups and $P = .094$ for insurance status). [a] Red flags included the following: no history of trauma, other injuries noted in the physical examination, caregiver report of previous CPS involvement, changing or conflicting history of trauma, and a delay in seeking medical care of >72 hours. [b] Complex skull fractures included multiple or bilateral, depressed, stellate, or diastatic fractures and those associated with minor ICH. Minor ICH included small foci of extraaxial hemorrhage underneath or opposite the fracture that were not associated with mass effect, midline shift, cerebral edema, or change in mental status. Patients with significant ICH were excluded from the study.

39% depressed, 19% multiple, 9% stellate, and 4% diastatic and 46% were associated with minor ICH. Fifty-eight percent of infants had simple fractures. At least 1 red flag was identified for one third of the infants.

Skeletal Survey Performance and Results

Skeletal surveys were performed for 41% of the infants but revealed non–skull fractures for only 2 of the 141 infants (1.4%; 95% confidence interval [CI]: 0.2%–5.0%). The 2 infants with positive skeletal survey findings had red flags (no history of trauma and changing history of trauma, in addition to an intoxicated caregiver). Both had simple linear skull fractures. Their skeletal surveys showed lower-extremity metaphyseal fractures.

Unadjusted analyses revealed that Medicaid-eligible/uninsured infants and black infants were more likely than privately insured infants and white infants, respectively, to receive skeletal surveys (Table 1). In addition, infants with complex fractures and no red flags and infants with red flags (regardless of fracture type) were more likely than infants with simple linear skull fractures and no red flags to receive skeletal surveys. In multivariate models controlling for age and race, there was an interaction between insurance status and clinical subgroup (Fig 1). Medicaid-eligible/uninsured infants and privately insured infants were equally likely to have skeletal surveys in the presence of simple skull fractures without red flags. However, Medicaid-eligible/uninsured infants were more likely than privately insured infants to have skeletal surveys performed in the setting of complex skull fractures without red flags or in the presence of any red flags regardless of fracture type ($P = .013$ for interaction). Among Medicaid-eligible/uninsured infants, the adjusted probability of skeletal survey receipt was 52% (95% CI: 47%–58%) among infants with complex skull fractures and no red flags, and the value increased to 83% (95% CI: 79%–87%) if there were any red flags, regardless of fracture type. The adjusted probabilities of skeletal survey receipt were 35% (95% CI: 30%–40%) and 48% (95% CI: 42%–53%) among privately insured infants in these 2 categories, respectively, controlling for all other factors in this model. In the multivariate model, black race was no longer a significant predictor of skeletal survey performance.

Referrals to CPS

Reports to CPS were made in 15% of the cases. Three fourths of the infants referred to CPS had red flags. Infants who were Medicaid-eligible/uninsured, black infants, infants with complex fractures and no red flags, and infants with red flags were again more likely to have a CPS referral in unadjusted analyses (Table 1). In multivariate analyses, there was no longer an interaction between insurance status and clinical subgroups; on the contrary, there was a nonsignificant trend toward increased reporting for Medicaid-eligible/uninsured infants across all clinical subgroups. This was most pronounced for the infants with complex skull fractures and no red flags and the infants with red flags regardless of fracture type ($P = .09$) (Fig 2). Controlling for race and age, the adjusted probability of CPS referral was 14% (95% CI: 10%–18%) among Medicaid-eligible/uninsured infants with complex skull fractures and no red flags, compared with 44% (95% CI: 38%–49%) among

Medicaid-eligible/uninsured infants with red flags. In contrast, among privately insured infants, only 8% (95% CI: 5%–11%) of infants with complex skull fractures and 29% (95% CI: 24%–34%) of infants with red flags were estimated to have CPS referrals.

DISCUSSION

We report the results for the largest cohort of infants presenting with skull fractures in the absence of significant intracranial injury, and we describe the factors associated with skeletal survey performance, skeletal survey findings, and CPS referrals. Although >40% of infants received skeletal surveys, only 2 of 141 had occult fractures suggesting inflicted trauma. Both of those infants had clinical findings concerning for abuse. Such results might imply that more-targeted screening of infants with clinical red flags might detect adequately the high-risk cases that would warrant subsequent imaging or reporting to CPS. This approach might limit radiation exposure to infants from a series that may include >20 radiographs,[19] might reduce anxiety within families, and might limit costs and waiting times in emergency departments.

In our study population, infants with lower SES (as indicated by insurance status) were more likely to have skeletal surveys performed and to be referred to CPS. Disparities in evaluations for suspected abuse based on SES and/or race were noted in previous research.[15,16,18] We observed this trend particularly among infants without red flags. Although lower SES has been associated with an increased incidence of child physical abuse,[20] our results raise concern that infants with lower SES may be overevaluated and reported to CPS unnecessarily. Conversely, our finding that the majority of privately insured infants with red flags did not receive skeletal surveys raises concern that cases of abuse might have been missed among infants with higher SES. This is particularly worrisome because previous research demonstrated that infants may suffer further abuse, including fatal injuries, when physicians fail to evaluate for and to recognize abuse.[18]

A particularly controversial group of infants with skull fractures is the group of infants with complex skull fractures who have histories similar to those of infants with simple skull fractures but otherwise have no clinical red flags, including infants with minor ICH or stellate, bilateral, multiple, or depressed skull fractures. Concerns have been voiced about these injuries because of older studies suggesting that common, accidental, household trauma mechanisms (short falls and stairway injuries) usually do not cause skull fractures[17,21–23] and that, when skull fractures do occur, they are mostly single[11] linear fractures not associated with ICH.[1,3,12,17] However, our finding that no infants with complex skull fractures (and no red flags) had positive skeletal survey results supports other literature findings suggesting that complex skull fractures do occur accidentally.[9]

Although our study represents the largest published study of infants with skull fractures, we urge caution in the interpretation of the results. We emphasize that these were single episodes in the lives of these children, and we were unable to identify longitudinally whether these infants had additional reports to CPS regarding maltreatment. We also did not have access to the outcomes of the CPS investigations that resulted from reports made because of the skull fractures. For better understanding of and development of more-definitive guidelines regarding the risks to infants with isolated skull fractures, we plan to study infants with skull fractures longitudinally.

The study also has other limitations. As a retrospective chart review study, it was prone to misclassification bias because of inaccuracies in the medical charts. Poor documentation of red flags by clinicians might have affected the results. In particular, racial or SES biases might have resulted in increased evaluation and documentation of red flags for some patients, classifying them as higher risk than they should have been. Red flags might have been underreported for other patients, classifying them as lower risk than they should have been. In addition, skeletal surveys were performed for a minority of infants, and the identification of injuries in infants who did not receive skeletal surveys is uncertain.

CONCLUSIONS

Accidental trauma is likely to explain most isolated skull fractures in infants for whom other red flags for maltreatment are not identified. Infants presenting with skull fractures and no significant ICH, particularly those of lower SES, frequently receive skeletal surveys to screen for occult fractures resulting from abuse. In the absence of red flags, however, it remains unclear whether these surveys provide additional value to the diagnostic evaluation. In contrast, many infants of higher SES for whom red flags are identified are not being screened with skeletal surveys. Future longitudinal study is needed to identify the infants at greatest risk for abuse associated with skull fractures. Such investigation might reveal the extent of evaluation that is necessary to protect those at risk without unnecessary evaluation for others for whom risk can reasonably be excluded.

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