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# Dating of Bruises in Children: An Assessment of Physician Accuracy

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**ABSTRACT.** *Objective.* To determine whether physicians can estimate accurately the age of an accidental bruise on direct physical examination.

*Methods.* Children who presented to the emergency department of a children's hospital with accidental bruises of known age and origin had demographic data and information about their injury recorded. History-blinded emergency pediatricians, other physicians, and trainees (fellows, residents, and medical students) independently examined the bruised area and recorded injury characteristics and age estimation and ranked characteristics that influenced their estimation.

*Results.* Fifty children with accidental bruises were enrolled. Emergency pediatricians' accuracy of age estimation within 24 hours of actual age was 47.6%. Individual emergency pediatrician's accuracy ranged from 0% to 100%, and the interobserver reliability was poor ( $\kappa = -0.03$ ). Accuracy within 24 hours of actual age was 29.4% for other physicians and 36.8% for trainees, which was similar to the emergency pediatricians. Observers reported using color primarily to estimate age, followed by tenderness and then swelling; however, none of these factors was significantly correlated with accuracy.

*Conclusions.* Physician estimates of bruise age are highly inaccurate within 24 hours of the actual age of the injury. Large individual variability and poor interrater reliability also suggest that caution must be used when interpreting these estimates. This study supports earlier studies, urging extreme caution in estimating bruise age, even when such estimates are based on direct examination of the injured area. *Pediatrics* 2003;112:804–807; *children, bruising, abuse, emergency.*

Physical abuse or inflicted trauma is 1 of the most common types of child maltreatment seen by physicians.<sup>1</sup> Physicians are often called on by child protection agencies to estimate the age of these injuries in an attempt to identify the perpetrator(s), to determine whether multiple episodes of trauma occurred, and to ensure the child's safety.

Bruising of the skin develops after the application of blunt force sufficient to disrupt blood vessels, resulting in blood extravasation and accumulation in the dermal layers. A bruise may not become appar-

ent for hours or even days after injury, depending on the depth of the vessels disrupted.<sup>2,3</sup>

After bleeding has started, the bruise continues to deepen in color until bleeding stops. As the blood separates into serum and clot, the serum starts to be reabsorbed and the associated swelling begins to resolve. Pathology texts comment that initially the color is blue to blue-black as a result of deoxygenated blood.<sup>2</sup> As macrophages ingest the erythrocytes and convert the hemoglobin to bilirubin, the color of a bruise changes, depending on the amount of blood extravasated and the distance from the surface of the skin. Both mobilization of the pigment by macrophages and further metabolism of bilirubin result in gradual fading of the bruise, beginning at the periphery and proceeding toward the center.<sup>2</sup>

Classically, textbooks have suggested that bruises undergo a clearly defined course of color changes with age; however, when comparing the color schemes between textbooks, there is no general consensus on the duration of each stage of color or the exact sequence of color changes.<sup>4,5</sup>

Two major studies, using photographs of bruises, have investigated the color changes of bruises with age and the ability to date the time of injury. Langlois and Gresham<sup>6</sup> studied 369 photographs of bruises (participants aged 10–100 years) of varying ages and assessed them for the presence of particular colors. On the basis of this study, they concluded that age of a bruise could not be determined consistently from color alone, although bruises that displayed yellow color were found to be >48 hours old.

Stephenson and Bialas<sup>7</sup> conducted a study in which a history-blinded observer estimated the age of 50 accidental bruises photographed from 23 children aged 8 months to 13 years. They concluded that aging of bruises from color alone was unreliable and much less precise than pathology textbooks suggested, although, an injury >48 hours old was unlikely to be estimated as one <48 hours old. Both these and other publications have commented on the unreliable nature of using photographic evidence of the injury and have suggested that a study based on direct visual assessment of the injury is required to address this issue further.<sup>5–8</sup>

The objective of this study was to determine whether the age of an accidental bruise could be more accurately estimated on the basis of information obtained from physical examination, when other factors of the injured area (eg, tenderness, abrasion, swelling) might influence the estimate. We also sought to determine whether there was any interobserver reliability between physicians and whether

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the level of clinical training or experience had any influence on the accuracy of dating bruises.

## METHODS

### Study Design

This was an observational study using a convenience sample of eligible patients enrolled over a 9-month period to determine the physicians' accuracy in estimating the age of accidental bruising. Approval for the study was granted by the Children's Hospital of Eastern Ontario Research Ethics Committee.

### Study Setting and Population

The study took place at the emergency department of the Children's Hospital of Eastern Ontario, a tertiary care center in Ottawa, Ontario, with a census of approximately 55 000 patients each year. All children who presented to the emergency department during the study period, whether patients or siblings of patients, were eligible for consideration of enrollment in the study. To be included, children had to be from birth to 18 years of age and have an accidental injury with associated bruising of known age. Children were excluded when the exact age of the injury was not known, when there were suspected nonaccidental injuries, when there were known medical disorders predisposing to easy bleeding/bruising, or when there was severe injury and/or the patient was unstable. Only 1 bruise per child was examined.

### Study Protocol

Patients or siblings of patients were either self-identified (posters about the study were placed throughout the emergency department) or identified by the triage nurse, examining nurse, or emergency department physician. Patients and parents were then approached by a study assistant, who obtained informed written consent for participation. Once a patient was enrolled, the study assistant obtained demographic data and documented the location of the bruise. Information about the exact mechanism of injury and bruise age was obtained by consensus of child and parent. Observers were then asked to complete a standardized study form detailing 1) the bruise's location, 2) any colors seen in the injured tissue, 3) the presence of any other signs of injury (eg, swelling, abrasions, tenderness), 4) the estimated age of the bruise, and 5) which factors influenced their age estimation the most. The observers bisected a timeline to give an exact estimate of bruise age (within hours) and also estimated the age by 1 of 3 broad categories ("fresh": <48 hours old; "intermediate": 48 hours–7 days old; and "old": >7 days old). These age categories were chosen on the basis of standard age groupings used in previous photographic studies estimating bruising age.<sup>7</sup> Each observer remained history-blinded throughout the study period and was not permitted to ask the participant any questions other than whether pain was present on palpation. All observers were physicians or trainees who worked in the emergency department and were divided into the following physician/observer groups: emergency pediatricians, "other" physicians (family physicians and nonemergency trained pediatricians), and trainees (medical students, residents, and fellows).

### Outcome Measures

The main outcome for this study was the physician accuracy in determining bruise age. Secondary outcomes included a comparison of accuracy among levels of clinical training, interobserver accuracy of age estimation and bruise characteristics (eg, color, tenderness, swelling), and association between the age and the color of a bruise.

### Statistical Analysis

Descriptive statistics and comparisons between observer/physician groups are based on a randomly sampled subset of observers that contains at most 1 observer per physician group. This was done to ensure independence between observations within a group because several different observers within each physician group may have examined the same bruise. Emergency pediatricians', other physicians', and trainees' accuracy levels are expressed in percentage for each broad age category of bruises. Using only bruises that had been seen by an emergency pediatri-

cian, other physician, or trainee, a McNemar test was used to compare accuracy levels. Interobserver reliability between different raters assessing the same bruise was measured using  $\kappa$  statistics. Because there are a variable number of observers per bruise, we stratified the patients by the number of ratings and computed a  $\kappa$  for each stratum<sup>9</sup> using a formula based on identities between intraclass correlation coefficients and  $\kappa$  statistics.<sup>10</sup> Then,  $\kappa$  statistics were combined using weights that were related to the stratum sample sizes to yield a summary stratified  $\kappa$ .<sup>11</sup>  $\kappa$  coefficients were computed separately for emergency pediatricians, other physicians, and trainees from the complete data set of observers. Fisher exact test was used to determine whether there was an association between the age and the colors of the bruises as well as the accuracy level and the factors used to estimate the age of a bruise.

## RESULTS

Patients were recruited between August 2000 and March 2001. Fifty children with accidental bruises were enrolled. The mean age of the children was 6.5 years (range: 1 week–18 years) and 29 (58%) of 50 were male. Bruise age ranged from 2 hours to 16 days with 26 (52.0%) bruises being <48 hours old ("fresh"), 20 (40.0%) bruises between 48 hours and 7 days of age ("intermediate"), and 4 (8.0%) bruises >7 days of age ("old"). Bruises were located on the head and neck (48.0%), upper extremity (8.0%), trunk (4.0%), and lower extremity (40.0%). The majority (96.0%) of the bruises were caused by falls or a direct blow. Skin complexion was described as fair in 33 (66.0%) of 50 children, medium in 6 (12.0%) of 50 children, and not documented in 11 (22.0%) of 50 children.

Sixteen different emergency physicians, 8 different other physicians, and 39 different trainees were involved in the study as observers. Forty-two of the bruises were examined by emergency pediatricians, 17 were examined by other physicians, and 38 were examined by trainees. Thirteen bruises were observed by at least 1 emergency pediatrician, 1 other physician, and 1 trainee.

The accuracy of emergency pediatricians, other physicians, and trainees in dating bruises is reported in Table 1. The accuracy of individual emergency pediatricians in dating bruises ranged from 0% to 100%. The interobserver reliability for age estimation by emergency pediatricians within broad categories, calculated from the 6 bruises that were examined by 2 emergency pediatricians, was poor ( $\kappa = -0.07$ ; 95% confidence interval:  $-0.83$  to  $0.77$ ) according to Landis and Koch's standard.<sup>12</sup> Accuracy of individual trainees also ranged from 0% to 100%. Again, there was poor interobserver reliability ( $\kappa = -0.26$ ; 95% confidence interval:  $-0.61$  to  $0.10$ ), based on observations of 19 bruises. We could not obtain a reliability measure for the "other" physician group, because only 3 bruises were examined by >1 physician within this group but individual accuracy ranged from 0% to 100%. When estimating the age of the bruises within 24 hours of the actual age, there was no significant difference between the emergency pediatricians', other physicians, or the trainees' overall accuracy (McNemar test = 5.692,  $df = 4$ ,  $P = .223$ ). When estimating the age of bruises by broad age categories, we found similar results (McNemar test = 5.859,  $df = 4$ ,  $P = .210$ ).

The 3 main factors that emergency pediatricians

**TABLE 1.** Accuracy of Different Physician Groups in Estimating Age of Accidental Bruising

	Emergency Pediatricians (n/N, %) <sup>†</sup>	Other Physicians* (n/N, %)	Trainees (n/N, %)
Accurate within 24 h	20/42 (47.6)	5/17 (29.4)	14/38 (36.8)
Accurate within categories‡			
Overall	32/42 (76.2)	9/17 (52.9)	20/38 (52.6)
Fresh bruises	17/22 (77.3)	5/8 (62.5)	8/18 (44.4)
Intermediate bruises	10/13 (76.9)	3/5 (60.0)	9/15 (60.0)
Old bruises	5/7 (71.4)	1/4 (25.5)	3/6 (50.0)

\* Includes nonemergency trained pediatricians and family physicians working in the emergency department.

† Number of accurate age estimates/total number of bruises observed.

‡ Fresh bruise <48 hours old, intermediate bruises 48 hours to 7 days old, and old bruises >7 days.

used for age estimation were color alone (50.0%), followed by color and tenderness (21.4%) and color and swelling (7.1%). Trainees also indicated using color alone most often (36.8%), followed by color and tenderness (23.7%) and color and swelling (7.9%). The other physicians indicated using color alone (47.1%) and color and tenderness (35.3%) to estimate the age of a bruise. None of these factors was significantly correlated with dating accuracy ( $P = .632$  for pediatricians,  $P = .789$  for trainees,  $P = .190$  for family physicians/other pediatricians), and of those observers who did achieve higher levels of individual accuracy, there was no consistent injury factor used. Also of note, the accuracy was not correlated with any given anatomic location. The accuracy of observers who reported using the presence of an abrasion as a factor in estimating the age of a bruise was 55.6% (5 of 9) compared with 65.6% (80 of 122) for those who did not report using the abrasion as a factor. Although this finding is based on a small number of observations, it suggests that taking account of an abrasion does not by itself substantially increase the observer's accuracy.

There is an association between color and bruise age ( $P < .001$ ) in that red, blue, and purple colors were more commonly seen in bruises <48 hours of age; however, these colors were also seen in bruises older than 7 days. Yellow, brown, and green colors were most often seen in bruises older than 7 days; however, these colors were also seen in bruises <48 hours of age (see Table 2).

The entire group of observers did not always agree on the colors seen or the injury characteristics present (eg, tenderness, swelling). Interobserver reliability assessments revealed (see Table 3) that there was moderate observer agreement only when colors

**TABLE 2.** Bruise Color Reported Compared With Actual Bruise Age

Actual Age of the Bruise	Colors Reported by Observers*			
	Fresh	Mixed	Old	Total
Fresh (<48 h)	30	2	7	39
Intermediate (48 h to 7 d)	4	12	9	25
Old (>7 d)	3	1	9	13
Total	37	25	15	77

$P < .001$ .

\* Fresh, red, blue, purple; old, yellow, green, brown; mixed, combination of "fresh" and "old" colors.

**TABLE 3.** Interrater Reliability of Trainees and Physicians for Color and Other Injury Characteristics (All Observers)

Items	n	$\kappa$ (95% Confidence Interval)
Color (fresh, mixed, old)*	36	0.40 (0.29–0.51)
Swelling	19	0.59 (0.32–0.86)
Tenderness	19	0.36 (0.08–0.63)
Abrasion	19	0.75 (0.48–1.00)

\* Colors grouped into categories on the basis of traditional teaching: fresh, red, blue, purple; old, yellow, green, brown; mixed, combination of fresh and old colors.

were grouped into categories based on traditional teaching (fresh: red, blue, purple; old: yellow, brown, green; and mixed: combination of these).

## DISCUSSION

Pediatricians continue to provide expert witness testimony in child protection investigations, estimating the age of a suspected inflicted injury in an attempt to help identify the perpetrator(s). Recent literature, based on photographic studies, has suggested that age estimation of a bruise on the basis of color alone is neither accurate nor sufficiently specific to provide useful information in a child abuse investigation.<sup>5,7,8</sup> This study eliminated the inconsistency of photographic quality variability by providing information obtained from direct physical examination of the injured area. The association of swelling, tenderness, and abrasions with directly observed colors provided an additional dimension in an attempt to improve further the accuracy of age estimation.

Despite this extra information, observers still reported using color as the primary factor on which the age estimation was based. They had poor agreement on the colors and other injury characteristics seen and were unable to estimate the age of the injured tissue with clinically or legally useful accuracy. There was a wide range of individual observer accuracy, and even pediatricians with the highest individual accuracy did not define a consistent characteristic of the injury that most influenced their estimation. When the age estimates were compared within 24 hours of the actual bruise age, the accuracy for each group was <50%, and there was no significant difference between the pediatricians' estimates and those of the trainees. How accurate does one need to be in estimating the age of a bruise? This

would surely vary depending on the clinical and legal scenario. For example, when one is attempting to determine who had the opportunity to inflict injury or whether injuries are of different ages, then an accurate estimate of age (within 24 hours) likely is essential.

As was reported by the recent studies assessing accuracy of bruise age estimation on the basis of photographic evidence,<sup>6,7</sup> this study also found that colors traditionally associated with fresh bruises tended to be seen more often in bruises <48 hours old; however, they are also seen in bruises >7 days of age. Likewise, colors that are thought to be heralding the resolution of a bruise were seen more often in bruises >7 days of age but were also seen in bruises <48 hours old. This, coupled with the differences in colors and injury characteristics reported between observers for a given bruise, leads to additional inaccuracy and difficulty in consistent age estimation.

Although 50 bruises were observed, the number of bruises observed by an emergency pediatrician as well as another physician and a trainee was only 13. These bruises were used to compare accuracy between the physician/observer groups and to analyze the impact of associated characteristics of the injury on accuracy of age estimation. When interrater reliability was assessed for accuracy of age estimation, smaller pairings within the groups had to be used (only 19 bruises were observed by >1 trainee, and only 6 bruises were observed by >1 emergency pediatrician). These small numbers result in decreased power and impair the ability to detect smaller differences between the observer groups and the various injury characteristics. Perhaps a study using larger numbers of bruises observed would have been able to detect a trend toward increased accuracy of age estimation using direct physical examination.

Given these limitations, this study has still provided information that has serious implications regarding the interpretation of estimates of bruise age. Even when the bruised area was examined directly, it was still difficult for observers, despite the level of clinical training, to estimate reliably the age of a bruise. Physicians continued to use color of the bruise as the primary factor influencing their age estimate, which may suggest that the other clinical information obtained from direct visualization of the injury was not very helpful in achieving better accuracy and would be consistent with traditional training. The child welfare and criminal justice systems make judgments of great consequence based on physician opinions regarding clinical evidence. That even emergency pediatricians, front-line workers

who assess injured tissue on a regular basis, have inadequate accuracy in estimating the age of a bruise underscores the need for extreme caution when interpreting these estimates in both a clinical setting and a court of law.

## CONCLUSIONS

Physician estimates of bruise age within 24 hours are inaccurate and seem to be not much better than chance alone. Within larger time frames, physicians may be accurate; however, given the large individual variability and poor interrater reliability, caution must be used when interpreting these estimates. This is highlighted by the fact that the observers could not even agree on the individual colors seen or the presence of tenderness or swelling for a given injury. This study supports earlier studies, urging extreme caution in estimating bruise age, even when such estimates are based on direct examination of the injured area.

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## REFERENCES

1. Schmitt BD. The evaluation of physical abuse. In: Helfer RE, Kempe RS, eds. *The Battered Child*. 5th ed. Chicago, IL: University of Chicago Press; 1997:175-220
2. Rubin E, Farber JL. Environmental and nutritional injuries: physical injuries. In: Rubin E, Farber JL, ed. *Pathology*. 2nd ed. Philadelphia, PA: Lippincott; 1988:318
3. Ophoven JJ. Forensic pathology. In: Stocker JT, Dehner LP, eds. *Pediatric Pathology, I*. Philadelphia, PA: Lippincott; 1992:257-323
4. Wilson EF. Estimation of the age of cutaneous contusions in child abuse. *Pediatrics*. 1977;60:750-752
5. Stephenson T. Ageing of bruising in children. *J R Soc Med*. 1997;90:312-314
6. Langlois NE, Gresham GA. The aging of bruises: a review and study of the colour changes with time. *Forensic Sci Int*. 1991;50:227-238
7. Stephenson T, Bialis Y. Estimation of the age of bruising. *Arch Dis Child*. 1996;74:53-55
8. Schwartz AJ, Ricci LR. How accurately can bruises be aged in abused children? Literature review and synthesis. *Pediatrics*. 1996;97:254-257
9. Kraemer HC, Periyakoil VS, Noda A. Tutorial in biostatistics: kappa coefficients in medical research. *Stat Med*. 2002;21:2109-2129
10. Fleiss JL. *The Measurement of Interrater Agreement. Statistical Methods for Rates and Proportions*. 2nd ed. New York, NY: John Wiley and Sons; 1981:212-236
11. Barlow W, Lai MY, Azen SP. A comparison of methods for calculating a stratified kappa. *Stat Med*. 1991;10:1465-1472
12. Landis RJ, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33:159-174

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