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Bruising Characteristics Discriminating Physical Child Abuse From Accidental Trauma

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KEY WORDS

bruising, decision rule, nonaccidental trauma, predictors, screening tools

ABBREVIATIONS

CART—classification and regression tree
MVC—motor vehicle collision
TEN—torso, ear, and neck
TEN-4 BCDR—body region- and age-based bruising clinical decision rule

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WHAT'S KNOWN ON THIS SUBJECT: Bruising occurs with both physical child abuse and accidental trauma, and bruising characteristics discriminate between the 2 groups.

WHAT THIS STUDY ADDS: This study develops a clinically sensible model in the form of a bruising clinical decision rule to identify children and infants with bruising who are at high risk for physical abuse and require further evaluation.

abstract

OBJECTIVE: Our objective was to conduct a pilot study to identify discriminating bruising characteristics and to model those findings into a decision tool for screening children at high risk for abuse.

METHODS: A case-control study of children 0 to 48 months of age who were admitted to a PICU because of trauma was performed. Case subjects ($N = 42$) were victims of physical abuse, and control subjects ($N = 53$) were children admitted because of accidental trauma during the same time period. Bruising characteristics (total number and body region) and patient age were compared for children with abusive versus accidental trauma. The development of a decision rule for predicting abusive trauma was accomplished with the fitting of a classification and regression tree through binary recursive partitioning.

RESULTS: Ninety-five patients were studied. Seventy-one (33 of 42 patients in the abuse group and 38 of 53 in the accident group) were found to have bruising, and the characteristics were modeled. Characteristics predictive of abuse were bruising on the torso, ear, or neck for a child ≤4 years of age and bruising in any region for an infant <4 months of age. A bruising clinical decision rule was derived, with a sensitivity of 97% and a specificity of 84% for predicting abuse.

CONCLUSIONS: Discriminating differences exist in bruising characteristics for abusive versus accidental trauma. The body region- and age-based bruising clinical decision rule model functions as a clinically sensible screening tool to identify young children who require further evaluation for abuse. *Pediatrics* 2010;125:67–74

Up to 75% of abuse may be missed in the acute care setting because medical professionals fail to recognize signs of abuse.[1] This lack of recognition leads to errors in decision-making, lost opportunities to intervene, and potentially poor patient outcomes from repeat injuries.[1–8] Many repeat injuries may be preventable through earlier recognition.

Bruising is one of the most common and most readily visible injuries resulting from physical child abuse, but it is missed as a warning sign in up to 44% of fatal and near-fatal cases.[9] Bruising may be overlooked because it is usually clinically insignificant. In cases of abuse, however, it may be the only visible sign of injury or signal of internal injuries.[10,11] Bruising can be an indicator of occult trauma and thereby mandates an increased index of suspicion for additional injury, with further evaluation.[12–19] The seatbelt sign[13–16] and tin ear syndrome[12] are notable examples of how bruising can have clinical significance and drive decision-making and action. Currently, no evidence-based guidelines exist to aid clinicians in discriminating bruises caused by abusive versus accidental trauma. However, measurable differences have been described.[20–26] The predictive accuracy of these differences in bruising characteristics has not yet been determined or incorporated into a practical decision-making model for the acute care setting.

The goal of this study was to develop such a model in the form of a bruising clinical decision rule to identify children and infants with bruising who are at high risk for physical abuse and require further evaluation. The specific aims of this study were to identify discriminating differences in bruising characteristics for children with abusive versus accidental trauma and to derive a clinical decision rule on the basis of those findings.

METHODS

Study Design

We conducted a retrospective, case-control study of patients with abusive or accidental trauma who were admitted to the PICU of a children's hospital between January 1, 2002, and December 31, 2004. Cases analyzed in this study were consecutive admissions of patients with abusive trauma. Control subjects were children admitted to the PICU with injuries sustained from accidental trauma during the same 2-year time period. The control subjects were age-matched as closely as possible (days to months) within the constraints of the available patient population. All eligible patients <1 year of age with accidental trauma were included. This study was approved by the University of Louisville Institutional Review Board.

Identification of Potential Study Subjects

Trauma Registry

Subjects were identified for the study by using the hospital trauma registry, which categorizes patients according to age, stated mechanism of trauma, and injury cause, defined as abuse, accident, or indeterminate. All injury cause determinations in the trauma registry were made independent of, and before, this study.

Inclusion Criteria

Included children (1) were 0 to 48 months of age, (2) were admitted to the PICU because of trauma during the 2-year study period, and (3) had an injury cause identified through the trauma registry as abuse or accident.

Exclusion Criteria

Children with (1) traumatic injuries of indeterminate cause and/or (2) coagulation disorders or abnormalities (eg, hemophilia or cancer) were excluded.

Criteria Required for Categorization as Case or Control Subject

The criteria for case subjects (abuse) were as follows: (1) trauma registry categorized the trauma as abuse; (2) hospital medical team determined the injuries to be highly suggestive of abuse; (3) stated cause of injury did not account for the type, severity, and/or number of injuries; (4) history of trauma was absent, vague, or changing; or (5) state social services that determined the patient was abused. The criteria for control subjects (accident) were as follows: (1) trauma registry categorized the trauma as an accident; (2) hospital medical team determined the injuries to raise no concerns regarding abuse; (3) stated cause of injury was consistent with the type, severity, and/or number of injuries; (4) history was detailed, thorough, and consistent; and (5) no indicators of abuse were found when skeletal survey, social service assessment, and/or forensic team evaluations were performed. Skin findings were not among the criteria used to categorize patients as case or control subjects, and categorization occurred before any data analysis.

Data Abstraction

Data Abstracted

The following variables were abstracted from each patient's traditional and/or electronic medical record: patient age, race, and gender, total number of bruises, body location of bruising, associated (nonskin) injuries, and stated cause of injury, as provided on the trauma sheet. Data abstraction included the use of the standardized nursing database, hospital medical records, and autopsy reports (when applicable and available).

Nursing Skin Assessment Database

Skin assessment data were recorded for all PICU patients as the standard of care before and without knowledge of this study. All skin findings were recorded, according to hospital protocol, in a prospectively maintained skin assessment database that allows for region-specific documentation.

The nursing skin assessments for the initial 72 hours of each patient's admission (or until discharge from the PICU, if the length of stay was <72 hours) were entered into the research database. Each entry consisted of the (1) type of skin finding (eg, bruise or abrasion), (2) body region of skin finding, and (3) count.

Medical Record and Autopsy Review

Study investigators also performed a comprehensive medical record review of each subject's traditional and/or electronic medical record and autopsy report (when applicable and available). Any newly identified bruise locations or counts were added to the data set, such that the final data set consisted of all cutaneous findings abstracted from the nursing database, medical record reviews, and autopsy reports. Once a bruise was identified on a specific body region of a given patient, it was not recounted.

Data Analysis

Descriptive Statistics

Descriptive statistics were calculated for patient age, cumulative bruise counts, and bruise location. Bruise counts were summed per location. The difference in cumulative bruise counts for children with abusive versus accidental trauma was tested with a negative binomial regression, with a single factor accounting for type of trauma.

Classification and Regression Tree and Clinical Decision Rule Derivation

The development of a clinical decision rule for predicting abusive trauma was accomplished with the fitting of a classification and regression tree (CART) through binary recursive partitioning (R 2.3.1; R Development Core Team, Vienna, Austria). This method allowed each patient to be classified into 1 of 2 possible categories for the outcome variable, that is, abusive or accidental trauma. The binary recursive partitioning algorithm identified successive "splits" for a set of predictor variables, such that each predictor variable split a parent node into 2 child nodes. The child nodes then became either terminal nodes or parent nodes subject to subsequent splits on the basis of additional criteria. The predictor variables maximized the homogeneity of the nodes with respect to an outcome variable (abusive or accidental trauma). The tree was defined so that it was inclusive and exhaustive, that is, all patients were evaluated under all splitting criteria and a terminal node was established for all patients. A goal of perfect or near-perfect sensitivity was established. The fitting of successive trees to the data set was performed in concert with a visual examination of the bruising characteristics. The decision tree also was assessed for clinical sensibility.

TABLE 1 Sample Demographic Characteristics

	Complete Sample	Abusive Trauma (Case Subjects)	Accidental Trauma (Control Subjects)
All patients enrolled, *N*	95	42	53
Age, mo			
Mean ± SD	12.3 ± 12.6	9.8 ± 12.2	14.4 ± 12.7
Range	0.3–48.4	0.3–48.4	1.0–42.1
Male, %	63	71	57
Patients with bruising, *N*	71	33	38
Age, mo			
Mean ± SD	13.0 ± 12.8	11.3 ± 13.4	14.4 ± 12.3
Range	0.3–48.4	0.3–48.4	1.0–40.9
Male, %	65	67	63

RESULTS

Study Group

A total of 95 patients met the enrollment criteria. Sample demographic features are presented in Table 1, and the causes of injury for patients categorized as control subjects are presented in Table 2. Seventy-one patients with bruising were identified; the bruising characteristics of those patients were analyzed and used for modeling.

Cumulative Numbers of Bruises

The total bruise counts per patient were significantly different between the patients with physical abuse and those with accidental trauma (negative binomial regression, $z = 9.6$, $P < .0005$). Patients with abusive trauma

TABLE 2 Causes of Injury for Patients in Control Group

Cause of Injury	*n*
MVC	29
Non–MVC	24
Fall (ground based)[a]	1
Fall from bed/couch/table[a]	5
Fall in car/bouncy seat from table/counter[a]	4
Fall out of bed of pick-up truck	1
Fall with caregiver	2
Fall from father's shoulders	1
Fall from moving golf cart	1
Pedestrian vs truck	1
Jumped out of car	1
All-terrain vehicle accident	1
Dropped by caregiver	2
Bouncy seat collapsed	1
Stair fall (in walker)	1
Stair fall (with caregiver)	1
Caregiver fell on child	1
Total	53

[a] According to hospital protocol, all young children with intracranial hemorrhage are admitted to the PICU for observation. Seven children had small areas of contact epidural or subdural hemorrhage. Three children had minimally depressed or linear skull fractures with no intracranial injury, but concussive symptoms were present. All 10 children were <1 year of age. None required further treatment or intervention, and all were in neurologically normal condition at discharge.

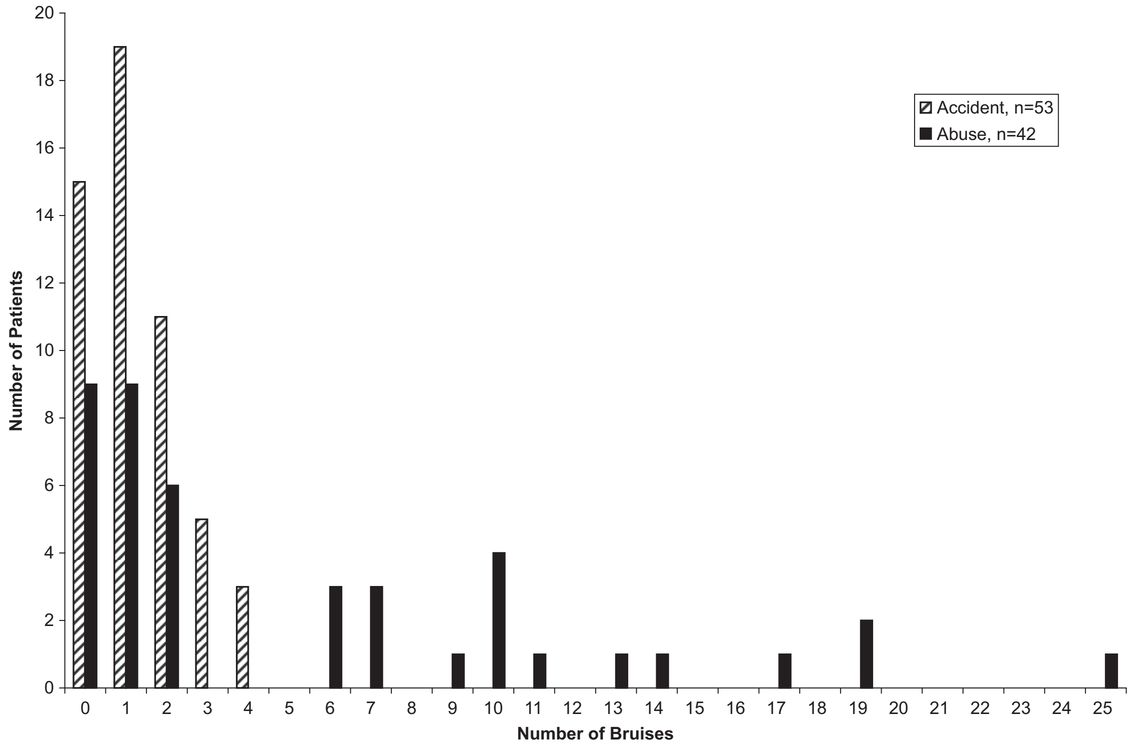

FIGURE 1
Comparison of cumulative numbers of bruises for patients with abusive versus accidental trauma.

had as many as 25 bruises, with a median of 6 bruises (interquartile range: 1–10 bruises), compared with a median of 1.5 bruises (interquartile range: 1–2 bruises) for patients with accidental trauma. All patients with accidental trauma had ≤4 bruises (Fig 1).

Body Regions With Bruising

Discriminating differences in body regions with bruising were identified for children with abusive versus accidental trauma. All bruising to the ear, neck, hands, right arm, and chest and buttocks regions of the torso were perfectly predictive of abuse, with no patients with accident-related trauma demonstrating bruising in those areas. The back and abdominal regions of the torso were statistically significant or approached statistical significance, respectively, for discriminating abuse. All bruising to the genitourinary area and hip occurred only in patients with abusive trauma, but the number was too small for determination of statistical significance. The face, cheek, scalp, head, and legs showed bruising in patients with abusive and accidental trauma and was not discriminating for abusive trauma (Fig 2).

CART and Clinical Decision Rule Derivation

Overview

The development of a decision rule for predicting abusive trauma was accomplished with the fitting of a CART through binary recursive partitioning. The tree exhibited splits on the basis of the presence (or absence) of bruising to an aggregate body region and patient's age.

Split 1: Aggregate Body Region

Maximal sensitivity and clinical sensibility for predicting abuse was achieved with an aggregate region consisting of the torso, ear, and neck (TEN). The torso includes the chest, abdomen, back, buttocks, genitourinary region, and hip. This TEN aggregate region included all body regions in which a bruise indicated abuse, with the exceptions of the hands and right arm. These 2 regions, although perfectly predictive, did not become splitting criteria because the patients with hand or right arm bruises were already captured by the other criterion. Bruises in the TEN aggregate region were uncommon in the accident group (Table 3).

Split 2: Age

Age correctly captured 7 additional patients with abusive trauma by using a split at an age of <4 months. These patients would have been missed on the basis of region alone.

On the basis of the CART results, bruising in the TEN aggregate region or bruising in a young infant serves as a red flag. If the cause of this unusual bruising cannot be verified as acciden-

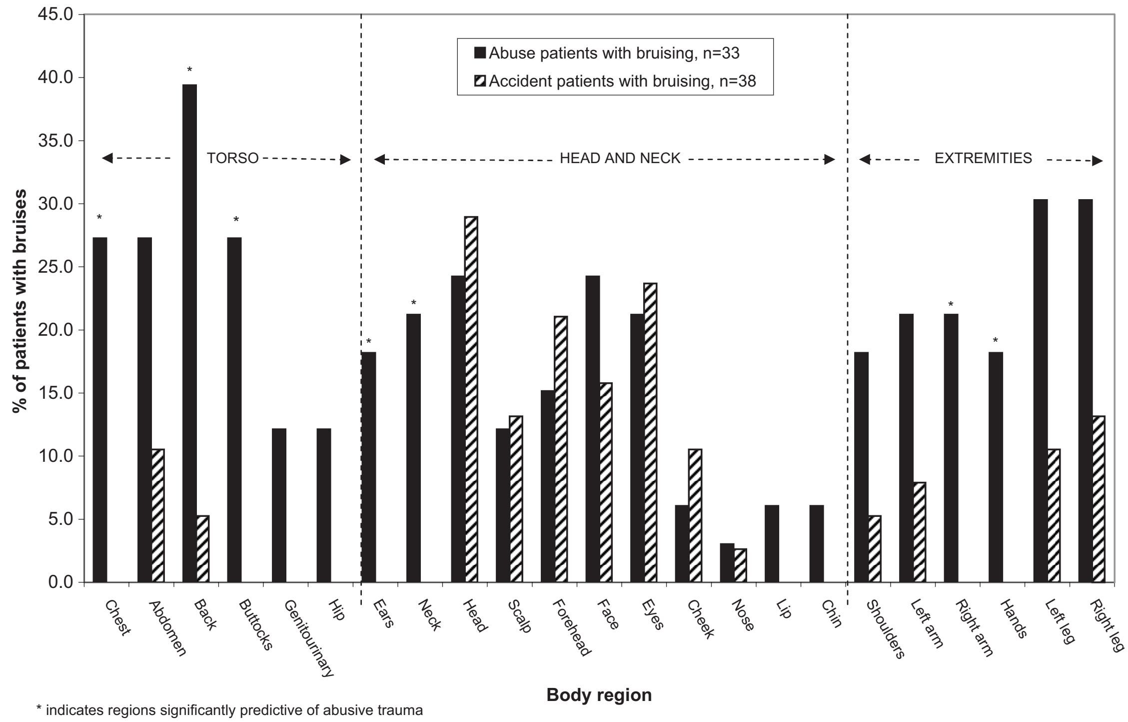

FIGURE 2
Bruise distribution for patients with abusive and accidental trauma.

TABLE 3 Bruise Counts According to Body Region Within TEN Aggregate

TEN Body Regions	No. of Bruises		
	Abuse	Accident	
		MVC	Non–MVC
Chest	13	0	0
Abdomen	17	2	2
Back	20	1	1
Buttocks	18	0	0
Genitourinary area	4	0	0
Hip	5	0	0
Ear	8	0	0
Neck	18	0	0
Total	103	3	3

tal, then a screen for child abuse is warranted. The following 3 questions constitute the proposed model. (1) Is there bruising in the TEN region of a child ≤4 years of age? (2) Is there bruising in any region of an infant <4 months of age? (3) Is there a confirmed accident in a public setting that accounts for the bruising in the TEN region or on the infant? This model correctly classified 32 of 33 abuse victims, for a sensitivity of 97%, and 32 of 38 accident victims, for a specificity of 84% (Fig 3). The 1 abuse victim who was classified incorrectly was a 19-month-old child with an eye bruise. Table 4 illustrates the low frequency of bruising in the TEN aggregate region and on infants <4 months of age among patients with accidental versus abusive trauma.

DISCUSSION

Decision Rule

Our study differs from previous work in that it is the first study to investigate and to compare bruising characteristics of children ≤4 years of age from 2 trauma populations (abuse and accident) with injuries warranting admission to the PICU. A body region- and age-based bruising clinical decision rule (TEN-4 BCDR) was derived on the basis of discriminating bruising characteristics, to inform decision-making. Meeting either the first or second criterion of the TEN-4 BCDR indicates the need for further evaluation for possible physical abuse if a clear accidental cause that accounts for the specific bruising, such as a motor vehicle collision (MVC), cannot be confirmed.

Model Usability and Comparison With Previously Developed Models

Our model uses skin examination findings and the age of the patient. The resulting simplicity of the TEN-4 BCDR enhances its clinical sensibility and potential utility in all clinical environments. To our knowledge, Dunstan et al[26] conducted the only other study for decision-model development related to discriminating bruising caused by abuse. Their model showed discriminating differences, giving credence to our work. However, complexity differs significantly between the 2 models. The system described by Dunstan et al[26] may have limited practical use in fast-paced and/or high-acuity environments. Our study specifically established design constraints to facilitate the derivation of a model that could be applied in the acute care set-

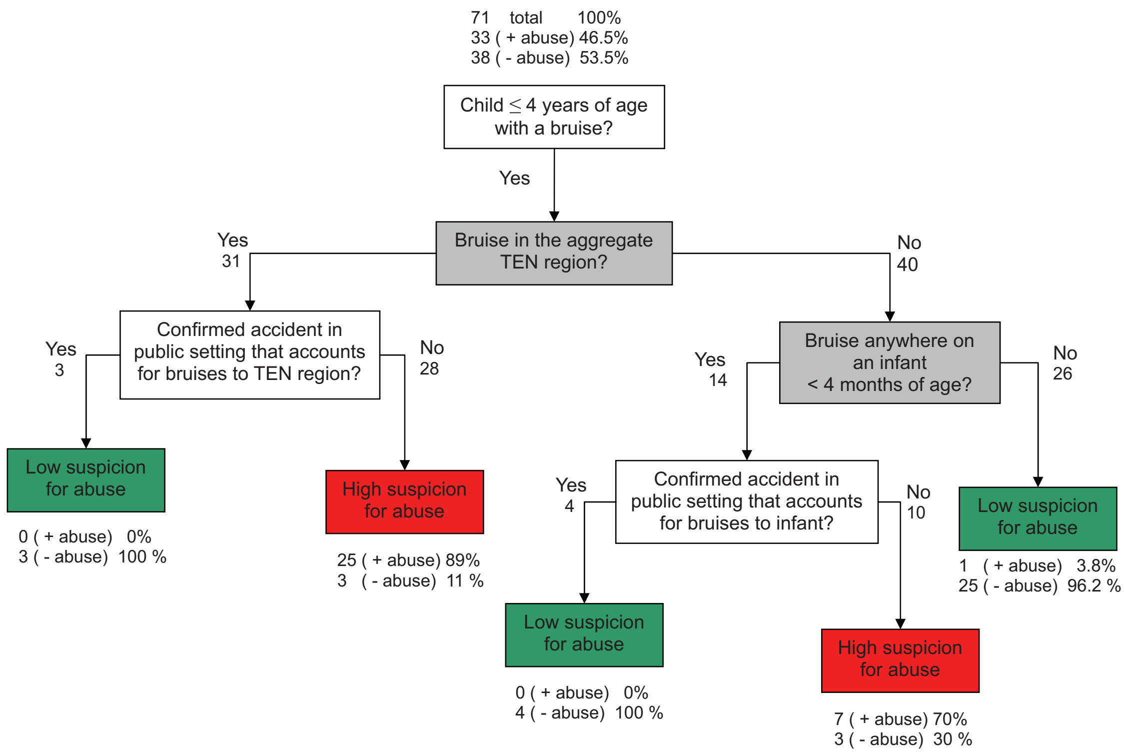

FIGURE 3
Dendrogram of CART.

TABLE 4 Summary of Cumulative Bruise Counts and Numbers of Patients

	Abuse	Accident		
		MVC	Non–MVC	All
Total no. of bruises (no. of patients)	226 (33)	49 (24)	19 (14)	68 (38)
No. of bruises in TEN aggregate region (no. of patients)	103 (25)	3 (3)	3 (3)	6 (6)
No. of bruises (all regions) on patients <4.0 mo of age (no. of patients)	74 (14)	9 (4)	4 (3)	13 (7)
No. of patients with >4 bruises	18	0	0	0

ting. We sought to derive a decision rule that was based on readily available data obtained as part of routine patient care, and we excluded the use of factors that are known to be highly associated with abuse but often are unavailable or unreliable in the acute care setting at the time of the initial assessment. For example, factors such as clinical history, past injuries, and family history of domestic violence and drug abuse were excluded. In cases of possible child abuse, the history provided often is intentionally deceptive and caregivers often are dishonest about past events. A rule based on such factors likely would yield false-negative results.

Body Regions With Bruising

We sought to identify which body regions had bruising unique to physical assault. In general, victims of abuse were found to have multiple bruises on multiple regions of the body, which emphasizes that all parts of the body are vulnerable during assault. This is in direct contrast to the bruising findings for patients with accidental trauma. In the accident group, bruising within the TEN aggregate region was absent or rare, regardless of MVC or non–MVC injury cause (Table 3). Our study supports the existing evidence that, although bruising occurs from both physical abuse[12,20,26–30] and accidental trauma,[21–25] bruising characteristics discriminate between the 2 groups.

The current consensus findings assert that precruising infants rarely bruise and, when bruising is present, the total number of bruises is small and bruising occurs over bony, prominent areas once the child is mobile.[22–25] Certain sites, such as the TEN, rarely or never bruise. Conversely, these regions were identified as common bruising sites among abused patients.[20,25–27,30]

Maguire et al[31] reported the consensus findings of 23 articles that indicated that bruises to the face, back, abdomen, arms, buttocks, ears, and hands suggest physical child abuse. Our study of PICU patients with trauma paralleled these findings, with the exception of facial bruising. The face was not a splitting criterion because facial bruising was common in accidental and abusive trauma. Bruises to the scalp, head, forehead, eyes, face, cheek, and nose accounted for 68% of all bruises from accidental causes. It is possible that bruises designated as "facial" in other publications would have been classified more specifically, for example, as ear, chin, eyes, or forehead in our study (Fig 2).

Patient's Age

Eight patients with abusive trauma were misclassified as sustaining accidental trauma, on the basis of body region splitting criteria; 7 were young infants and 1 was a 19-month-old child. An age splitting criterion of <4 months allowed the capture of all 7 nonmobile young infants. Bruising is uncommon on infants without independent mobility.[22–24,31] Sugar et al[22] identified only 2 infants <6 months of age with bruising not related to a medical cause. In addition, infant homicide rates are highest in the first 4 months of life, which supports the age cut-off value of <4 months in our model. Models fit to larger data sets likely will exhibit an age cut-off value reflecting the nonambulatory population, but it may not be 4 months.

Cumulative Numbers of Bruises

Abusive trauma often involves multiple impacts. In both our study and previous studies, patients with abusive trauma sustained significantly larger numbers of bruises than did patients with accidental trauma.[22–24] The cumulative number of bruises was not used as a splitting criterion in our model because the sensitivity and specificity were maximized with other splitting criteria.

Limitations

The certainty of each case's categorization as abuse or accident is a limitation inherent in the retrospective nature of this study. Strict criteria for categorization were applied before the start of the study. Each patient's medical record was analyzed for recurrent medical visits during the study period, and no patient in the accidental trauma group returned with a repeat injury.

Greater attention might have been paid to documentation if physical abuse was suspected. Hospital protocol specifies that all patients in the PICU receive a comprehensive skin assessment every 4 hours, with standardized documentation of all skin findings. This protocol decreases the likelihood of bias or error.

Most MVCs are confirmable accidental causes of trauma in which abuse is not in question. However, their inclusion allows for comparisons between severely injured patients with multiple-impact accidental trauma and those with multiple impacts from abusive trauma. In the control group, skin injuries were similar for MVC and non–MVC cases, with respect to regions and numbers of bruises (Tables 3 and 4).

The results of this study are based on findings for children with abusive or accidental trauma who were admitted to the PICU. Conclusions can be drawn only regarding bruises on severely injured children. However, similarities between our results and the collective analysis of 2400 published skin examinations conducted in ambulatory settings indicate that our results may be applicable in less-acute settings.[22–24]

Our use of an exploratory technique such as a CART model may be considered a limitation. We think that the use of this technique was justified, because we were interested in model-building rather than hypothesis-testing. Fitting a classification tree is a purely exploratory technique, which makes no assumptions about the data and how they were generated.

CONCLUSIONS

Our study generated TEN-4 BCDR to discriminate bruises caused by physical child abuse in children ≤4 years of age. The intent of this rule is to identify children who are at high risk for abuse and require further evaluation, according to the guidelines of the American Academy of Pediatrics.[32] Our findings and literature findings provide compelling evidence that bruising without a clear confirmatory history for any infant who is not cruising and bruising to the torso, ears, or neck of a child ≤4 years of age should be considered "red flags" and should serve as signs of possible physical child abuse. The TEN-4 BCDR requires prospective testing and validation in different clinical settings.

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Inside Edge on NIH Grant Funding May Be to New Investigators: *Recognizing the declining number of individuals opting for a research career in biological sciences, the National Institutes of Health have decided to increase their funding to new investigators who have never received NIH funding. According to an article in* The New York Times *(Harris G,* The New York Times*, September 22, 2009), of the 19 percent of "exception" grants, totaling more than $380 million awarded to individual scientists outside of grant review committees, nearly half went to young scientists, an increase of almost 30 percent since 2003. With the recent economic stimulus money being added to the NIH budget, it will be interesting to see if the young investigator continues to have the inside edge. Now if we could only see the statistics regarding how many of these young scientists were actually funded to do pediatric research!*

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