Development of Guidelines for Skeletal Survey in Young Children With Intracranial Hemorrhage

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abstract

BACKGROUND AND OBJECTIVE: As evidenced by the variation and disparities in evaluation, there is uncertainty in determining which young children with intracranial hemorrhage (ICH) should undergo evaluation with skeletal survey (SS) for additional injuries concerning for abuse. We aimed to develop guidelines for performing initial SS in children <24 months old presenting with ICH by combining available evidence from the literature with expert opinion.

METHODS: Using the RAND/UCLA Appropriateness Method, a multispecialty panel of 12 experts used the literature and their own clinical expertise to rate the appropriateness of performing SS for 216 scenarios characterizing children <24 months old with ICH. After a moderated discussion of initial ratings, the scenarios were revised. Panelists re-rated SS appropriateness for 74 revised scenarios. For the 63 scenarios in which SS was deemed appropriate, the panel rated the necessity of SS.

RESULTS: Panelists concluded that SS is appropriate for 85% (63), uncertain for 15% (11), and inappropriate for 0% of scenarios. Panelists determined that SS is necessary in all scenarios deemed appropriate. SS was deemed necessary for infants <6 months old and for children <24 months old with subdural hemorrhage that is not tiny and under a skull fracture. For children 6 to 23 months old with epidural hemorrhage, necessity of SS depended on the child's age, history of trauma, signs/symptoms, and ICH characteristics.

CONCLUSIONS: The resulting clinical guidelines call for near-universal evaluation in children <24 months old presenting with ICH. Detailed, validated guidelines that are successfully implemented may decrease variation and disparities in care.

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Ms Paine drafted the initial manuscript, had full access to all of the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis; Ms Paine and Drs Scribano and Wood conceptualized and designed the study; Ms Paine and Dr Wood acquired the data; Ms Paine and Drs Localio and Wood analyzed and interpreted data; Drs Scribano, Localio, and Wood reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and take public responsibility for the content presented in the manuscript.

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WHAT'S KNOWN ON THIS SUBJECT: Abusive head trauma is the leading cause of mortality among abused young children, yet the diagnosis is often initially missed. Uncertainty in determining who should undergo evaluation for additional injuries of concern for abuse may contribute to missed diagnoses.

WHAT THIS STUDY ADDS: The results of this study, based on the literature and knowledge of experts in diverse specialties, provide guidelines for identifying which children <24 months old presenting with intracranial hemorrhage should undergo skeletal survey as part of child abuse evaluations.

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In the United States, infants and young toddlers are more likely to suffer from child abuse and neglect than any other age group.¹ In fact, of the 1520 deaths with a known cause of child maltreatment in 2013, 74% were of children <3 years old.¹ Among abused infants and toddlers, abusive head trauma (AHT) is the leading cause of mortality.² Prompt recognition and accurate diagnosis of AHT by medical providers is key in ensuring appropriate medical care and facilitating protection of the child from further harm, yet ~31% of diagnosed AHT cases are initially missed by physicians, leading to reinjury and even death in some cases.³

Distinguishing cases of AHT from accidental head trauma can be challenging, because young children have limited communication skills, the history provided by the caregiver can be unreliable, and not all abusive injuries may be detected solely by physical examination and history. Young victims of AHT frequently have additional injuries, including fractures, not suspected on history or physical examination but revealed on imaging studies.⁴ The skeletal survey (SS) is an important tool in the evaluation for additional injuries.⁵ Young victims of AHT frequently have occult fractures that may be detected on SS.^{6,7} One study identified occult fractures in 34% of infants <1 year old with suspected AHT who underwent SS.⁶ Another study found that 29% of hospitalized infants <1 year old with unwitnessed head trauma who underwent SS had occult fractures.⁷ Identifying occult fractures that do not match the reported history of trauma can confirm a suspicion of abuse and may also provide additional information on the timing of the injury.⁵ For this reason, the American Academy of Pediatrics (AAP) recommends evaluating for occult fractures using SS in all children <2 years old who

are suspected victims of physical abuse, including AHT.^{5,8}

The AAP provides valuable guidance on factors to consider when determining which children presenting with head trauma may warrant an abuse evaluation. Specifically, the AAP clinical report on the evaluation of suspected child physical abuse advises that, compared with victims of accidental trauma, child abuse victims are more likely to be younger and to have “subdural hemorrhage, retinal hemorrhages, and associated cutaneous, skeletal, and visceral injuries.”⁸ However, more specific guidelines on which young children with head trauma should undergo a child abuse evaluation, including SS, are not available but needed. As a result, there exists wide variation in practice. In a study of 40 pediatric hospitals, only 68% of infants <1 year old with traumatic brain injury (cerebral contusion, laceration, and/or intracranial hemorrhage [ICH]) were evaluated for occult fractures, with adjusted rates ranging from 44% to 86% across hospitals.⁹ Even greater variation in rates of occult fracture evaluation in this population were observed in a study of primarily non-pediatric hospitals; rates of SS performance ranged from 26% to 98% after adjusting for case mix.¹⁰ Previous studies have also shown that among infants with similar type and severity of traumatic brain injury, infants of minority race or without private insurance were more likely to undergo SS than infants of white race or with private insurance.^{7,11} Utilization of more specific guidelines for performing SS may eliminate these disparities and variations in evaluation.⁷ Therefore, we aimed to develop guidelines for initial SS in young children presenting with ICH, with emphasis on including diverse provider disciplines and perspectives.

METHODS

We applied the RAND/UCLA Appropriateness Method (RAM)¹² to identify clinical scenarios in which initial SS is appropriate and scenarios in which initial SS is necessary as well as appropriate for children <2 years old with ICH. We focused on children with subdural hemorrhage (SDH) and epidural hemorrhage (EDH), as these are the most common types of ICH encountered in this population with etiologies of abuse or falls.¹³ This methodology was previously used to identify scenarios in which SS is appropriate and necessary for children <2 years old with fractures or bruises.^{14,15} RAM is a modified Delphi process that informs clinical decision-making by combining the evidence from a systematic review of the literature with clinical expertise to determine the benefit-harm ratio of tests and screening procedures for various clinical scenarios. Unlike similar consensus methods, RAM provides experts with an opportunity to discuss their clinical judgments with each other and modify scenarios accordingly. It has high content, construct, and predictive validities for developing appropriateness criteria.^{12,16–18} A procedure is considered appropriate for a clinical scenario if, exclusive of cost, the expected health benefit sufficiently outweighs the expected negative consequences to make it worthwhile.¹² A procedure deemed appropriate can also be considered necessary if it meets these additional criteria: (1) not offering the procedure would be improper; (2) there is a reasonable chance that the procedure will benefit the patient; and (3) the magnitude of the benefit is not small.¹² The process of RAM is described below and summarized in Fig 1.

The Children’s Hospital of Philadelphia’s Institutional Review Board exempted this study as non-human subjects research.

FIGURE 1

RAM procedure for assessing appropriateness and necessity of SS. (Figure adapted from previously published figure in Wood JN, Fakeye O, Feudtner C, Mondestin V, Localio R, Rubin DM. Development of guidelines for skeletal survey in young children with fractures. *Pediatrics*. 2014;134(1):47.)

Literature Review

Before the 3 rounds of ratings, panelists received the results of 3 published systematic reviews on clinical and neuroradiologic features distinguishing abusive from accidental head trauma. See Supplemental Information A for the list of included reviews. In addition, they received the results of our unpublished systematic review on the efficacy, utilization patterns, benefits, risks, and costs of SS in young children with suspected abuse. We searched PubMed/Medline and CINAHL databases by using search terms in Supplemental Table 3 and limiting the search to studies published in English between 1990 and 2014. Using a pre-specified protocol that rated each study's methodology and excluded surveys, reviews, editorials, case studies, and conference abstracts, we finalized a list of 26 included studies. Data were extracted and summarized for the panelists. See Supplemental Information B for the list of included studies.

Expert Panel Assembly

We recruited 12 experts from key pediatric fields, including child abuse, emergency medicine, trauma surgery, neurosurgery, critical care, and pediatric hospitalists (Supplemental Table 4). We identified candidates through the following mechanisms: (1) nominations, including

self-nominations, from individuals with leadership roles in national professional organizations; (2) review of the literature to identify individuals publishing in the field; and (3) solicitations of recommendations from colleagues. Selection purposively ensured diversity of clinical views across specialty, practice location, gender, and years in practice.

Appropriateness Criteria: Development of Scenarios and Round 1

Based on review of the mentioned literature, we developed a Web-based questionnaire in Research Electronic Data Capture containing 216 clinical scenarios organized into 3 modules that characterize children <24 months old with ICH for which SS might be considered. The clinical scenarios for the first 2 modules were categorized by ICH type (EDH or SDH) and explored the role of these additional parameters on the decision to obtain SS in a child with ICH: (1) child age and developmental ability, (2) caregiver-reported history of trauma to explain the ICH (to determine if the reported mechanism of injury matches the severity of injury), (3) presenting signs and symptoms, and (4) presence of overlying signs of impact. For the SDH scenarios, the following additional parameters were explained: (1) location of SDH, (2) distribution of SDH, and (3)

presence of benign enlargement of the subarachnoid spaces (BESS). Scenarios in the third module explored histories and injuries highly suggestive of abuse, such as caregiver-reported history of child abuse, domestic violence explaining the injury, or additional injuries (eg, whip marks, extensive bruising, burns, frenulum lacerations). See Table 1 for a description of parameters used in scenario development. Scenarios were pilot-tested with physicians outside the panel for clarity and modified as needed.

Each panelist received an e-mail with an introduction, the literature reviews, an electronic link to the questionnaire, and standard instructions on rating the appropriateness of performing SS for each scenario on a Likert scale of 1 to 9, where 1 = extremely inappropriate, 5 = uncertain, and 9 = extremely appropriate. Panelists were advised to use evidence from the literature review and their own clinical judgment to rate SS appropriateness, considering the average patient who presents for care with the conditions specified in each scenario. We asked panelists to make the following assumptions unless otherwise specified in the scenario: (1) patient was not in an independently witnessed and verifiable accidental trauma, such as a motor vehicle accident;

TABLE 1 Parameters Considered in Scenario Development

Parameter	Categories
Child age and developmental ability	<6 mo (cannot crawl) 6–11 mo (can crawl but cannot walk independently) 12–23 mo (can walk independently)
Caregiver-reported history of trauma	None Short fall <3 feet (eg, off of couch) High fall ≥3 feet (eg, off of high chair) Crush injury (eg, TV falling on child)
Presenting signs and symptoms ^a	Clinically well Non-specific signs (ie, irritability and/or emesis) Clinically ill with signs of central nervous system injury (ie, apnea and/or seizures)
Signs of impact (scalp hematoma and/or skull fracture) ^b	Present Absent
ICH type	SDH EDH Tiny extra-axial hemorrhage underlying a skull fracture ^c
Location of hemorrhage ^{b,d}	Convexity Interhemispheric Infratentorial/posterior fossa
Distribution of hemorrhage ^{b,d}	Multiple sites Unilateral Bilateral
BESS ^{b,d}	Present Absent
Finding suggestive of abuse	History of witnessed or confessed abuse explaining injury History of domestic violence explaining injury Additional injuries suggestive of abuse (eg, whip marks, extensive bruising, burns, frenulum lacerations)

^a Deleted after moderated discussion from scenarios in which there was no history of trauma to explain the injury for infants <6 mo with EDH and infants <12 mo with SDH.

^b Deleted after moderated discussion.

^c Added after moderated discussion.

^d Location and distribution of hemorrhage applied only to SDH. The presence or absence of BESS also applied only to SDH.

(2) there is no known history of underlying bleeding disorder (eg, hemophilia, von Willebrand disease); (3) physical examination does not reveal any significant obvious injuries suggestive of abuse (eg, no whip marks, extensive bruising, burns, frenulum lacerations); and (4) there is not a clear history of birth trauma explaining the injury. In the first round, panelists rated the appropriateness of SS for each ICH scenario independently, without interaction with other panelists.

Appropriateness Criteria Rating: Moderated Conference Call and Rounds 2 and 3

To prepare for the moderated discussion, each panelist received an anonymized summary of the distribution of the panel's ratings as well as their own individual ratings for each scenario from Round 1.

During the moderated telephone conference, panelists discussed the ratings, focusing on scenarios for which there was disagreement and scenarios that were deemed ambiguous. During the discussion, the moderator encouraged everyone to participate. More passive participants and participants who were outliers in rating a set of scenarios were prompted to offer their opinions. The panelists then proposed and voted on modifications to the scenarios.

The panelists voted to delete the following parameters from all scenarios, as there was agreement that the information did not influence their decisions to order a SS: presence of overlying signs of impact and presence of BESS. Presenting signs and symptoms were removed from scenarios in which there was

no history of trauma for infants aged <6 months with EDH and for infants aged <12 months with SDH, because there was consensus that this information did not influence the decision to order SS in these scenarios. Panelists expressed concern that location of SDH, which did not significantly influence the ratings of appropriateness, may not always be readily available to frontline clinicians, and that including this information may make the resulting practice guidelines too complicated to implement. As a result, location of SDH was removed. In addition, 1 module of scenarios was added because panelists stated that they view a clinically well child with a tiny extra-axial hemorrhage directly underlying a skull fracture differently than other children with ICHs.

The modifications resulted in 74 scenarios in Round 2 for which panelists rated the appropriateness of SS. After panelists completed Round 2 ratings, we calculated the median rating and the dispersion of ratings for each scenario. Based on RAM, we classified scenarios for which ≥4 panelists' ratings were in each extreme (1–3 and 7–9) as having disagreement. Scenarios with median ratings of 7 to 9 without disagreement were categorized as appropriate, and scenarios with median ratings of 1 to 3 without disagreement were deemed inappropriate. Scenarios with median ratings of 4 to 6 or any median with disagreement were categorized as uncertain.

In Round 3, panelists independently rated the necessity of SS for scenarios that were classified as appropriate in Round 2. Scenarios with median ratings of 7 to 9 without disagreement were categorized as necessary, and those with median ratings of 1 to 3 without disagreement as appropriate but not necessary. Median ratings of 4 to 6 or any median with disagreement

TABLE 2 Necessity of SS for Children <24 Months Old Presenting With ICH

Caregiver-Reported History ^a		Clinical Presentation	Age, mo		
			<6	6–11	12–23
Tiny extra-axial hemorrhage directly under skull fracture					
None	External signs of head trauma and clinically well appearing	N	N	N	
Short fall	Clinically well appearing	N	N	U	
High fall	Clinically well appearing	N	U	U	
Crush injury	Clinically well appearing	N	N	U	
EDH					
None	External signs of head trauma and clinically well appearing	N	N	U	
	Non-specific signs ^b	N	N	N	
	Clinically ill with signs of CNS injury ^c	N	N	N	
Short fall	Clinically well appearing	N	N	U	
	Clinically ill with signs of CNS injury ^c	N	N	N	
High fall	Clinically well appearing	N	U	U	
	Clinically ill with signs of CNS injury ^c	N	N	U	
Crush injury	Clinically well appearing	N	N	U	
	Clinically ill with signs of CNS injury ^c	N	N	U	
SDH					
None	External signs of head trauma and clinically well appearing	N	N	N	
	Non-specific signs ^b	N	N	N	
	Clinically ill with signs of CNS injury ^c	N	N	N	
Short fall	Clinically well appearing	N	N	N	
	Clinically ill with signs of CNS injury ^c	N	N	N	
High fall	Clinically well appearing	N	N	N	
	Clinically ill with signs of CNS injury ^c	N	N	N	
Crush injury	Clinically well appearing	N	N	N	
	Clinically ill with signs of CNS injury ^c	N	N	N	

Summary of panelists' ratings on clinical scenarios related to presentations of children <24 mo old presenting with ICH. SS was rated as one of the following for each scenario: appropriate but not necessary, inappropriate, uncertain whether appropriate or not, appropriate and necessary, or appropriate but uncertain whether necessary. All scenarios were deemed either uncertain whether appropriate or not (U) or appropriate and necessary (N) by the panelists. CNS, central nervous system.

^a In the scenarios presented in the first column, history of trauma explaining the ICH is provided as none (no history provided); short fall <3 feet (eg, off of couch); high fall ≥3 feet (eg, off of high chair); crush injury (eg, TV falling on child).

^b Examples of non-specific signs included irritability and/or emesis.

^c Examples of signs of CNS injury included apnea and/or seizures.

were categorized as appropriate but uncertain whether necessary.

Summary guidelines were synthesized by the study team based on categorizations of scenarios from Rounds 2 and 3.

RESULTS

Panelists determined that SS was appropriate for 85% (63), uncertain for 15% (11), and inappropriate for none of the 74 revised scenarios rated in Round 2 (Table 2). For all 11 scenarios deemed uncertain, panelists agreed that there was uncertainty about the appropriateness of SS. Of the 63 scenarios for which SS was deemed appropriate, SS was deemed necessary for 100% of scenarios. We developed guidelines for SS in

children <24 months old presenting with ICH based on these results (Fig 2).

Confessed Abuse, Intimate Partner Violence, and Additional Injuries

Panelists agreed that SS was necessary for children <24 months old presenting with an extra-axial brain hemorrhage from reported abuse or intimate partner violence or presenting with additional injuries unrelated to the ICH (specifically whip marks, extensive bruising, burns, frenulum lacerations).

Tiny Extraaxial Hemorrhage Directly Under a Skull Fracture

Panelists concluded that SS was necessary for asymptomatic children <24 months old with a tiny extra-axial hemorrhage (SDH or EDH) directly under a skull fracture when

no history of trauma was reported by the caregiver. In addition, panelists determined that SS was necessary for asymptomatic infants <12 months old with a tiny extra-axial hemorrhage directly under a skull fracture with a history of trauma, except for infants 6 to 11 months old with a history of high fall (≥3 feet).

SDH

SS was deemed necessary for children <24 months old presenting with SDH regardless of presentation or history.

EDH

SS was deemed necessary for infants <12 months old presenting with EDH, regardless of presentation or history, except for clinically well infants 6 to 11 months old with a history of a high

I.	<p>Skeletal survey is <i>necessary</i> in children <u><24 months old</u> with ICH (SDH or EDH) if <u>any</u> of the following features are present:</p> <ul style="list-style-type: none"> • History of witnessed or confessed abuse causing the ICH • History of ICH occurring during domestic violence • Additional injuries on physical exam suggestive of abuse (eg, whip marks, multiple bruises, burns, etc)
II.	<p>Skeletal survey is <i>necessary</i> in all children <u><6 months old</u> with ICH</p>
III.	<p>Skeletal survey is <i>necessary</i> in all children <u>6–11 months old</u> with ICH <u>except</u> in the following cases if there are no additional concerns:</p> <ul style="list-style-type: none"> • Clinically well child with history of high fall (≥ 3 feet) and tiny-extra hemorrhage under a fracture • Clinically well child with history of high fall (≥ 3 feet) and EDH
IV.	<p>Skeletal survey is <i>necessary</i> in children <u>12–23 months old</u> with ICH (SDH or EDH) if <u>any</u> of the following features are present:</p> <ul style="list-style-type: none"> • Any SDH <u>except</u> tiny SDH under fracture • Clinically ill patient without history of trauma or with only history of short fall (<3 feet) <p>These guidelines apply to children who do not have a verifiable mechanism of accidental trauma (ie, MVC or witnessed/corroborated fall in public place), do not have underlying bleeding disorder such as hemophilia, and who do not have a clear history of birth trauma that accounts for the injury.</p>

FIGURE 2

Summary of key SS guidelines for examination of children <24 months old with ICH. MVC, motor vehicle crash.

fall (≥ 3 feet). SS was also deemed necessary for young, symptomatic toddlers 12 to 23 months old with EDH unless there was a history of high fall (≥ 3 feet) or crush injury.

DISCUSSION

By drawing on evidence in the literature and clinical experience, a multispecialty expert panel determined that SS was appropriate and necessary for a majority of clinical scenarios describing children <24 months old presenting with ICH, enabling the development of clinical guidelines in this population. It is not surprising that most scenarios required SS and that SS was not deemed inappropriate for any scenarios, given the high likelihood of abuse and related occult fractures in young children with head trauma.^{19, 20} The type of ICH and the history of presentation influenced the panelists' decisions regarding the necessity of SS in children 6 to 23 months old. SS was rated necessary in all clinical scenarios involving SDHs but not in all scenarios involving EDHs, which have been associated with a lower risk of abuse.^{21,22} In addition, SS was not deemed necessary when a tiny extra-axial hemorrhage directly under a skull fracture was found in children 12 to 23 months old with

a history of trauma and infants 6 to 11 months old with a history of a high fall (≥ 3 feet). Panelists had specifically requested the addition of scenarios specifying a tiny extra-axial hemorrhage under a skull fracture, as this injury was thought to be consistent with a direct impact mechanism, such as a fall, and of less concern for abuse than larger SDHs. SS was deemed universally necessary in children <6 months old, likely because they are much less likely than older infants and toddlers to suffer from accidental ICH due to their lack of independent mobility.²¹ Nonetheless, universal evaluation in these populations is not the norm, which may contribute to missed opportunities to diagnose AHT.^{7,11} Studies have shown that age- and injury-specific clinical guidelines regarding SS use have the potential to eliminate disparities in evaluation and improve abuse detection.^{7,23}

There are several limitations to our study. First, although we attempted to recruit a purposive sample of experts with demographic variability, the opinions of our selected experts, drawn from the fields of pediatric and general emergency medicine, child abuse pediatrics, and other pediatric fields, might not reflect the full range of opinions of colleagues in their respective fields. Second,

additional clinical details that were not included in the scenarios, such as presence of parenchymal hemorrhages or diffuse axonal injury on neuroimaging,^{21,22} might influence determinations of appropriateness and necessity of SS in actual clinical settings. Third, for each included clinical feature, we selected a limited number of categories that may not have fully captured differences between groups. For example, children ages 6 to 11 months were included in a single category, but there may be differences in the mobility and risk for accidental head trauma between ages 6 months and 11 months. Fourth, the available scientific evidence that panelists used to inform their decisions is limited, requiring panelists to rely on their clinical experience and judgment in addition to the literature when rating the appropriateness and necessity of performing a SS. We do not know the extent to which panelists relied on the existing evidence versus their experience. RAM is specifically designed to bridge the existing science with expert clinical practice to foster informed medical decision-making in precisely these clinical contexts. Fifth, the guidelines have not been validated and may not accurately identify those children with ICH at the highest risk

for having occult fractures from abuse. Finally, these guidelines focus specifically on SS, but there are other important components to the evaluation of suspected AHT, including fundoscopic examination.

These results provide detailed consensus guidelines for performing initial SS in children <24 months old with ICH. The guidelines developed in this study were not developed by the AAP Section on Child Abuse and Neglect and are not intended to conflict with its general recommendation to perform SS in children <24 months old who are suspected victims of physical abuse. Rather, they are intended to provide additional guidance on specific ICH scenarios for which it is appropriate to suspect abuse and perform SS. Future studies should focus on evaluating the predictive validity of the guidelines to identify children with positive evaluations for occult fractures. Researchers should

also consider developing additional guidelines for SS use in children 24 to 35 months old, as a recent study of children evaluated by hospital child protection teams for concern of physical abuse demonstrated a similar rate of occult fracture identification at ages 24 to 35 months (10%) and 12 to 23 months (12%).²⁴

CONCLUSIONS

By using RAM, a multispecialty panel determined the appropriateness and necessity of SS in children <24 months old with ICH of various presentations, enabling the development of detailed guidelines for performing SS in this population. Detailed, validated guidelines that are successfully implemented have great potential to decrease variation and disparities in care, increase detection of abuse, and decrease use of SS in children with low risk for occult fractures.

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ABBREVIATIONS

AAP:	American Academy of Pediatrics
AHT:	abusive head trauma
BESS:	benign enlargement of the subarachnoid spaces
EDH:	epidural hemorrhage
ICH:	intracranial hemorrhage
RAM:	RAND/UCLA Appropriateness Method
SDH:	subdural hemorrhage
SS:	skeletal survey

they have been involved in the care of the child and been subpoenaed to testify; Ms Paine and Dr Localio have indicated they have no financial relationships relevant to this article to disclose.

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