

Antoinette L. Laskey,¹ M.D., M.P.H.; Kelly L. Haberkorn,² M.P.H.; Kimberly E. Applegate,³ M.D., M.S.; and Michele J. Catellier,⁴ M.D.

Postmortem Skeletal Survey Practice in Pediatric Forensic Autopsies: A National Survey*

ABSTRACT: Recommendations for the evaluation of an unexplained death in infancy include a postmortem skeletal survey (PMSS) to exclude skeletal trauma. Objectives of this study were to assess adherence to these recommendations in forensic autopsies in children equal to or less than 36 months of age, and what factors influence the use or nonuse of the PMSS. We surveyed pathologists who were members of the American Academy of Forensic Sciences. The survey included practice characteristics about where, when, and how PMSS were done. Nearly all respondents (99.6%) indicated they performed PMSS at least some of the time; however, almost a third did not use PMSS for all suspected Sudden Infant Death Syndrome (SIDS), abuse, unsafe sleep, or undetermined causes of death. Despite evidence that "babygrams" are inappropriate in a SIDS workup, 30% of pathologists use them preferentially. Despite SIDS being a diagnosis of exclusion that requires a PMSS, almost 10% of pathologists do not order a PMSS. Future research is necessary to reduce barriers to this important component of the pediatric forensic autopsy.

KEYWORDS: forensic science, forensic pathology, postmortem skeletal survey, child abuse, pediatrics, SIDS, fractures

Determining the cause and manner of death in infants can be challenging and is based on a number of factors, both environmental and clinical. Distinguishing between a case of Sudden Infant Death Syndrome (SIDS) and abuse is no easy task, and is sometimes impossible. SIDS, the leading cause of death in children 1–6 months of age, is a diagnosis of exclusion that can only be made after a thorough death scene investigation and a complete autopsy that includes toxicology, genetic, and radiologic studies (1,2). Comparatively, in children under the age of 1 year, abuse is the leading cause of non-natural deaths. Among the c. 1500 children in the United States who died due to physical abuse, 40% were infants under 1 year (3). Injuries may not be apparent upon external examination. A common manifestation of abuse in infants is skeletal trauma, which may be identifiable only through radiological imaging (4,5).

While autopsies provide direct visualization of the axial skeleton, fractures in the appendicular skeleton may go unrecognized, especially the classic metaphyseal fracture, even with prosection of the limbs. A high-detail skeletal survey is necessary to identify whether skeletal injuries consistent with abuse are present in infants and children (6,7). Studies show that postmortem radiography

contributes important information to the determination of the cause and manner of death (8–10).

In living children <2 years of age, the American Academy of Pediatrics and the American College of Radiology (ACR) guidelines on the diagnostic imaging of suspected child abuse mandates a skeletal survey, consisting of a minimum of 19 films (see Fig. 1) (4,11). A 2004 study by Kleinman and colleagues showed that of 107 pediatric health care facilities, 31% performed 16–20 images, closely approximating the ACR recommendations (5). The American Academy of Pediatrics (AAP) and the Society for Pediatric Radiology (SPR) recommend performing a postmortem skeletal survey (PMSS) consisting of a minimum of five films (each arm, paired hands, paired legs and paired feet) with additional axial films as needed, within 24 h of death in cases of suspected SIDS. The National Association of Medical Examiners (NAME) concurs, and specifies at minimum the necessity of radiographic images of the long bones and suggests the skeletal surveys be conducted by appropriately trained technologists and radiologists (7).

We sought to determine how well pathologists adhere to guidelines on how to conduct forensic autopsies in children ≤36 months of age, and to describe the spectrum of their use of PMSS.

Methods

We conducted a national mail survey of pathologist members of the American Academy of Forensic Sciences (AAFS) ($n = 573$) from June 2005 to December 2005. Only members who conducted forensic autopsies of children ≤36 months of age were eligible, and were asked to complete a short paper survey (15 questions) related to their PMSS practices. Pathologists were asked to indicate in which types of cases they would use postmortem radiography: probable/possible SIDS, possible overlay/positional asphyxia, possible abuse/foul play, undetermined cause of death, or other cause of death not listed. To reflect their varying practices, respondents could choose more than one answer. They were also asked how

¹Department of Pediatrics, Riley Hospital for Children, Children's Health Services Research, Indiana University School of Medicine, 410 West 10th Street, Suite 1020, Indianapolis, IN 46202.

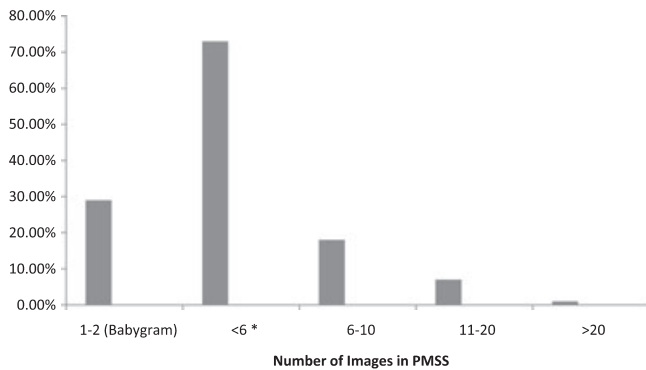
²Children's Health Services Research, Indiana University School of Medicine, 410 West 10th Street, Suite 1020, Indianapolis, IN 46202.

³Departments of Radiology and Pediatrics, Riley Hospital for Children, Indiana University School of Medicine, 702 Barnhill Dr., Indianapolis, IN 46202.

⁴Office of the Iowa State Medical Examiner, 2250 S. Ankeny Blvd, Ankeny, IA 50023.

*Presented in poster format at the Pediatric Academic Societies Annual Meeting in San Francisco, CA, April 29-May 2, 2006; and at the 59th Annual Meeting of the American Academy of Forensic Sciences in San Antonio, TX, February 19-24, 2007.

Received 18 Nov. 2007; and in revised form 21 June 2008; accepted 21 June 2008.



* <6 includes babygrams

FIG. 1—Number of images in PMSS.

many films were included in a typical PMSS, what type of equipment they used for PMSS, who performed the study, and who interpreted the study. A \$2 incentive was offered to enhance participation. Results were analyzed using univariate descriptive statistics with STATA 8.0 (College Station, TX). This study was approved by the Institutional Review Board of Indiana University.

Results

Of 573 members surveyed, 103 were ineligible (e.g., retired, deceased, did not perform autopsies on children ≤ 36 months). Two hundred fifty-nine responded to the survey and answered the main outcome question (Do you perform postmortem skeletal surveys in children ≤ 36 months of age?), for a response rate of 55%. Respondents practiced more commonly in a medical examiner system as opposed to a coroner or mixed system, and served a population of $>500,000$ (Table 1). Nearly half had resident physicians or fellows in their offices. Overwhelmingly, respondents indicated they performed some type of postmortem imaging at least some of the time, with only one respondent answering “no” to the key outcome question.

Respondents were asked to indicate the number of films typically included in their postmortem imaging protocol (response choices of 1–2 [“babygram”], 3–5, 6–10, 11–15, 16–20, >20). Nearly a fifth of respondents (18%) chose more than one of these answers; therefore, we analyzed the data in groups encompassing their highest and lowest answers. Nearly a third (29%) indicated that their postmortem imaging routinely consisted of only 1–2 films. One hundred eighty-two respondents (73%) performed 1–5 films (marking either “1–2,” “3–5,” or both) as part of their protocol. Only 5% indicated that they routinely performed 16 or more films (Fig. 1).

To determine how postmortem skeletal surveys were performed, we asked about the equipment used, the location of the studies, and who performed and interpreted the studies. Overwhelmingly, respondents indicated their primary means of imaging was radiography (either film or digital); however, many used supplemental equipment. Two hundred (77%) used traditional film radiography alone, with the next most common category being digital x-ray images only at 7%. Other imaging equipment included fluoroscopy ($n = 12$), CT scans ($n = 5$), and MRI ($n = 2$). Seventy-nine percent completed all imaging studies on-site exclusively, while an additional 14% performed studies on-site at least some of the time. Only 18 respondents indicated that they never used on-site imaging. The most common off-site location for imaging was hospitals.

TABLE 1—Survey sample characteristics.

Characteristic	Number (%) Reported
Forensic system	
Medical examiner	156 (60)
Coroner	67 (26)
Mixed system or other	15 (11)
No response	9 (3)
Population served	
$>500,000$	175 (68)
100,000–499,999	62 (24)
1,000–99,999	10 (4)
No response	10 (4)
Annual median case load	
All Cases	750
Cases ≤ 36 months of age	50
Trained residents or fellows	49%
Performed any postmortem skeletal surveys	99.6%

According to 12% of respondents, at least some of the time their imaging was done at a children’s hospital; 10% indicated their use of a nonchildren’s hospital. When the postmortem imaging was performed on-site at the same location as the autopsy, morgue assistants were the most commonly used personnel to conduct the study (46%) followed by radiology technologists (36%). PMSS interpretation was largely a joint effort of the pathologist with a radiologist as needed (79%). Only 13% of pathologists reported reading all of their own films without a radiologist; only 8% reported using a radiologist exclusively.

Of the types of cases from which respondents could choose, 87% indicated that they performed radiological studies in all of the listed types of cases (e.g., probable/possible SIDS, possible overlay/positional asphyxia, possible abuse/foul play or undetermined cause of death). Four percent indicated they only performed imaging in cases of suspected foul play. Nine percent indicated that they did no imaging in suspected SIDS cases.

Discussion

This study is the first to use a national sample of forensic pathologists to understand routine postmortem imaging practices in cases involving children <36 months of age. While both NAME and SPR recommend fewer images in a postmortem study as compared with a study in a living child, a “babygram” is universally considered inadequate to visualize the areas of interest—namely the metaphyses. Unfortunately, as our study demonstrates, this “babygram” is all that is routinely performed by nearly a third of pathologists. An additional 30% typically obtain 3–5 films, which closely approximates the minimal standards set forth by NAME and SPR. Given the lack of routine appendicular dissection, adequate imaging is necessary. Classic metaphyseal injuries are commonly not visible at autopsy, and are best visualized through dedicated films of the limbs. These lesions in an infant could affect the determination of cause and manner of death.

While the number of pathologists who indicated that they did not perform imaging studies in cases of suspected SIDS was small (9%), it is especially important to be cognizant of the diagnostic criteria related to SIDS. Given that SIDS is a diagnosis of exclusion, made only after a complete autopsy which includes radiological examination as well as complete death scene investigation, internal examination and appropriate histologic, microbiologic, and toxicologic studies (12,13), it is concerning that cases without the appropriate radiological studies could be incorrectly labeled as SIDS.

There are several limitations of this study. Only forensic pathologists who were members of the AAFC were chosen to participate in this study. These members of the AAFC may have different practices related to pediatric autopsies. Further, when compared to nonrespondents, those who chose to answer our survey may be systematically different. Given that we found 99.6% of respondents use PMSS, a response bias likely exists. Further, it is important to acknowledge the existence of clinical variability. Our purpose in conducting this survey was not an audit of pathology practices; rather it was to determine the scope of practices among those who are currently conducting autopsies in children ≤ 36 months. Again, as the tendency would be to over-report one's own practices, our results might indicate the best case scenario.

We were interested in assessing why a pathologist might *not* perform skeletal surveys, hypothesizing that cost, lack of available imaging equipment or a radiologist would influence the practice. As only one respondent answered that they did not use PMSS, we were unable to address this question. It is important to note that, regardless of whether it is performed at the site of the autopsy or in a hospital, postmortem imaging can be expensive. The costs associated with films and processing, special equipment and lead-lined rooms, radiology technologist time if done at a hospital, and an "official" reading by a radiologist can amount to tens of thousands of dollars annually. Given the budgetary restrictions under which forensic pathologists operate, some offices may choose to spend their limited dollars on other components of the autopsy.

A recently released statement from the NAME states that a complete skeletal series is the "clearly recognized gold standard," but at minimum a single view "babygram" should be performed (1). The severe limitations of the "babygram" in detailing the very areas of the body least likely to be directly visualized at autopsy, however, make this a poor option. While some radiography might be considered to be better than none, the medical community should strive to work collaboratively (e.g., pathologists, radiologists, pediatricians, and hospitals) to ensure affordable and timely access to the gold standard. Without a PMSS, important clinical information (e.g., documentation of potentially inflicted fractures) could be missed in a decedent and other children (e.g., siblings of unsuspected cases of abuse) could be endangered.

Acknowledgments

The authors wish to thank Russell Black for his invaluable assistance with data management and Dr. Andrew Sexton for his help with survey design. This project was supported

financially by the Department of Pediatrics, Riley Hospital for Children.

References

1. Corey TS, Hanzlick R, Howard J, Nelson C, Krous H. A functional approach to sudden unexplained infant deaths. *Am J Forensic Med Pathol* 2007;28:271-7.
2. Hymel KP. Distinguishing sudden infant death syndrome from child abuse fatalities. *Pediatrics* 2006;118:421-7.
3. US Department of HHS, editor. *Child Maltreatment 1999: Reports from the States to the National Child Abuse and Neglect Data System*. Washington, DC: United States Government Printing Offices, 2001.
4. Anonymous. ACR practice guidelines for skeletal surveys in children. *J Am Coll Radiol* 2006;253-7. http://acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/pediatric/skeletal_surveys.aspx
5. Kleinman PL, Kleinman PK, Savageau JA. Suspected infant abuse: radiographic skeletal survey practices in pediatric health care facilities. *Radiology* 2004;233:477-85.
6. American Academy of Pediatrics. Distinguishing sudden infant death syndrome from child abuse fatalities. *Pediatrics* 2001;107:437-41.
7. The Society for Pediatric Radiology—National Association of Medical Examiners. Post-mortem radiography in the evaluation of unexpected death in children less than 2 years of age whose death is suspicious for fatal abuse. *Pediatr Radiol* 2004;34:675-7.
8. Kleinman PK, Blackburne BD, Marks SC, Karellas A, Belanger PL. Radiologic contributions to the investigation and prosecution of cases of fatal infant abuse. *N Engl J Med* 1989;320:507-11.
9. McGraw EP, Pless JE, Pennington DJ, White SJ. Postmortem radiography after unexpected death in neonates, infants, and children: should imaging be routine? *AJR Am J Roentgenol* 2002;178:1517-21.
10. Thomsen TK, Elle B, Thomsen JL. Post-mortem radiological examination in infants: evidence of child abuse? *Forensic Sci Int* 1997;90:223-30.
11. Anonymous. Diagnostic imaging of child abuse. *Pediatrics* 2000;105:1345-8.
12. Krous HF, Beckwith JB, Byard RW, Rognum TO, Bajanowski T, Corey T, et al. Sudden infant death syndrome and unclassified sudden infant deaths: a definitional and diagnostic approach. *Pediatrics* 2004;114:234-8.
13. Bajanowski T, Vege A, Byard RW, Krous HF, Arnestad M, Bachs L, et al. Sudden infant death syndrome (SIDS)—standardised investigations and classification: recommendations. *Forensic Sci Int* 2007;165:129-43.

Additional information and reprint requests:

Antoinette L. Laskey, M.D., M.P.H.
Department of Pediatrics, Riley Hospital for Children
Children's Health Services Research
Indiana University School of Medicine
410 West 10th Street, Suite 1020
Indianapolis, IN 46202
E-mail: alasky@iupui.edu