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Effective Radiation Dose in a Skeletal Survey Performed for Suspected Child Abuse

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Effective dose of a skeletal survey in infants using digital radiography was estimated to be 0.2 mSv using Monte Carlo simulation. Radiation risk from this procedure is, therefore, low. Radiation concern should not be an overriding factor when deciding whether skeletal survey is needed in cases of possible physical abuse. *(J Pediatr 2016;171:310-2).*

Child physical abuse is a leading cause of morbidity and mortality in children.[1] The skeletal survey (SS) is an important screening tool to identify occult fractures in young children when there are concerns for physical abuse.[2-4] In its most recent policy statement related to physical abuse, the American Academy of Pediatrics recommended that a SS be performed in all children less than 2 years of age with concern for abuse and in children 2- to 5-years of age at the discretion of the treating physician.[1]

Over the past several years, there have been multiple studies that raised concerns about radiation exposure in children.[5-8] The level of concern in young children is particularly high because they have more years in their lives to develop cancer after their exposure to radiation and because developing tissue and organs of children are more sensitive than those of adults to ionizing radiation.[9] Although several studies have estimated the radiation dose attributable to common imaging procedures in children,[10-12] to the best of our knowledge, no study has estimated the effective radiation dose of a SS in an infant. For the purposes of this manuscript, an infant is defined as a child less than 1 year of age.

In order to make clinical decisions about the risk:benefit of any procedure that exposes an infant to ionizing radiation and to be able to discuss this issue with parents and caregivers, clinicians should understand the radiation risk from that procedure. Using a Monte Carlo simulation software program, we estimated the effective radiation dose to female and male infants undergoing a SS.

Methods

A SS performed for suspected child abuse at Children's Hospital of Pittsburgh consists of 15 different radiographic examinations using an X-ray system with a digital flat panel detector and manually set technique factors (**Table**). These technique factors have been optimized to provide a high quality diagnostic image at the lowest possible radiation dose. Organ and effective doses were estimated for each of these radiographic projections using PCXMC ver. 2.0, a Monte Carlo program for estimating patient doses in medical X-ray examinations (STUK—Radiation and Nuclear Safety Authority, Helsinki, Finland). The incident air kerma (Ka,i) for each radiograph was estimated by the program based on the X-ray energy (kVp) and tube current-time product (mAs). Each projection was simulated on the phantom, using a beam center entrance reference coordinate in relation to the patient anatomy, and typical image dimensions. The effective dose and estimate of the patient's risk of exposure-induced cancer death (REID) were estimated for a newborn phantom. The PCXMC software uses the International Commission on Radiological Protection Publication 103 tissue weighting factors and the age- and sex-dependent risk models of the Biological Effects of Ionizing Radiation VII report.[9]

REID	Risk of exposure-induced cancer death
SS	Skeletal survey

Results

The total effective dose from the 15 radiography examinations included in the SS was estimated to be 0.2 mSv for both a female and a male infant. This is approximately 7% of the average annual exposure from natural background radiation in the US (3 mSv), or the equivalent of 24 days of background radiation dose.[13] The estimated REID from a SS is, therefore, 5/100 000 for a female and 2/100 000 for a male. By comparison, the rate of severe or fatal abusive head trauma, the leading cause of death from physical abuse, has been estimated to be just under 30/100 000 based on a population-based study.[14]

Discussion

Using a Monte Carlo simulation software program, we have demonstrated that a standard SS performed in a children's hospital exposes infants to just 0.2 mSv of radiation. This effective dose is lower than the radiation dose from multiple

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The authors declare no conflicts of interest.

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http://dx.doi.org/10.1016/j.jpeds.2016.01.017

Table. X-Ray energy (kVp), tube current-time product (mAs), and effective radiation dose in mSv; each radiographic view included in the standard SS performed at Children's Hospital of Pittsburgh

Radioigraphic view	kVp	mAs	mSv
AP axial skull	55	2	0.005
Lateral skull	60	2.5	0.008
AP chest (including all ribs)	60	0.63	0.008
Left oblique ribs	68	3.2	0.05
Right oblique ribs	68	3.2	0.06
AP entire spine	68	3.2	0.03
Lateral entire spine	65	4	0.03
AP pelvis-lower Extremity	55	2	0.009
Lateral lower extremity	55	2	0.002
AP feet	50	1.6	<0.001
AP upper left extremity	55	2	<0.001
AP upper right extremity	55	2	<0.001
Lateral upper left Extremity	55	2	<0.001
Lateral upper right Extremity	55	2	<0.001
AP hands	50	1.6	<0.001

AP, anterior-posterior.

chest radiographs because many of the radiographs done for the SS include regions of the body, such as the limbs, which are not highly radiosensitive organs. Although we looked specifically at infants, there would be very little difference in the effective radiation dose to slightly older children with larger body habitus. In older children, the technique factors are increased, which escalates the radiation dose, but that increase is partially offset by the larger body size, such that the estimated effective dose remains approximately the same. The trade-off between changing the techniques and the larger body size is not exact, but very close.[15] Importantly, the overall dose is very low so that even a change of 25% would still result in a very small effective radiation dose and would not affect a clinician's assessment of the appropriateness of a SS. The lack of a difference in the effective dose for a male and a female is a result of the PCXMC program, which calculates the effective dose based on International Commission on Radiological Protection Publication 103 tissue weighting factors methodology as discussed above. This methodology uses an average tissue-weighting factor for both sexes. In contrast, the REID uses sex-specific tissue risk coefficients, and cancer incidence calculation takes into effect the gonadal exposure.

Importantly, the effective dose, which was estimated, is based on optimizing imaging techniques using digital radiography to ensure that children who undergo SS receive the lowest radiation dose possible.[14] We intentionally included the kVp, mAs, and mSv in the **Table** to allow other institutions to develop a protocol with the same radiation exposure as our hospital. By comparison, the effective dose of a head computed tomography is approximately 1.5-1.9 mSv in a 0- to 2.5-year-old child.[16]

These data are also important for parents who are concerned about their children's exposure to radiation. When asked by parents, physicians now have data that allows them to discuss the estimated radiation dose of a SS and how this dose compares with background radiation or radiation exposure from airline travel, for example. In addition, our data should alleviate concerns of physicians who have been hesitant to screen for physical abuse with a SS because of concern about radiation exposure.

Concern about radiation exposure is unlikely to factor into the decision about whether to obtain a SS in a high-risk situation, as in an infant with a fracture or a bruise, for example, because in this type of scenario, there is no question that the risk (eg, radiation dose)/benefit (eg, detection of child abuse) ratio favors completion of the SS. However, in lower risk situations, such as an infant with an apparent life-threatening event or fussiness, it is reasonable for physicians to weigh carefully risk:benefit because the yield of the SS in these situations is likely to be much lower, despite the fact that these scenarios are all well-documented presentations of missed physical abuse.[17-21] Data from this study should allay physician concern about obtaining SS in these scenarios and suggests that the radiation dose is low enough that the risk:benefit supports obtaining SSs more routinely in these situations.

We recognize that the SS is often only one of several radiologic tests performed in children with suspected physical abuse and, thus, the effective dose from the SS may be only a fraction of the total effective dose to a given child. For many of these children, however, the SS is the first radiologic evaluation for child abuse; other tests (eg, bone scan, repeat SS, head computed tomography) are done because of the findings on the SS. As a result, the decision to obtain the SS is the clinical decision-point that must be considered in order to improve detection of child physical abuse. Once a SS demonstrates unexpected and/or unexplained fractures, other radiologic tests are completed as part of the required evaluation of a child with suspected abuse, and then discussion of acceptable radiation exposure changes significantly. For many children, however, a single SS may be the only test that is done (eg, in an infant with an apparent life-threatening event or a single bruise or a fracture which is of concern, but not diagnostic, for abuse).

In conclusion, given the morbidity and mortality of physical abuse and specifically the mortality and morbidity of missing early signs of physical abuse,[22-24] our data suggest that risk:benefit is tipped strongly in favor of performing SS whenever there is a concern for physical abuse. ■

Submitted for publication Sep 21, 2015; last revision received Dec 10, 2015; accepted Jan 5, 2016.

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