








**CME**

# Identifying Maltreatment in Infants and Young Children Presenting With Fractures: Does Age Matter?

Ian C. Mitchell, MD<sup>1</sup> , Bradley J. Norat, MD<sup>2</sup>, Marc Auerbach, MD, MSCI<sup>3</sup> , Colleen J. Bressler, MD<sup>4</sup> , John J Como, MD, MPH<sup>5</sup> , Mauricio A. Escobar Jr., MD<sup>6</sup> , Katherine T. Flynn-O'Brien, MD, MPH<sup>7</sup>, Daniel M. Lindberg, MD<sup>8</sup> , Todd Nickoles, RN, MBA<sup>9</sup>, Norell Rosado, MD<sup>10</sup> , Kerri Weeks, MD<sup>11</sup>, and Sabine Maguire, MBE, MBCh<sup>12</sup>

## ABSTRACT

**Objectives:** Child abuse is a significant cause of morbidity and mortality in preverbal children who cannot explain their injuries. Fractures are among the most common injuries associated with abuse but of themselves fractures may not be recognized as abusive until a comprehensive child abuse evaluation is completed, often prompted by other signs or subjective features. We sought to determine which children presenting with rib or long-bone fractures should undergo a routine abuse evaluation based on age.

**Methods:** A systematic review searching Ovid, PubMed/Medline, Scopus, and CINAHL from 1980 to 2020 was performed. An evidence-based framework was generated by a consensus panel and applied to the results of the systematic review to form recommendations. Fifteen articles were suitable for final analysis.

**Results:** Studies with comparable age ranges of subjects and sufficient evidence to meet the determination of abuse standard for pediatric patients with rib, humeral, and femoral fractures were identified. Seventy-seven percent of children presenting with rib fractures aged less than 3 years were abused; when those involved in motor vehicle collisions were excluded, 96% were abused. Abuse was identified in 48% of children less than 18 months with humeral fractures. Among those with femoral fractures, abuse was diagnosed in 34% and 25% of children aged less than 12 and 18 months, respectively.

**Conclusion:** Among children who were not in an independently verified incident, the authors strongly recommend *routine* evaluation for child abuse, including specialty child abuse consultation, for: 1) children aged less than 3 years old presenting with rib fractures and 2) children aged less than 18 months presenting with humeral or femoral fractures (Level of Evidence: III Review).

From the <sup>1</sup>Departments of Surgery, University of Texas Health Science Center at San Antonio and Baylor College of Medicine, San Antonio, TX; <sup>2</sup>University of Texas Health Science Center at San Antonio, San Antonio, TX; <sup>3</sup>Pediatrics and Emergency Medicine, Yale School of Medicine, New Haven, CT; <sup>4</sup>Department of Pediatrics, Medical University of South Carolina, Charleston, SC; <sup>5</sup>Department of Surgery, Case Western Reserve University School of Medicine, Cleveland, OH; <sup>6</sup>Department of Surgery, Mary Bridge Children's Hospital and Health Center, Tacoma, WA; <sup>7</sup>Department of Surgery, Children's Wisconsin, Medical College of Wisconsin, Milwaukee, WI; <sup>8</sup>Emergency Medicine and Pediatrics, University of Colorado School of Medicine, Aurora, CO; <sup>9</sup>Phoenix Children's Hospital, Phoenix, AZ; <sup>10</sup>Department of Pediatrics, Northwestern University Feinberg School of Medicine, Chicago, IL; <sup>11</sup>Department of Pediatrics, University of Kansas School of Medicine, Wichita, KS; <sup>12</sup>Honorary Research Fellow in Child Health, Cardiff University Medical School, Cardiff, UK.

Received April 6, 2020; revision received August 11, 2020; accepted August 22, 2020.

The authors have no relevant financial information or potential conflicts to disclose.

Author contributions: IM, BN, and SM performed initial title/abstract screening; all authors performed article reviews and participated in the panel; IM, BN, and SM wrote original draft of manuscript; and all authors participated in editing and revision processes

Supervising Editor: Michelle L. Macy, MD, MS.

Address for correspondence and reprints: Ian Mitchell, MD; e-mail: [ian.mitchell@christushealth.org](mailto:ian.mitchell@christushealth.org).

If you wish to receive credit for this activity, please refer to the website: <http://www.wileyhealthlearning.com/aem>

ACADEMIC EMERGENCY MEDICINE 2021;28:5–18.

Child abuse affects more than 120,000 victims and resulted in 1,770 deaths in 2018 with \$124 billion in total costs in the United States per year.<sup>1-3</sup> Any child presenting with concern for physical abuse should undergo a standardized evaluation process, with significant concern for abuse being reported to the relevant authorities.<sup>4-6</sup> The challenge is for the clinician to know which injuries *are* concerning for abuse, given how commonly childhood injuries are seen. When child abuse is suspected a comprehensive child abuse evaluation must be undertaken, including a battery of additional laboratory, radiologic, and social services assessments.<sup>6</sup> Barriers to screening for abuse include inability to recognize injury patterns suggestive of abuse, reconciling development with the observed injury, and overcoming ingrained racial and socioeconomic biases. Furthermore, such evaluations may be stressful for a family, regardless of the determination.

Fractures are a common abusive injury in children, but unfortunately, health care providers often do not pursue a child abuse evaluation when children present with fractures that could suggest maltreatment.<sup>7</sup> Thorpe et al.<sup>8</sup> found that 33% of children aged two weeks to three years presenting with fractures had a previous visit demonstrating symptoms or signs suggestive of inflicted injury but were not recognized or evaluated for potential abuse. In addition, patients with lower-extremity fractures and recurrent abuse have demonstrated a significantly higher mortality than those with a single episode of abusive injury.<sup>9</sup>

Certain types of skeletal injuries are highly suggestive of abuse but are also highly dependent on the development of the child.<sup>4-6</sup> Older children can often describe how they were injured; thus, their specific age is less relevant than other factors in the decision to pursue an abuse evaluation. The preverbal child (often, but not exclusively, below the age of 3 years) cannot give a history. While only a surrogate for developmental milestones, age is an objective, reproducible, and well-reported variable that can guide practitioners as to when to pursue an abuse evaluation.

Bias may also influence decisions about abuse investigations. Bias is more common toward African American families and those with low socioeconomic status, whereas abuse is more likely to be missed in Caucasian families and those with higher socioeconomic status.<sup>10,11</sup> The risks of recurrent trauma when abuse is not identified and the disparities in evaluation across health care settings make evidence-based recommendations essential. These could help identify

children with potentially abusive fractures, even when presenting with an apparently accidental fracture.

The aim of this study was to provide evidence-based recommendations to guide which children presenting with a fracture (when not involved in a publicly witnessed incident) must undergo a comprehensive child abuse evaluation based on their age, regardless of other social or subjective features. Components of an abuse evaluation were not defined due to process variability and resource availability by center. Some require subspecialty abuse expert evaluation, others utilize a social worker for the abuse evaluation, and some have a protocolized approach to testing and reporting.<sup>12,13</sup> Best practice guidelines are available from the American Academy of Pediatrics and the American College of Surgeons to help develop local systematic programs, and every hospital must have a robust system in place.<sup>5,6</sup> This guideline was a collaborative effort between members of the guideline committees of the Pediatric Trauma Society (PTS), the Eastern Association for the Surgery of Trauma (EAST), and the Ray E. Helfer Society (Child Abuse Pediatrics).

## METHODS

### Search Strategy

A scoping search of OVID PubMed/Medline was conducted to identify existing reviews and to refine search terms for fractures relating to each long bone (Figure 1). Following this, a comprehensive search of OVID, PubMed/Medline, Scopus, and CINAHL databases, for the period 1980 to 2020, was conducted to identify material relevant to each bone (rib, femur, humerus, forearm/hand, and lower leg). The search was limited to English language articles and excluded case reports, case series, review articles, and book chapters. Studies that dealt only with a specific fracture subtype or morphology were excluded to minimize bias because some, such as classical metaphyseal lesions, are felt to have a specific association with abuse. Likewise, skull fracture was excluded as this overlaps with abusive head trauma (AHT) and many children with AHT do not have skull fractures and present with varied symptoms (fussiness, vomiting, seizures) warranting a separate search strategy, analysis, and recommendations.<sup>14,15</sup>

Title/abstract reviews were conducted by three independent reviewers to determine eligibility, and relevant studies underwent full critical appraisal and risk of bias assessment. Any disagreements were resolved by

Database	Search terms
<b>OID PubMed/Medline</b>	Child Abuse/ OR exp Battered Child Syndrome/ OR exp Shaken Baby Syndrome/ ("child abuse" or "child maltreatment" or "battered child").ti,ab. OR "child abuse".kw.
<b>SCOPUS</b>	(( (( TITLE-ABS-KEY ( "child abuse" ) OR TITLE-ABS-KEY ( "battered child syndrome" ) OR TITLE-ABS-KEY ( "shaken baby syndrome" ) OR TITLE-ABS-KEY ( "child maltreatment" ) OR TITLE-ABS-KEY ( "battered child" ) ) ) ) )
<b>CINAHL</b>	(MH "Child Abuse+") OR "battered child syndrome" OR (MH "Shaken Baby Syndrome") OR (TI "child abuse" OR AB "child abuse") OR (TI "child maltreatment" OR AB "child maltreatment") OR (TI "battered child" OR AB "battered child")

Search terms used for skeletal injuries:

OID PubMed/Medline:

RIB	Exp Rib Fractures/ OR rib*.mp. AND (exp Fractures, Bone/ OR fracture*.ti,ab.)
HUMERUS	Exp Humeral Fractures/ OR (humer*.mp. AND (exp Fractures, Bone/ OR fracture*.ti,ab.)
HAND/FOREARM	Exp Humeral Fractures/ OR (humer*.mp. AND exp Fractures, Bone/ OR fracture*.ti,ab.)
FEMUR	Exp Femoral Fractures/ OR (femur.mp. AND exp Fractures, Bone/ OR fracture*.ti,ab.)

FOOT/LEG	Exp Foot Injuries/ OR (foot.mp. AND exp Fractures, Bone/ OR fracture*.ti,ab.) OR (Exp Leg Injuries/ OR (leg.mp. AND exp Fractures, Bone/ OR fracture*.ti,ab.)
----------	---

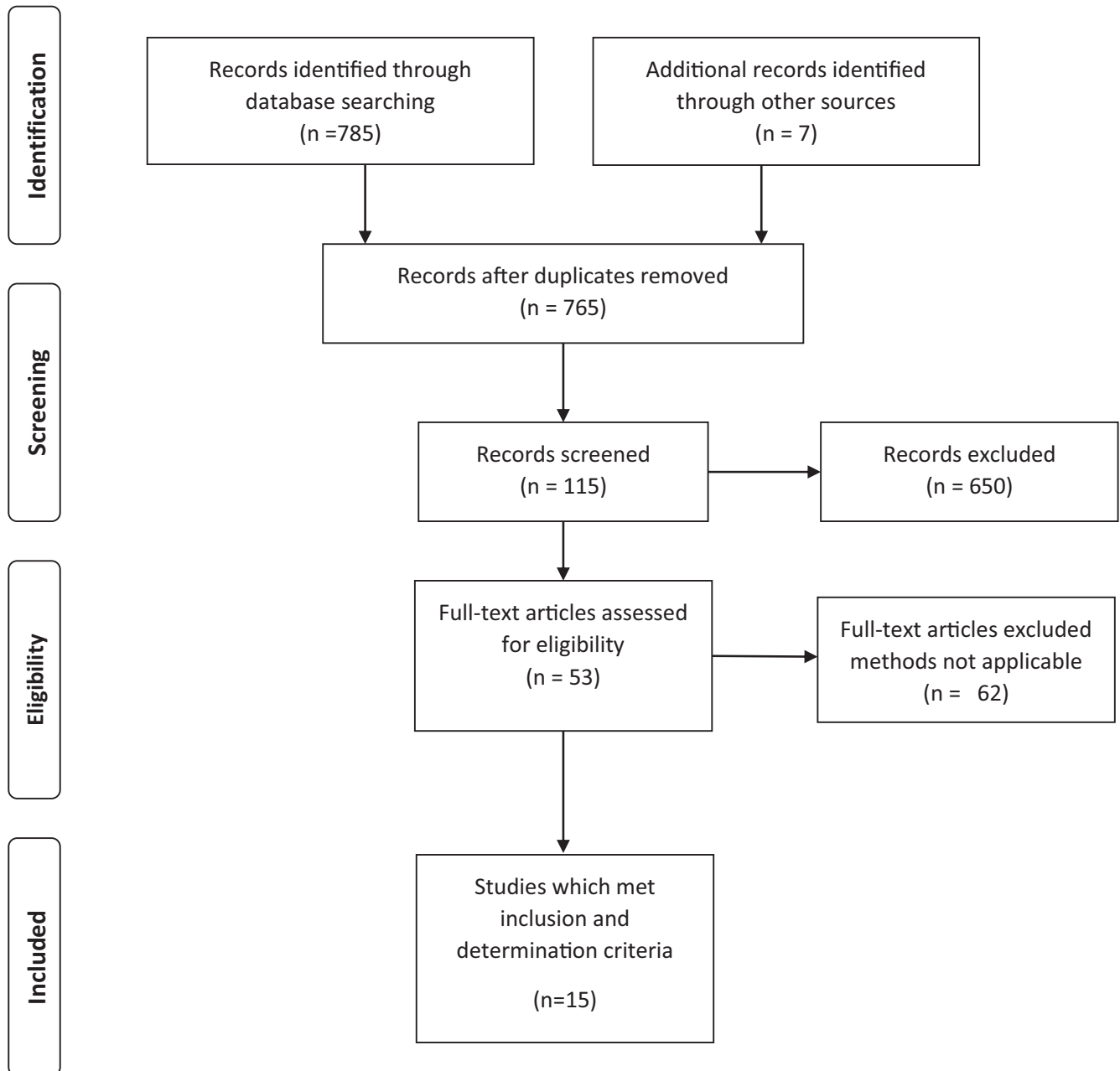
SCOPUS

RIB	(TITLE-ABS-KEY (rib w/1 fracture*))
HUMERUS	(TITLE-ABS-KEY (humer* w/1 fracture*))
HAND/FOREARM	(TITLE-ABS-KEY (hand* w/1 fracture*) OR (TITLE-ABS-KEY (radius w/1 fracture* OR radial w/1 fracture*) AND NOT (TITLE-ABS-KEY (humer* w/1 fracture*))
FEMUR	TITLE-ABS-KEY (femor* w/1 fracture*) OR (femur w/1 fracture*)
FOOT/LEG	(TITLE-ABS-KEY (foot w/1 fracture*) OR (feet w/1 fracture*)) OR TITLE-ABS-KEY (leg w/1 fracture*) AND NOT (TITLE-ABS-KEY (femor* w/1 fracture*) OR (femur* w/1 fracture*))

CINAHL

RIB	(MH "Rib Fractures+" OR (rib* AND (MH Fractures+ OR (TI fracture* OR AB fracture*)))
HUMERUS	(MH Humeral Fractures+ OR (humer* AND (MH Fractures+ OR (TI fracture* OR AB fracture*)))
HAND/FOREARM	(MH "Finger Fractures") OR (MH "Ulna Fractures+") OR (MH "Radius Fractures") OR ((MH "Forearm Injuries+") OR (MH "Hand Injuries+") OR (MH "Finger Injuries+") OR (MH "Forearm Injuries+")) AND (MH Fractures+ OR (TI fracture* OR AB fracture*))
FEMUR	(MH "Femoral Fractures+") OR (femur AND (MH Fractures+ OR (TI fracture* OR AB fracture*)))
FOOT/LEG	(MH "Foot Injuries+") OR (foot AND (MH Fractures+ OR (TI fracture* OR AB fracture*))) OR (MH "Leg Injuries+") OR (leg AND (MH Fractures+ OR (TI fracture* OR AB fracture*)))

Figure 1. OVID PubMed/Medline search.



**Figure 2.** PRISMA diagram.

consensus. Authors were contacted when necessary to clarify data details (see PRISMA flowchart, Figure 2).

### Quality Ranking

Quality measures were based on strength of study design and an evaluation of risk of bias within the studies, as well as exclusion of motor vehicle collisions (MVCs), underlying metabolic bone disease, and iatrogenic causes. All studies identified included children presenting with fractures to ribs, femur, humerus, forearm/hand, or lower leg, within which a cohort of children experiencing abuse was identified. Confirmation of abuse varied widely between studies. To

accommodate for this source of heterogeneity methods of abuse determination were classified utilizing a modified version of “ranking of abuse” by Maguire et al.<sup>16</sup>

Definition of child abuse criteria for determination of abuse/nonabuse included:

1. Confessed, witnessed, or confirmed abuse by court proceeding;
2. Abuse determination contemporaneously with presentation including multidisciplinary team and/or social services;
3. Abuse determination contemporaneously with presentation by single provider regularly tasked with making clinical child abuse evaluations;

4. Abuse determined retrospectively;
5. Suspected abuse, referral only to abuse specialist or social services without determination, or ICD-9/10 coding.

Only studies with a definition of child abuse criteria ranking 1 to 3 were eligible for inclusion, to ensure the highest-quality data.

### Data Analysis

All studies were imported into an Excel database, and the incidence of abuse was calculated using MedCalc (Medcalc Software, Ostend, Belgium) based on a random-effects model. Incidence of abused cases, 95% confidence intervals (CI) and  $I^2$  values were listed where appropriate in the text and figures. Sensitivity analyses could not be performed because studies often reported only age bands (i.e., 0–12 months or 0–18 months); however, any study that reported data from older children was reported in the qualitative narratives. All adjustments for additionally provided unpublished data are reconciled and explained when necessary.

### Guideline Development

Following the systematic review and meta-analysis, an expert panel (Data Supplement S1, available as supporting information in the online version of this paper, which is available at <http://onlinelibrary.wiley.com/doi/10.1111/acem.14122/full>), which advised and contributed to the systematic review design, was convened to review the evidence and develop a recommendation framework. The panel included experts from the field of pediatric emergency medicine, pediatric and adult surgery, and child abuse, and over a 2-day period all members were presented with the included studies and an analysis of the data available. A framework was developed, utilizing the principles in Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) methodology to rate the level of evidence identified by the systematic review and determine the strength of recommendation that could be made.<sup>17</sup> Rigid GRADE methodology could not be applied given the nature of child abuse studies and the ethical limitations of all children presenting with a fracture undergoing a full child abuse evaluation. Even in studies that note hospital policies for routine abuse evaluations below certain ages, significant noncompliance was noted and was often associated with patient race. Furthermore, a diagnostic test was not applicable, as there is no “criterion standard”

test that can be applied to diagnose abuse. Although unable to perform a GRADE analysis, the principles of considering bias, imprecision, inconsistency, heterogeneity, and indirectness were evaluated for each included study, and these principles underpinned the consensus recommendations. The panel convened in October 2018 and an updated search through June 2020 identified two further studies, which following critical appraisal were included with the panel’s agreement.

### Outcome Measures

Panel members agreed that the critical outcome was the identification of child abuse in children presenting to a health care facility with a fracture. Outcomes such as length of stay and mortality were considered but felt not to be relevant for this analysis. Several variables affect length of stay including concomitant injuries and social factors, in addition to treatment of the fracture. In addition, mortality in the abused population is most often a result of head injury. In the fracture literature, the cause of mortality in nonabused patients is not well described.

### Evidence to Recommendation Framework

There is currently no criterion standard testing protocol to determine child abuse, although some guidelines for child abuse evaluation exist.<sup>5,18</sup> The panel felt that the end user of this guideline should weigh our recommendations *in the context of their local and regional resources* to decide the appropriate evaluation protocol, which should include appropriate investigations and consultation with a specialist in child abuse.

From the perspective of the abused child, the group felt that they would want abuse identified before worse injury or death ensued. The nonabused child may also warrant such an evaluation, because neglect or other medical or social conditions may be identified that demand attention. Nonabusive caregivers may be unaware that abuse is occurring and would want it identified. Practitioners concerned about bias and subjectivity would benefit from this, because these recommendations could prompt more standardized evaluation criteria. It is acknowledged that children may experience discomfort from additional laboratory studies and radiation exposure as part of their abuse evaluation. Likewise, the family may experience significant stress from the evaluation, including increased hospital stays, postdischarge social services issues and/or legal difficulties up to the possibility (considered by the panel to be low, but serious) of erroneous removal of custody from the primary caregiver.

Routine evaluations for child abuse in any child presenting with fractures would undoubtedly place a high burden on health care facilities and social services. Abuse evaluations are resource and time intensive, and reimbursement rarely compensates for the expense and time involved. For facilities that do not have such resources, there is the additional burden to them (and families) associated with transfer to specialized centers.

From a societal perspective, the panel placed great weight on the profound loss of productive life years from abusive deaths and the trauma of living with repeated abuse, which may be avoided if evaluations prevented subsequent more serious abuse recurrences. In contrast, it was also reiterated that erroneous removal from custody due to suspected abuse, while felt to be uncommon overall, produces a profoundly negative emotional, physical, and financial impact on families that would also be borne by society at large.

The consensus of the panel, through a single ballot process, was that routine evaluation for abuse in children presenting with a particular fracture should be strongly recommended *if the incidence of abuse in the specified age group was more than 10%*. A conditional recommendation would imply recommending that if a child presented with a fracture and other concerning factors were present, they should of course be evaluated for abuse. This is already a standard of care in the evaluation of such children.<sup>5</sup> Our consensus 10% threshold is identical to one published entirely independently in the United Kingdom in a multicenter study of fractures and child abuse, three months after our panel meeting.<sup>19</sup> There was also unanimous agreement that all recommendations apply to children presenting with fractures who were *not* in an independently verified incident. Thus, our recommendations apply *when the mechanism of injury cannot be verified by an individual unrelated to the child's care*.

## RESULTS AND RECOMMENDATIONS

### Rib Fractures

*“In young children presenting to a health care facility with a rib fracture, at what age should a routine evaluation for child abuse be performed?”*

Five studies of abusive rib fractures in children met the inclusion criteria. Three of these had an age band including the 3-year mark and were included in a quantitative analysis. The remaining two had different upper age limits of four and 5 years old and are included in the narrative synthesis.

**Evidence.** In a 6-year retrospective cross-sectional analysis, Barsness et al.<sup>20</sup> examined all children attending a tertiary children's hospital with rib fractures. Of the 78 children identified, 16 were 3 years of age and older, none of whom were diagnosed with abusive fractures. Of those younger than 3 years, 82% (51/62) of children had fractures attributed to abuse. Of the 11 children whose fractures were deemed nonabusive, all had known medical or postsurgical conditions or were involved in a MVC. Rib fractures in 100% of children younger than 3 years, excluding the 11 with explicit mechanisms of fracture, were attributed to abuse.<sup>20</sup>

A cross-sectional study from 2000 by Cadzow and Armstrong,<sup>21</sup> reviewed data of all children younger than 3 years of age presenting with rib fractures to a tertiary pediatric hospital. Of the 18 patients identified, 15 were found to have abusive fractures (83%) and all the abused children were less than 1 year of age. Of the three accidentally injured patients, two sustained motor–pedestrian collision (MPC) injuries and the third had end-stage liver disease and severe osteopenia. When these patients were excluded the incidence of abuse in children younger than 3 years of age presenting with rib fractures was 100%.

Darling et al.<sup>22</sup> reviewed data from children younger than 3 years of age with radiologically identified rib fractures over a 7-year period. In this cross-sectional analysis, children with medical disorders were excluded, while MVC victims were included. Of the 65 children identified, 47 (72%) were found to have been abused. Eleven of the 18 nonabused children were MVC or MPC victims. If these children were excluded from the analysis, then 87% of children (47/54) less than 3 years old with rib fractures were abused.

A meta-analysis of these studies (Table 1) found a 77% (95% CI = 70% to 83%) incidence of abuse in children younger than 3 years presenting with a rib fracture. Of all our analyses, only the rib data were detailed enough to exclude patients who were in an independently verified incident or had known metabolic diseases. Excluding these events in children younger than three years, 96% were abused (95% CI = 83% to 99%; Table 2).

Two other studies warranted inclusion in the narrative synthesis. A case-control study of children aged below 4 years from a large tertiary pediatric center by Pandya et al.<sup>23</sup> in 2009 identified that 85% (83/98) of children younger than 18 months with rib fractures

were victims of abuse. An additional 38% (11/29) of children with rib fractures between 19 and 48 months were abused. Of note, independently verified public injuries were included in the nonabusive cohort.

In a relevant, but slightly different population, Brennan et al.<sup>24</sup> reported a study of children up to 5 years of age who presented with a condition unrelated to abuse (such as cough, wheezing, or gastrointestinal complaint) and were found to have a rib fracture. The focus was on rib fractures that may prompt a child abuse evaluation. Of 67 children, 58% were abused, including 64% of those younger than 12 months. It is notable that 28% of all patients were found to have diagnoses that may have lessened clinical suspicion for abuse (e.g., osteopenia without prior diagnosis, birth/witnessed trauma, cardiopulmonary resuscitation). Only two of nine patients more than 12 months old were abused.

**Grading the Evidence.** All studies pertaining to abuse in children presenting with rib fractures were retrospective and observational, but most had similar settings, populations, methods of accrual, and abuse determination. There was some inconsistency due to the smaller sample sizes as reflected in nonsignificant or high  $I^2$  values (Tables 1 and 2). This was balanced by the overwhelming rates of abuse in children younger 3 years, which reached as high as 96% when public incidents were removed. The overall quality of evidence in children below 3 years of age was determined to be moderate.

Pandya, Barsness, and Brennan examined the incidence of abuse in children presenting with fractures over 3 years old. Pandya notes that the incidence of abused children in the 18- to 48-month age band is 38% but does not specifically examine the 36-month-old time point. Brennan noted 22% of children from

Table 1

Proportional Meta-analysis of the Incidence of Abuse in Children Under 3 Years of Age Presenting With a Rib Fracture

Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Barsness	62	82.258	70.469 to 90.796	42.57	42.57
Cadzow	18	83.333	58.582 to 96.421	12.84	12.84
Darling	65	72.308	59.810 to 82.690	44.59	44.59
Total (fixed effects)	145	77.560	69.981 to 84.002	100.00	100.00
Total (random effects)	145	77.560	70.511 to 83.895	100.00	100.00

Q	1.9765
DF	2
Significance level	P = 0.3722
$I^2$ (inconsistency)	0.00%
95% CI for $I^2$	0.00 to 96.61

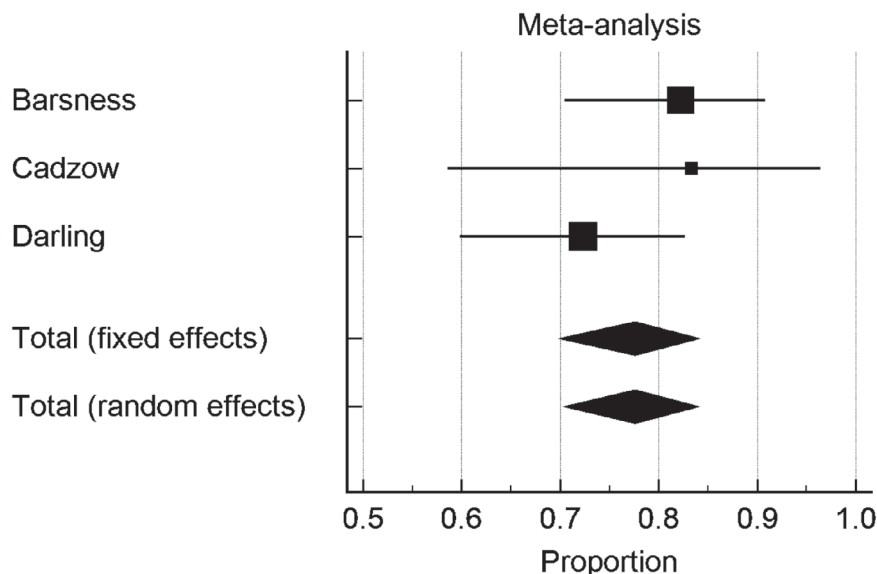


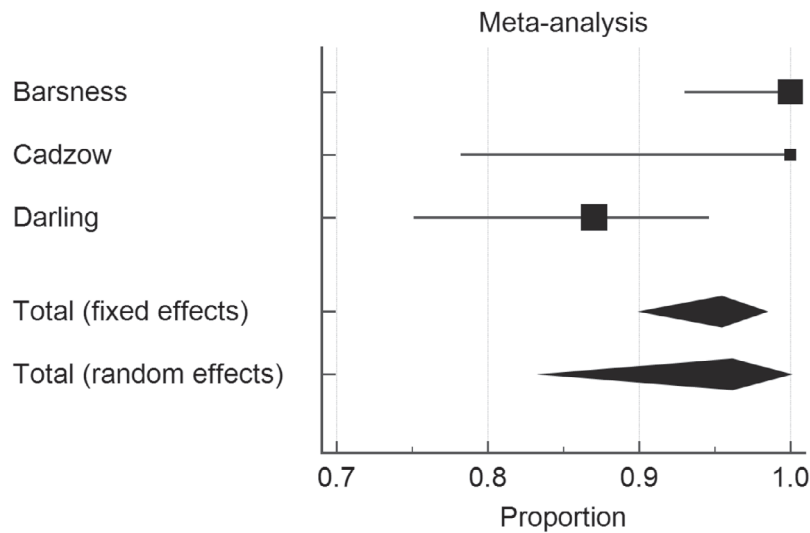
Table 2

Proportional Meta-analysis of the Incidence of Abuse in Children Under 3 Years of Age Presenting with a Rib Fracture, Not Involved in a Motor Vehicle Collision

Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Barsness	51	100.000	93.022 to 100.000	42.28	36.13
Cadzow	15	100.000	78.198 to 100.000	13.01	27.46
Darling	54	87.037	75.099 to 94.626	44.72	36.41
Total (fixed effects)	120	95.453	90.123 to 98.388	100.00	100.00
Total (random effects)	120	96.151	83.709 to 99.958	100.00	100.00

Test for heterogeneity

Q	10.7509
DF	2
Significance level	P = 0.0046
I <sup>2</sup> (inconsistency)	81.40%
95% CI for I <sup>2</sup>	42.14 to 94.02



ages 1 to 5 years old were abused in a more limited study population. Barsness specifically examined the incidence of abusive rib fractures above the age of 3 and found it to be zero.

**Recommendation.** Although the evidence was of moderate quality, the extremely high incidence of abuse led us to conclude unanimously that:

*“In children presenting to a health care facility with a rib fracture, who were not in an independently verified incident, we strongly recommend routine child abuse evaluations for patients younger than 3 years of age.”*

**Humeral Fractures**

*“In young children presenting to a health care facility with a humeral fracture, at what age should a routine evaluation for child abuse be performed?”*

Applying our strict inclusion criteria, four studies addressing humeral fractures were included (Table 3).

**Evidence.** In a case-control study, Worlock et al.<sup>25</sup> reviewed county child protection team records of all children who sustained an abusive fracture over a 6-year period. These 35 children were compared to all children attending the emergency department (ED) of that county’s only ED for a fracture over a 6-month contemporaneous period. To account for the accrual time difference, control data were multiplied by 12. Among the 10 infants 18 months of age or less who presented with a humeral fracture, all 10 were due to abuse. In the toddler group (19 months-5 years), four children sustained an abusive humeral fracture, but 180 children had a humeral fracture that was accidental (adjusted from 15 to account for accrual). In



summary, in this countywide study, 100% of humeral fractures in infants less than 18 months were due to abuse, while the incidence of abusive humeral fractures in children aged 19 months to 5 years was only 2%.

Rosado et al.<sup>26</sup> conducted a cross-sectional study of the records of all children less than 18 months of age presenting with a humeral fracture. Of the 48 patients 12 months and younger, 22 were determined to have suffered an abusive fracture, while 10 were not abusive and five were indeterminate. An additional 11 were not evaluated by the Child Protection Team (CPT), despite hospital protocols mandating evaluation for children less than 12 months with fractures. The incidence of abusive fractures in children less than 12 months was found to be 51% (22/43), when the indeterminate cases were eliminated. In children between 12 and 18 months with a humeral fracture who were evaluated by the CPT, two of five were abused (40%), but only seven of the 49 underwent evaluation. The overall incidence of abuse in children less than 18 months with a humeral fracture was 26%; however, most children 12 to 18 months did not undergo evaluation.

Pandya et al.<sup>27</sup> published a large case-control study at a Level I trauma center comparing children with humeral fractures in their Suspected Child Abuse and Neglect (SCAN) database to those in their trauma registry. For the purposes of analysis, we adjusted the controls by a factor of three to account for different accrual times. For children less than 18 months presenting with a humeral fracture, 43% were determined to have been caused by abuse (30/69). Only 2% (6/252) were caused by abuse in the 18 months to 4-year age group, yielding an odds ratio (OR) for abuse in the younger age group versus older group of 18 (95% CI = 7 to 45). Patients with underlying diseases were excluded; however, MVC victims were included.

Mitchell et al.<sup>19</sup> conducted a large cross-sectional study in seven hospitals in the United Kingdom over a 4-year period, to determine rates of abuse in young children. Supracondylar fractures were excluded based on the previously published association with nonabusive injury.<sup>28</sup> Independently witnessed trauma and metabolic bone diseases were not excluded but were noted within the data set. The published data contained only CIs where the 95% CI for the probability that a humeral fracture resulting from abuse in children aged 0 to 18 months ranged from 16.5% to 54%. The authors recommended routine screening for

abuse in this population up to 24 months of age (but specified nonsupracondylar fractures).

A meta-analysis of these studies, which includes raw data provided by Mitchell et al. (Table 3) found a 48% (95% CI = 24% to 72%) incidence of abuse in children less than 18 months old presenting with a humeral fracture.

**Grading the Evidence.** Overall, an age group cutoff of less than 18 months was the most common in the included studies, all of which were retrospective and observational, but had similar settings, methods of accrual, age bands, and abuse determination. There was notable heterogeneity in the results due to sample size differences, exclusion of classic metaphyseal lesions, and/or supracondylar fractures and inclusion of MVCs. These all contributed to wide CIs, but each of these concerns implies that the true proportion of abuse in the population is underestimated. This heterogeneity was balanced by the high proportion of abuse in children less than 18 months presenting with a humeral fracture. The overall quality of evidence was determined to be moderate.

Three of the four studies contained data examining the proportion of abuse in patients older than 18 months who presented with humeral fractures.<sup>19,25,27</sup> While all three found an incidence of 2% or lower, they did not have similar upper age limits.

**Recommendation.** The panel agreed that, although the evidence was of moderate quality, the serious inconsistency seen in the data would bias toward a conservative estimate of abuse in children less than 18 months compared to older children. The high incidence of 48%, despite a wide CI, remains well above our panel threshold of 10%. For the reasons stated in our framework:

*“In children presenting to a health care facility with a humeral fracture, who were not in an independently verified incident, we strongly recommend routine child abuse evaluations for patients younger than 18 months of age.”*

### Femoral Fractures (Tables 4 and 5)

*“In young children presenting to a health care facility with a femoral fracture, at what age should a routine evaluation for child abuse be performed?”*

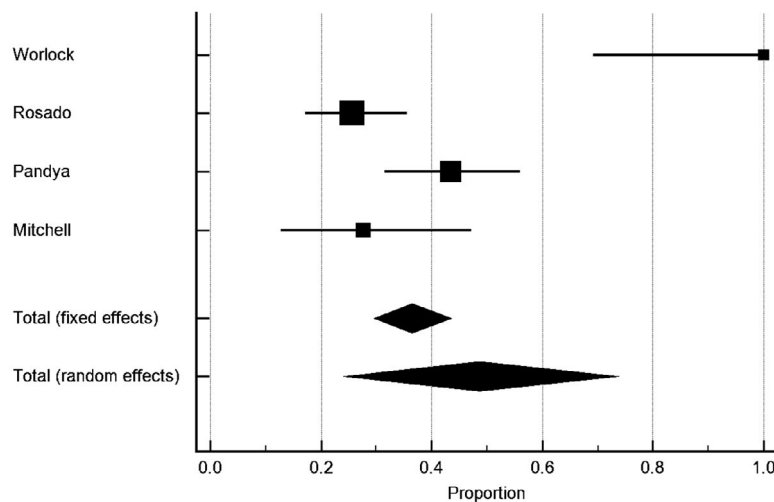
Of the large number of studies examining femoral fractures in young children, eight met our inclusion criteria. Many used an upper age limit of 3 years; others used 4<sup>29,30</sup> or 5 years.<sup>31</sup> In addition, several

**Table 3**  
Proportional Meta-analysis of the Incidence of Abuse in Children Under 18 Months of Age Presenting With a Humeral Fracture

Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Worlock	10	100.000	69.150 to 100.000	5.34	20.53
Rosado	94	25.532	17.094 to 35.567	46.12	27.43
Pandya	69	43.478	31.576 to 55.958	33.98	27.00
Mitchell	29	27.586	12.734 to 47.238	14.56	25.04
Total (fixed effects)	202	36.436	29.860 to 43.408	100.00	100.00
Total (random effects)	202	48.691	24.801 to 72.904	100.00	100.00

**Test for heterogeneity**

Q	33.5153
DF	3
Significance level	P < 0.0001
I <sup>2</sup> (inconsistency)	91.05%
95% CI for I <sup>2</sup>	80.18 to 95.96



studies used 12 months as the lower age cutoff, while others used 18 months as the youngest age group.

Six included studies reported an incidence of child abuse in children less than 12 months of age (Table 4).<sup>19,29–33</sup> An analysis of these studies (including raw data provided by Scherl et al.<sup>32</sup>) found a 34% incidence of abuse in children less than 12 months presenting with a femoral fracture. No significant bias or indirectness was noted, and all studies contained patients within this age band. There was significant heterogeneity as noted in a higher I<sup>2</sup>, which could be explained by the inclusion of MVCs in the data sets. Additionally, the study by Scherl et al. was the only one in this review which was limited to a particular part of the specified bone (in this case, the femoral shaft). It was included because it fits our abuse determination criteria, had consistent age groups, and focused on all femoral shaft fracture types. The exclusion of distal femoral fractures including CMLs would also account for some heterogeneity, suggesting a lower incidence of abuse than the actual rate.

This heterogeneity in the evidence is balanced by a very high incidence of abuse seen in the pooled analysis of this population. Over one-third of children in this age group were identified to have been abused when presenting with a femoral fracture.

Our systematic review identified four studies that examined the incidence of abuse in children presenting less than age 18 months with femoral fractures (Table 5).<sup>19,25,32,34</sup> Again, there was significant heterogeneity that would be explained by similar factors to the less than 12 months age group, but bias, indirectness, and other confounding factors remained minimal. There was a slightly lower pooled incidence when compared to the less than 12 months age group (25% vs. 34%), but this would be expected, because this age band includes more children who are independently mobile. The studies demonstrate that more than a quarter of children younger than 18 months who present with a femoral fracture have been abused.

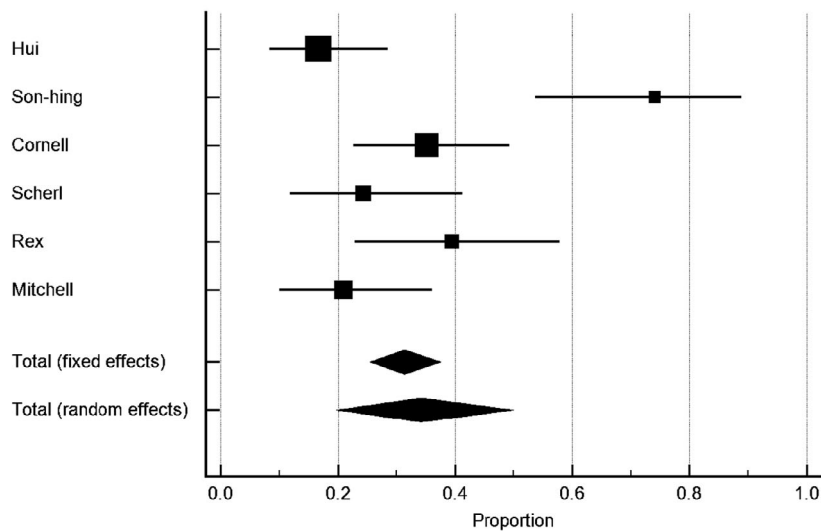
The fourth study, Mitchell et al., has been described in the humeral fracture section above. It found the

**Table 4**  
Proportional Meta-analysis of the Incidence of Abuse in Children Under 12 Months of Age Presenting With a Femur Fracture

Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Hui	60	16.667	8.293 to 28.522	23.46	17.61
Son-hing	27	74.074	53.715 to 88.886	10.77	15.52
Cornell	54	35.185	22.681 to 49.376	21.15	17.39
Scherl	37	24.324	11.773 to 41.199	14.62	16.47
Rex	33	39.394	22.907 to 57.861	13.08	16.14
Mitchell	43	20.930	10.044 to 36.042	16.92	16.86
Total (fixed effects)	254	31.257	25.673 to 37.274	100.00	100.00
Total (random effects)	254	34.079	20.319 to 49.372	100.00	100.00

**Test for heterogeneity**

Q	32.1344
DF	5
Significance level	P < 0.0001
I <sup>2</sup> (inconsistency)	84.44%
95% CI for I <sup>2</sup>	67.81 to 92.48



95% CI for the probability that a child aged 0 to 18 months presenting with a femoral fracture was abused ranged from 6% to 25%. Once again, this study did not exclude children with known metabolic diseases or independently witnessed incidents, yielding a probability of abuse estimate that is likely lower than the true probability. The authors concluded that all children 0 to 18 months sustaining a femoral fracture should undergo an abuse evaluation.

Over the age of 18 months, individual study abuse rates of 0% (Worlock, upper age five years), 2.4% (Baldwin, 4 years), 3% (Mitchell 3 years), and 9% (Scherl, 3 years) are much lower than for the less than 18 months age group (25%). Unfortunately, as the studies use different upper age limits, a quantitative analysis could not be performed.

**Grading the Evidence.** All studies examining femoral fractures were retrospective, but have largely

similar settings, methods of accrual and abuse determination. Heterogeneity in the less than 12 months and less than 18 months age groups was present; however, the incidence of abuse remains high (34 and 25%, respectively). The differences in the upper age limits yield predictable changes in the incidence, which decreases between the 12- and 18-month age ranges, consistent with increasing independent mobility. The overall quality of evidence for the incidence of abuse in children presenting with a femoral fracture for both those aged less than 12 and 18 months was moderate.

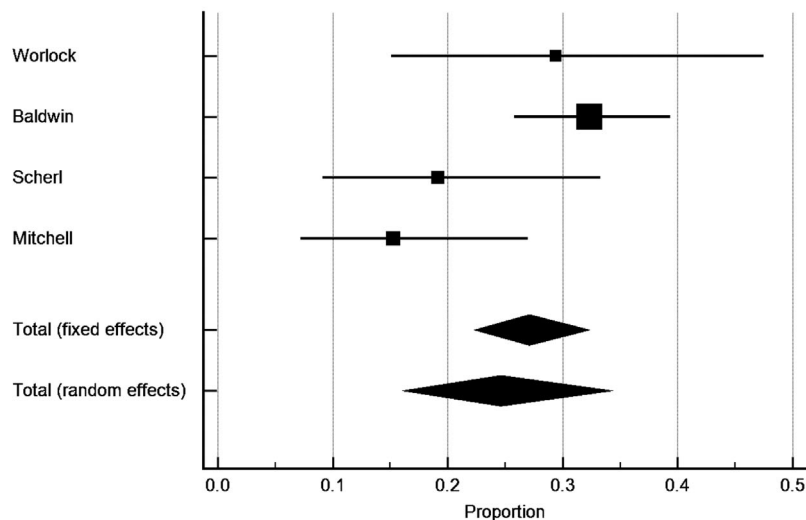
**Recommendation.** The panel agreed that, although the evidence was of moderate quality, the variability seen in the data would bias toward a conservative estimate of the likelihood of abuse in children less than 18 months compared to older children. With no exclusions for MVCs or MPCs, the true

**Table 5**  
Proportional Meta-analysis of the Incidence of Abuse in Children Under 18 Months of Age Presenting With a Femur Fracture

Study	Sample size	Proportion (%)	95% CI	Weight (%)	
				Fixed	Random
Worlock	34	29.412	15.098 to 47.478	10.32	19.53
Baldwin	195	32.308	25.803 to 39.360	57.82	33.19
Scherl	47	19.149	9.149 to 33.260	14.16	22.59
Mitchell	59	15.254	7.220 to 26.992	17.70	24.68
Total (fixed effects)	335	27.107	22.445 to 32.173	100.00	100.00
Total (random effects)	335	24.628	16.323 to 34.015	100.00	100.00

**Test for heterogeneity**

Q	8.8185
DF	3
Significance level	P = 0.0318
I <sup>2</sup> (inconsistency)	65.98%
95% CI for I <sup>2</sup>	0.20 to 88.40



abuse incidence in our intended clinical setting is assuredly higher.

“In children presenting to a health care facility with a femoral fracture aged less than 18 months, who were not in an independently verified incident, we strongly recommend routine evaluation to identify child abuse.”

### Additional Extremity Fracture Types

The systematic review revealed many studies that examined the presence or absence of abuse in children who sustained forearm, hand, lower leg, and/or foot fractures. Unfortunately, there were not enough studies with age-comparative data that also met the inclusion criteria to produce an evidence-based recommendation for *routine or universal evaluation*. Children with such injuries should continue to be evaluated based on clinical suspicion and factors other than age alone.<sup>4,5</sup>

### Using These Guidelines in Clinical Practice

These recommendations are intended to guide practitioners and facilities in standardizing the age at which

an abuse evaluation is *routinely* initiated for young children presenting with rib, humeral, and/or femoral fractures who were not in an independently verified incident, *regardless* of clinical suspicion. The standard that *any* child with a clinical suspicion of abuse warrants an evaluation should govern care for all children. This is true even though there was inadequate data that met our criteria to inform recommendations for routine evaluations in other fracture types.

These recommendations are intended to complement (and not replace) those made in the American Academy of Pediatrics' Committee on Child Abuse and Neglect 2015 position statement.<sup>5</sup> That position statement described history, physical, laboratory, and radiologic findings that should prompt an abuse evaluation, emphasizing that children less than 2 years old are particularly vulnerable. Our recommendations reinforce this need for vigilance in young children, while providing data to reinforce *routine* evaluation for abuse in children with particular fracture types and ages. Providing objective indicators to mandate a child abuse evaluation, when applied across institutions, would

help to limit racial, socioeconomic, and other biases inherent in the selective evaluation of child abuse.<sup>35</sup>

Our framework also acknowledged that while we have identified a set of very-high-risk populations, many children who will be evaluated under these recommendations will be found to have sustained nonabusive injuries. It is recognized that this puts pressure on resources and can cause considerable distress to families. However, we seek to strike the balance between protecting abused children and their siblings from further harm and avoiding large numbers of unwarranted investigations; thus we are making these well-evidenced conservative recommendations.

## CONCLUSION

In children who were not in an independently verified incident, we strongly recommend routine evaluation for child abuse, including specialty child abuse consultation for:

1. Children aged less than 3 years old presenting with rib fractures.
2. Children aged less than 18 months presenting with humeral or femoral fractures.

Statistical support was provided by Annaliese E. Cothron, Director of Operations for the American Institute of Dental Public Health, with funds donated by the John L. Santikos Charitable Foundation, a fund of the San Antonio Area Foundation to The Children's Hospital of San Antonio. REDCap support was provided by Robert Geller, Information Technology Project Manager, Population Health Sciences, UT Health Sciences Center, San Antonio. Information sciences support was provided by Christine Gaspard, Liaison Librarian to the UT Health Sciences Center, San Antonio, School of Medicine. The authors thank Drs. Susan Scherl and Piers Mitchell, as well as their co-investigators, for sharing their raw data to be included in this article.

## References

1. Fang X, Brown DS, Florence CS, Mercy JA. The economic burden of child maltreatment in the United States and implications for prevention. *Child Abuse Negl* 2012;36:156–65.
2. Child Maltreatment 2018. 2020. Available at: <https://www.acf.hhs.gov/cb/resource/child-maltreatment-2018> Accessed Jan 02, 2020.
3. Sedlak AJ, Mettenburg J, Basena M, et al. Fourth National Incidence Study of Child Abuse and Neglect (NIS-4): Report to Congress. Washington, DC: Department of Health and Human Services, Administration for Children and Families, 2010.
4. Escobar MA Jr, Flynn-O'Brien KT, Auerbach M, et al. The association of nonaccidental trauma with historical factors, examination findings, and diagnostic testing during the initial trauma evaluation. *J Trauma Acute Care Surg* 2017;82:1147–57.
5. Christian CW; Committee on Child Abuse and Neglect, American Academy of Pediatrics. The evaluation of suspected child physical abuse [published correction appears in *Pediatrics*. 2015 Sep; 136(3):583]. *Pediatrics* 2015;135:e1337–54.
6. American College of Surgeons Trauma Quality Programs Best Practice Guidelines for Trauma Center Recognition of Child Abuse, Elder Abuse and Intimate Partner Violence. Available at: [https://www.facs.org/-/media/files/quality-programs/trauma/tqip/abuse\\_guidelines.ashx](https://www.facs.org/-/media/files/quality-programs/trauma/tqip/abuse_guidelines.ashx) Accessed Jan 04, 2020.
7. McMahon P, Grossman W, Gaffney M, Stanitski C. Soft-tissue injury as an indication of child abuse. *J Bone Joint Surg Am* 1995;77:1179–83.
8. Thorpe EL, Zuckerbraun NS, Wolford JE, Berger RP. Missed opportunities to diagnose child physical abuse. *Pediatr Emerg Care* 2014;30:771–6.
9. Deans KJ, Thackeray J, Askegard-Giesmann JR, Earley E, Groner JL, Minneci PC. Mortality increases with recurrent episodes of nonaccidental trauma in children. *J Trauma Acute Care Surg* 2013;75:161–5.
10. Wood JN, Hall M, Schilling S, Keren R, Mitra N, Rubin DM. Disparities in the evaluation and diagnosis of abuse among infants with traumatic brain injury. *Pediatrics* 2010;126:408–14.
11. Jenny C, Hymel KP, Ritzen A, Reinert SE, Hay TC. Analysis of missed cases of abusive head trauma [published correction appears in *JAMA* 1999 Jul 7;282(1):29]. *JAMA* 1999;281:621–6.
12. Shum M, Asnes A, Leventhal JM, Bechtel K, Gaither JR, Tiyyagura G. An Expert Panel Evaluation of a Child Abuse Pathway to Improve Decision-Making in Community Emergency Departments. Annual Meeting of the Helper Society April 20 2020. (virtual conference). Accessed Apr 20, 2020.
13. Riney LC, Frey TM, Fain ET, Duma EM, Bennett BL, Murtagh KE. Standardizing the evaluation of nonaccidental trauma in a large pediatric emergency department. *Pediatrics* 2018;141:e20171994.

14. Piteau S, Ward M, Barrowman N, et al. Clinical and radiographic characteristics associated with abusive and nonabusive head trauma: a systematic review. *Pediatrics* 2012;130:315–23.
15. Maguire SA, Kemp AM, Lumb RC, Farewell DM. Estimating the probability of abusive head trauma: a pooled analysis. *Pediatrics* 2011;128:e550–64.
16. Maguire S, Cowley L, Mann M, Kemp A. What does the recent literature add to the identification and investigation of fractures in child abuse: an overview of review updates 2005–2013. *Evid Based Child Health* 2013;8:2044–57.
17. Kerwin AJ, Haut ER, Burns JB, et al. The Eastern Association of the Surgery of Trauma approach to practice management guideline development using Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) methodology. *J Trauma Acute Care Surg* 2012;73:S283–7.
18. ACR Appropriateness Criteria Suspected Physical Abuse-Child. American College of Radiology. 2016. Available at: <https://acsearch.acr.org/docs/69443/Narrative/> Accessed Jan 02, 2020.
19. Mitchell PD, Brown R, Wang T, et al. Multicentre study of physical abuse and limb fractures in young children in the East Anglia Region, UK. *Arch Dis Child* 2019;104:956–96.
20. Barsness KA, Cha ES, Bensard DD, et al. The positive predictive value of rib fractures as an indicator of nonaccidental trauma in children. *J Trauma* 2003;54:1107–10.
21. Cadzow SP, Armstrong KL. Rib fractures in infants: red alert! The clinical features, investigations and child protection outcomes. *J Paediatr Child Health* 2000;36:322–6.
22. Darling SE, Done SL, Friedman SD, et al. Frequency of intrathoracic injuries in children younger than 3 years with rib fractures. *Pediatr Radiol* 2014;44:1230–6.
23. Pandya NK, Baldwin K, Wolfgruber H, Christian CW, Drummond DS, Hosalkar HS. Child abuse and orthopaedic injury patterns: analysis at a level I pediatric trauma center. *J Pediatr Orthop* 2009;29:618–25.
24. Brennan B, Henry MK, Altaffer A, Wood JN. Prevalence of Abuse and Additional Injury in Young Children With Rib Fractures as Their Presenting Injury. *Pediatric Emergency Care*. 2020. <http://dx.doi.org/10.1097/pec.0000000000002071>
25. Worlock P, Stower M, Barbor P. Patterns of fractures in accidental and non-accidental injury in children: a comparative study. *Br Med J (Clin Res Ed)* 1986;293:100–2.
26. Rosado N, Ryznar E, Flaherty EG. Understanding humerus fractures in young children: abuse or not abuse? *Child Abuse Negl* 2017;73:1–7.
27. Pandya NK, Baldwin KD, Wolfgruber H, Drummond DS, Hosalkar HS. Humerus fractures in the pediatric population: an algorithm to identify abuse. *J Pediatr Orthop B* 2010;19:535–41.
28. Farnsworth C, Silva P, Mubarak S. Etiology of supracondylar humerus fractures. *J Ped Orthop* 1998;18:38–42.
29. Son-Hing JP, Deniz OZ. The frequency of nonaccidental trauma in children under the age of 3 years with femur fractures: is there a better cutoff point for universal work-ups? *J Pediatr Orthop B* 2018;27:366–8.
30. Cornell EM, Powell EC. Skeletal survey yield in young children with femur fractures. *J Emerg Med* 2018;55:758–63.
31. Rex C, Kay PR. Features of femoral fractures in nonaccidental injury. *J Pediatr Orthop* 2000;20:411–3.
32. Scherl SA, Miller L, Lively N, Russinoff S, Sullivan CM, Tornetta P 3rd. Accidental and nonaccidental femur fractures in children. *Clin Orthop Relat Res* 2000;376:96–105.
33. Hui C, Joughin E, Goldstein S. Femoral fractures in children younger than three years. *J Pediatr Orthop* 2008;28:297–302.
34. Baldwin K, Pandya NK, Wolfgruber H, Drummond DS, Hosalkar HS. Femur fractures in the pediatric population: abuse or accidental trauma? *Clin Orthop Relat Res* 2011;469:798–804.
35. Higginbotham N, Lawson K, Gettig K, et al. Utility of a child abuse screening guideline in an urban pediatric emergency department. *J Trauma Acute Care Surg* 2014;76:871–7.

## Supporting Information

The following supporting information is available in the online version of this paper available at <http://onlinelibrary.wiley.com/doi/10.1111/acem.14122/full>

**Data Supplement S1.** Panel personnel.