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Invited Review

Skeletal surveys in young, injured children: A systematic review

Christine W. Paine[a,b,*], Joanne N. Wood[a,b,c,d]

[a] Division of General Pediatrics, Children's Hospital of Philadelphia, 3401 Civic Center Boulevard, Philadelphia, PA 19104, USA
[b] PolicyLab, Children's Hospital of Philadelphia, 2716 South Street, 10th floor, Philadelphia, PA, 19146, USA
[c] Department of Pediatrics, Perelman School of Medicine at the University of Pennsylvania, 3400 Civic Center Blvd, Philadelphia, PA, 19104, USA
[d] Leonard Davis Institute of Health Economics, University of Pennsylvania, Colonial Penn Center, 3641 Locust Walk, Philadelphia, PA 19104, USA

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ABSTRACT

Skeletal surveys (SSs) have been identified as a key component of the evaluation for suspected abuse in young children, but variability in SS utilization has been reported. Thus, we aimed to describe the utilization patterns, yield, and risks of obtaining SS in young children through a systematic literature review. We searched PubMed/MEDLINE and CINAHL databases for articles published between 1990 and 2016 on SS. We calculated study-specific percentages of SS utilization and detection of occult fractures and examined the likelihoods that patient characteristics predict SS utilization and detection of occult fractures. Data from 32 articles represents 64,983 children < 60 months old. SS utilization was high (85%-100%) in studies of infants evaluated by a child protection team for suspected abuse and/or diagnosed with abuse except in one study of primarily non-pediatric hospitals. Greater variability in SS utilization was observed across studies that included all infants with specific injuries, such as femur fractures (0%–77%), significant head injury (51%–82%), and skull fractures (41%–86%). Minority children and children without private insurance were evaluated with SS more often than white children and children with private insurance despite lack of evidence to support this practice. Among children undergoing SS, occult fractures were frequently detected among infants with significant head injury (23%–34%) and long bone fractures (30%) but were less common in infants with skull fractures (1%–6%). These findings underscore the need for interventions to decrease disparities in SS utilization and standardize SS utilization in infants at high risk of having occult fractures.

1. Introduction

The skeletal survey (SS), a series of radiographs of the entire body, is a key component of the evaluation of suspected physical abuse, as it can identify occult fractures. Identification of occult fractures characteristic of inflicted trauma can confirm concerns for abuse and enable protection of the child from further harm. In addition, dating the fractures can sometimes help determine the timing of the abuse. For these reasons, the American Academy of Pediatrics (AAP, 1991) published a policy in 1991 recommending that clinicians perform a SS in all cases of suspected physical abuse in children < 2 years old and on a case-by-case basis for children 2–5 years old. The AAP (AAP, 2000, 2009; Christian & Committee on Child Abuse and Neglect, 2015) reaffirmed their SS recommendations in 2000, 2009 and 2015. Since 1997, the American College of Radiology and The Society for Pediatric Radiology (2006, 2011, 2014, 2016) have also published practice parameters recommending that SSs be performed in infants and young children who are suspected victims of abuse. However, in clinical practice, determining which young, injured children warrant

* Corresponding author at: Christine Weirich Paine, MPH,Children's Hospital of Philadelphia, Roberts Center for Pediatric Research, 2716 South Street, Room 10274, Philadelphia, PA 19104, USA.
E-mail addresses: painec@email.chop.edu (C.W. Paine), woodjo@email.chop.edu (J.N. Wood).

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evaluation for suspected abuse and a SS can be challenging.

As a result, disparities by race and socioeconomic status as well as variation across high-risk groups in SS performance in young, injured children have been described (Higginbotham et al., 2014; Lane, Rubin, Monteith, & Christian, 2002; Lindberg, Beaty, Juarez-Colunga, Wood, & Runyan, 2015; Rangel et al., 2009; Wood et al., 2012). These disparities and variation in SS performance may contribute to missed opportunities to diagnose abuse and protect children from further harm. Retrospective studies suggest that between 13% and 39% of young children with abusive injuries had missed opportunities for diagnosis of abuse, and as a result, 17–28% of these children suffered additional injuries from ongoing abuse (Jenny et al., 1999; Oral et al., 2003; Oral et al., 2008; Pierce et al., 2008; Ravichandiran et al., 2010; Thorpe et al., 2014). To inform the development of interventions aimed at decreasing these disparities, increasing appropriate use of SS, and ensuring timely and accurate diagnosis of abuse, we sought to answer the following questions: To what extent are there variation and disparities in which young, injured children are evaluated with SS, and in what subpopulations are SS evaluations appropriate? A better understanding of the current utilization, benefits, and risks of obtaining SS in the evaluation of young, injured children is important for understanding the gaps in current practice and determining appropriate use of SS (as determined by the benefits and risks of SS in each subpopulation). Thus, we aimed to describe the utilization patterns (percentages of children who are evaluated), yield (percentages of children with occult fractures detected), and risks of obtaining SS in young, injured children through a systematic review of the literature.

2. Methods

2.1. Search strategy

We performed a systematic review of the literature on the areas listed in our aims using a pre-specified protocol with inclusion and exclusion criteria (available upon request) and developed this article using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. We searched PubMed/MEDLINE and CINAHL databases for studies published in English between January 1990 and December 2016 using the search terms listed in Appendix A in Supplementary file. Studies were also identified by reviewing reference lists of articles identified during the search.

2.2. Study selection

We included observational studies (including cross sectional and cohort, prospective and retrospective), but excluded surveys, reviews, editorials, textbooks, and unpublished literature. Studies were included if the majority of subjects were ≤ 60 months old or if the data for the subset of children ≤ 60 months old could be extracted. We chose a cutoff age of 60 months, since SSs are not recommended for children older than 60 months (5 years). Studies including fewer than 5 children ≤ 60 months old evaluated with SS were excluded, as such a small sample size would provide unstable study-specific estimates. Titles and abstracts of studies were screened by one of four reviewers (CP, JW, MG, or KK), and non-relevant studies were eliminated (see Fig. 1). Full articles for relevant studies were assessed for eligibility by two reviewers (CP, JW) in an unblinded, standardized manner, with disagreements resolved by consensus.

2.3. Data extraction, assessment of methodological quality, and analysis

Two reviewers (CP, JW) independently identified potential sources of bias and extracted the following information using a standardized form: 1) study population characteristics (ages, injury presentations, sample size, study location, and dates), 2) inclusion and exclusion criteria for subjects, 3) imaging methods and interpretation, 4) number of subjects who were evaluated with SS and who had positive SSs (occult fracture(s) detected on initial SS, and in some cases a composite of the findings of both initial and follow-up SS), and 5) risks of SS. In addition, the reviewers contacted the authors of publications for additional information as needed. The reviewers independently categorized the overall study methodology as A, B, or C using the rating presented in Table 1.

The two reviewers evaluated risk of bias by assessing whether 1) the study population was representative of the general population of children ≤ 60 months old who were evaluated with SS of the age group and/or injury type specified in the study (selection bias) and 2) the selection criteria used were clearly presented in the article (reporting bias). Disagreements between reviewers were resolved through discussion and consensus.

The percentage of subjects who were evaluated with an initial SS and percentage of subjects undergoing an initial SS who had occult fractures detected were calculated with 95% confidence intervals (CIs) for each relevant study. The study-specific positive likelihood and negative likelihood ratios for the associations of demographic and clinical characteristics with SS performance and detection of occult fractures were also computed. Likelihood ratios report the likelihood of an outcome based on the sensitivity and specificity of the test. We reported the likelihood of SS utilization and likelihood of a positive SS if the characteristic was present (LR +) and if the characteristic was absent (LR-). Formulae described by Simel, Samsa, and Matchar (1991) were applied to calculate 95% CIs for likelihood ratios. All analyses were performed using Stata 12 (StataCorp, College Station, TX). We chose not to perform a meta-analysis due to the heterogeneity of study populations and methodologies.

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