

Postmortem Radiography After Unexpected Death in Neonates, Infants, and Children: Should Imaging Be Routine?

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OBJECTIVE. The purpose of this study was to determine whether postmortem radiography of neonates, infants, and children provides additional information that is not detected at autopsy in cases of unexpected death.

MATERIALS AND METHODS. Inclusion criteria for 106 consecutive postmortem skeletal surveys (1998–2000) were neonates, infants, and children 2 years old or younger with no pre-existing medical condition to account for mortality. Pediatric radiologists interpreted all the radiographic examinations, which consisted of high-detail, collimated anteroposterior radiographs of the appendicular and axial skeleton, lateral radiographs of the axial skeleton, and oblique radiographs of the ribs. Imaging results were compared with those obtained from standard protocol autopsies on all children. Four categories of death were designated: homicide (i.e., abuse, $n = 14$), accidental (e.g., drowning, $n = 28$), natural (e.g., acute illness, $n = 43$), and undetermined ($n = 21$).

RESULTS. The causes of death in the 14 child abuse victims were blunt force injuries to the intracranial ($n = 11$) and chest and abdominal ($n = 1$) areas; asphyxia ($n = 1$); and shaking injury ($n = 1$). In six (43%) of these 14 patients, radiography detected 26 extremity fractures that had not been detected at autopsy; four (67%) of these six patients had fractures of different ages that involved more than one extremity. All fractures carried a high index of suspicion of abuse. No skeletal injuries were found in cases of accidental, undetermined, and natural deaths.

CONCLUSION. Postmortem radiography provides important additional information regarding the extent and chronicity of extremity trauma that may not be documented at autopsy. This finding supports the routine use of radiography in cases of suspected child abuse. Normal findings on postmortem skeletal radiography may help to distinguish cases of natural, accidental, and undetermined causes of death from those of abuse, aiding in the proper handling

A of these cases by medical and law enforcement personnel. According to the latest National Child Abuse and Neglect Reporting System report, an estimated 1100 children in the United States died of abuse and neglect in 1999 [1]. These data correspond to a rate of 1.6 deaths per 100,000 children in the general population. The true incidence of fatal child abuse is likely underestimated because not all states contributed data to this report and because many cases of abuse are not detected. Infants accounted for 42.6% of the reported fatalities, and children younger than 6 years accounted for 86.1% [1]. One of the difficulties in accurately reporting child abuse lies in its detection, which requires a high index of suspicion by both medical and law enforcement personnel. Once suspicion

is established, a thorough investigation by both parties ensues. The current standard dictates that suspected victims of child abuse undergo an autopsy, which may or may not include a radiographic evaluation. The objective of our study was to determine whether important additional information can be obtained with high-detail postmortem radiography and how this information influenced the ultimate disposition of cases of unexpected death in 106 neonates, infants, and children 2 years old and younger.

Materials and Methods

This internal review board-approved investigation consisted of the evaluation of 106 consecutive postmortem skeletal radiographic examinations performed from 1998–2000. Neonates, infants, and children 2 years old or younger who had no

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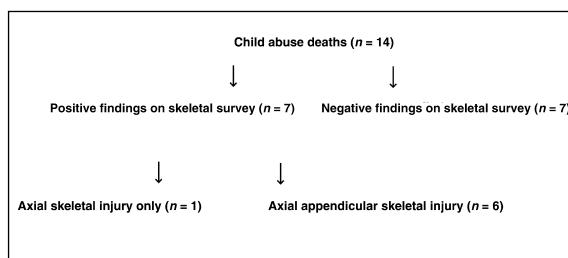


Fig. 1.—Flowchart of all child abuse deaths ($n = 14$) from 106 consecutive cases shows seven patients had fractures present on postmortem radiography. Six (43%) of 14 patients had fractures of both appendicular and axial skeleton. One (7%) of 14 patients had fractures involving only axial skeleton. Seven (50%) of 14 abuse victims had no skeletal survey findings.

preexisting medical condition to account for mortality were included in the study. None of the patients had undergone antemortem radiography for the evaluation of suspected abuse. The postmortem skeletal surveys were performed at no cost to the patients' families.

Skeletal surveys were performed on ultradetail, 10-lp/mm, film (Kodak InSight; Eastman Kodak, Rochester, NY) with collimated anteroposterior radiographs of the appendicular skeleton, anteroposterior and lateral radiographs of the axial skeleton, and oblique radiographs of the ribs. Twenty images were obtained for each study. Radiologists who

had obtained Certificates of Added Qualification in pediatric radiology and were based in a university children's hospital interpreted all radiographs and documented abnormalities. In some cases, the circumstances surrounding the death of the victim were known at the time of interpretation.

Fractures were classified not only by their specific location but also by their location in either the appendicular or axial skeleton. The age of each fracture was estimated; on the basis of fracture age, each fracture was classified as acute (fracture line clearly delineated with no surrounding subperiosteal new bone formation), subacute (loss of fracture line definition with subperiosteal new bone formation), or remote (callus formation surrounding fracture site). These criteria served as guidelines for fracture dating, although we realize that dating of classic metaphyseal fractures is more difficult because the signs of healing previously described are sometimes inconspicuous [2]. Results were given to the forensic pathologist at the time of the initial interpretation.

Forensic pathologists performed autopsies on all children using a routine protocol that included examination of the axial skeleton and visual examination of the external surfaces of the extremities. The pathologist designated four categories of manner of death: homicide (i.e., child abuse, $n = 14$), accidental (e.g., drowning, $n = 28$), natural (e.g., acute illness, $n = 43$), and undetermined ($n = 21$). Cases of sudden infant death syndrome ($n = 20$) were classified as natural deaths. Radiographic and autopsy results were then compared.

Results

Of the 106 postmortem skeletal surveys and autopsies performed, 14 cases were categorized as homicides; all were determined to have been caused by child abuse. Of the 14 abused children, six were male and eight were female, ranging in age from 2 weeks to 17 months. The average age was 3.6 months. Eleven died from blunt force injury of the head. Five of these 11 children also had coexisting blunt force injuries of the chest, abdomen, and back. Additional causes of death included asphyxia ($n = 1$), blunt force injury of the chest and abdomen ($n = 1$), and shaking injury ($n = 1$).

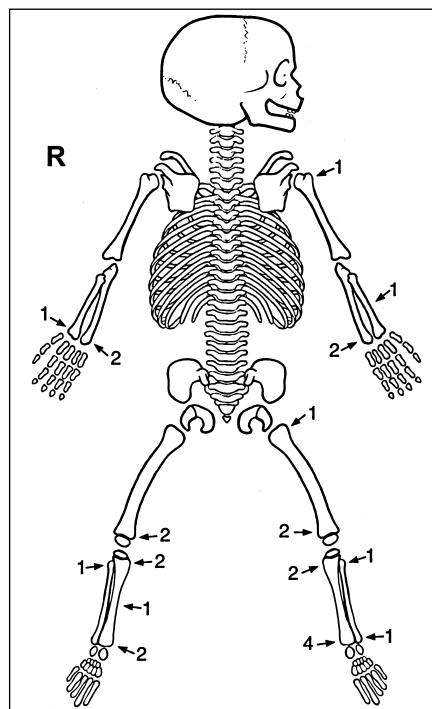


Fig. 2.—Diagram of infant skeleton reveals specific sites and total number of all extremity fractures detected on postmortem radiography in abuse victims. All fractures were classic metaphyseal lesions, which are associated with high index of suspicion of abuse, except two fractures that involved proximal right tibial diaphysis in one infant and left distal radial diaphysis in another infant. In two infants with these fractures, classic metaphyseal fractures were also present in other extremities. R = right.

The postmortem skeletal surveys detected skeletal abnormalities in seven (50%) of the 14 abuse victims. Six (43%) of these 14 patients had fractures involving both the appendicular and axial skeleton, and one victim had fractures involving only the axial skeleton (Fig. 1).

Twenty-six extremity fractures were detected radiographically (Fig. 2) in the 14 victims of child abuse. Twenty-four (92%) of these fractures were metaphyseal corner fractures, the type of fracture most associated with abuse (Fig. 3). A total of two diaphyseal fractures were detected in two infants. This type of injury, although not as specific for abuse as the classic metaphyseal corner fracture, also carries a high index of suspicion of abuse in the nonambulatory infant [2]. Interestingly, postmortem radiography revealed classic metaphyseal fractures in addition to the diaphyseal fractures in both of these patients. Only subacute metaphyseal fractures were present in two patients, only acute metaphyseal fractures were present in one patient, and a combination of both healing and acute fractures was seen in three patients (Table 1).

Fifty-three fractures of the axial skeleton were identified at autopsy. Twenty (38%) of these 53 fractures were acute fractures of the ribs ($n = 19$) and thoracic vertebral bodies ($n = 1$) that were not detected on postmortem radiography. These findings support previously published data [3, 4]. The rib fractures were nondisplaced, and 12 (63%) of these 19 fractures involved the anterior ribs. Acute, nondisplaced rib fractures were identified at autopsy by the presence of acute hemorrhage and edema overlying the fracture site. These findings then led the pathologist to digitally examine the rib cortex. Any cortical irregularity felt by the pathologist at digital examination of the site of overlying acute edema or hemorrhage was determined to represent an acute rib fracture. Healed fractures involving the posterior ribs at the costovertebral junction and lateral ribs were identified on radiographs by callus formation surrounding the prior fracture site. No fractures of the axial skeleton were detected solely on postmortem radiography.

In cases of accidental, natural, and undetermined causes of death, postmortem radiography detected no osseous injuries.

Discussion

More than 50 years ago, the medical community became aware of the radiologic manifestations of nonaccidental trauma. Since

Caffey's landmark article in 1946 [5], much has been learned about the mechanisms of injury and skeletal manifestations of child abuse. The characteristic locations and patterns of osseous injury seen in victims of child abuse have been well established previously and are beyond the scope of this article [2, 6, 7]. The main radiologic contribution to the evaluation of child abuse continues to be the documentation of radiologic features of osseous injuries that are specific for abuse. Performing a high-detail skeletal survey is the most common way of evaluating whether skeletal injuries specific for abuse are present in infants. Although high-detail skeletal surveys are routinely performed on living chil-

dren in cases of suspected abuse, the routine use of radiography in deceased children in whom abuse is suspected has not yet been established. If postmortem radiography is performed, then it is often done by those with no formal training in radiography, and the images are interpreted by nonradiologists. Prior reports have documented the utility of performing high-quality postmortem skeletal surveys for both the documentation of child abuse and the prosecution of offenders [3, 4, 7–9]. This study sought to expand the focus of prior studies to evaluate the utility of high-detail postmortem radiography in neonates, infants, and children not only in cases of suspected abuse, but also in cases of unexpected death.

Abuse is one of the four categories of causes of unexpected death in children. The other three categories are natural, accidental, and undetermined causes. In our study, the most common cause of death in cases of abuse was blunt force injury of the head. This finding corresponds to findings reported in another study [8]. Blunt force injury of the head was readily detectable at pathologic examination: findings most often consisted of contusions, skull fractures, cerebral cortical contusions, and subdural hemorrhages. Although the acute cause of death in these cases could be determined at routine autopsy examination, this examination did not address the issue of the presence of acute or re-

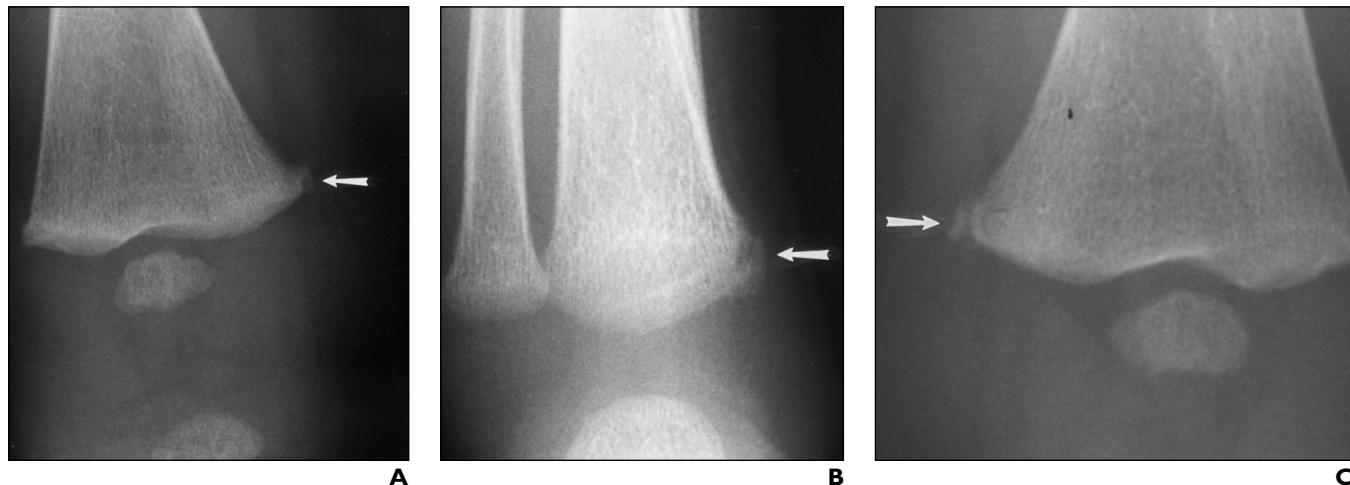


Fig. 3.—11-week-old male infant with blunt force injuries of chest and abdomen. Extremity fractures and healed rib fractures were detected only on postmortem radiography. Acute rib fractures were revealed both at autopsy and on postmortem radiography.

A, Anteroposterior radiograph of right distal femur shows corner fracture (classic metaphyseal lesion) of distal right medial femoral metaphysis (arrow).

B, Anteroposterior radiograph of distal right tibia shows classic metaphyseal fracture of distal right tibial metaphysis (arrow).

C, Anteroposterior radiograph of distal left femoral metaphysis shows classic metaphyseal fracture of distal left medial femoral metaphysis (arrow).

D, Anteroposterior radiograph of chest reveals fractures with callus formation of right lateral third and fourth ribs and right posterior ninth ribs (large arrows). Note acute fractures involving left posterior third, fourth, seventh, eighth, and ninth ribs (arrowheads) and left lateral sixth and seventh ribs (small arrows). Endotracheal tube terminates in distal trachea. Gastric dilatation resulted from resuscitative efforts at scene before intubation.

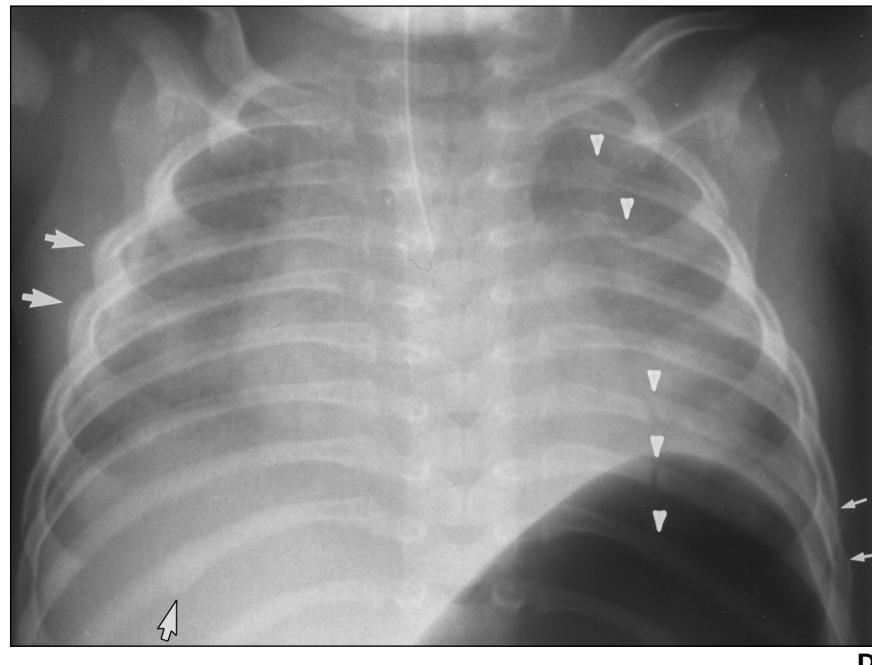


TABLE I Postmortem Radiographic Findings of Extremity Fractures in Six Pediatric Patients				
Patient	No. of Fractures			Total
	Acute	Subacute	Remote	
A	0	1	0	1
B	0	2	0	2
C	2	0	0	2
D	3	1	0	4
E	3	3	0	6
F	8	0	3	11
Total	16	7	3	26

mote coexisting extremity trauma because the routine autopsy protocol includes only visual examination of the extremities.

Previous reports have confirmed that routine gross inspection of the extremities at autopsy is insensitive for the documentation of metaphyseal injury; however, documentation of this type of injury is paramount in cases of suspected abuse [3, 8]. Information about the full extent and chronicity of trauma is critical to the investigation of child abuse and to the prosecution of offenders. The prosecution of abuse cases is often difficult because injuries sustained from an accidental fall can often mimic those of abuse. Similarly, the lack of findings in an asphyxiated infant at autopsy can make a case of suspected child abuse hard to substantiate. As Kleinman et al. [8] found, "The process ultimately rests on the perceived likelihood that a jury of the defendant's peers will view the strength of the evidence as sufficient to warrant a guilty verdict." Therefore, the medical community should take measures to identify all injuries that may support the suspicion that death resulted from inflicted trauma.

Postmortem radiographic finding of fractures that carry a high index of suspicion for abuse have proved extremely useful in the correct classification and prosecution of cases of suspected child abuse. At the time of this writing, five of the seven homicide cases that had positive findings on the skeletal survey were awaiting trial. The death of one patient, a 5-week-old female infant, was tried as a homicide and resulted in the conviction of the victim's father (Fig. 4). Subsequent neglect charges against the victim's mother are also being pursued. The skeletal survey findings in the other patient were helpful in obtaining a confession from the victim's father, who was convicted of neglect of a de-

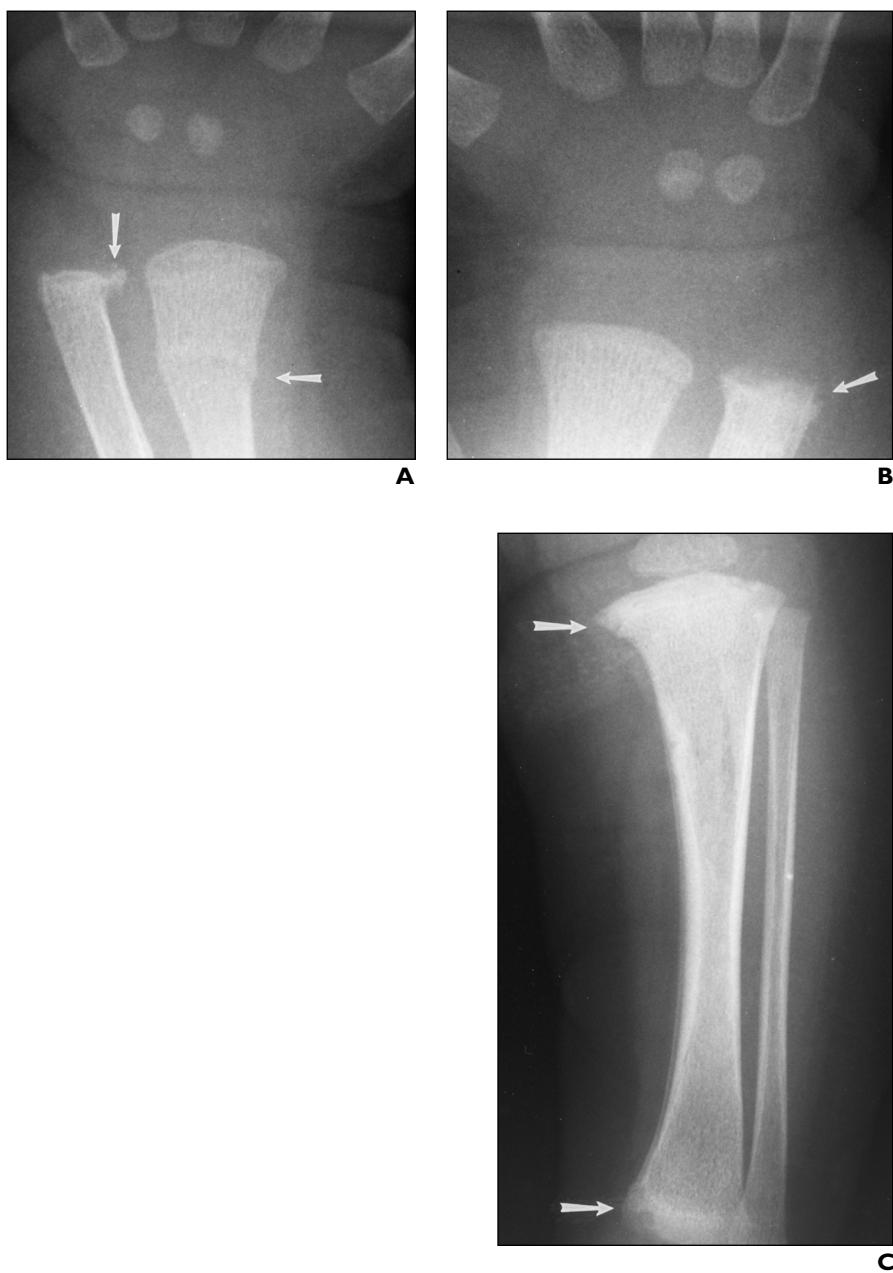


Fig. 4.—5-week-old female infant with multiple blunt force injuries of chest and abdomen and shaking injury of head (recent and remote subdural hemorrhage found at autopsy). These extremity fractures were detected on postmortem skeletal survey. Victim's father was convicted of murder and her mother was charged with neglect. **A**, Posteroanterior radiograph of left wrist reveals transverse fracture of distal left radial diaphysis and corner fracture of distal left ulnar metaphysis (arrows). **B**, Posteroanterior radiograph of right wrist shows classic metaphyseal fracture of distal right ulna (arrow). **C**, Anteroposterior radiograph of left tibia and fibula show classic metaphyseal fractures of proximal and distal left tibia (arrows).

pendent (Class C felony), involuntary manslaughter, and battery resulting in bodily injury. He received a 20-year prison sentence and 4 years of probation. Both the law enforcement personnel and the prosecutors in-

volved in these cases unanimously supported the use of high-detail postmortem skeletal surveys in the evaluation of unexpected childhood death (Hibbard RA, personal communication). This finding also supports those

of another study [8]. Of particular importance to the prosecution of the offenders was the severity of the charges that could be filed on the basis of the skeletal survey findings. The presence of both acute and healing injuries on skeletal surveys provided substantial evidence of the chronicity of physical abuse. According to several prosecutors, this evidence allowed the offenders to be charged with murder rather than aggravated battery, thus allowing much longer sentences if the defendants were convicted.

Although the justification for the use of postmortem skeletal surveys appears obvious in cases of homicide and suspected child abuse, it is also useful in cases of accidental, natural, and undetermined causes of death. Although negative findings on a skeletal survey do not exclude abuse, the absence of skeletal injury—when combined with the autopsy and death scene findings—may suggest sudden infant death syndrome as the cause of death. This information relieves the family and caretakers of unwarranted suspicion by medical and legal authorities and provides reassurance that the death of their infant could not have been prevented [10].

Similarly, postmortem skeletal surveys should be performed in cases in which the circumstances surrounding the child's death are unknown or not entirely clear in the perimorbid period. Although our data revealed no skeletal injuries in those who died of accidental or undetermined causes, it is important to remember that the manner of death is determined retrospectively by a pathologist after review of autopsy and death scene information. Often, the death scene investigation is only in its preliminary stages at the time of autopsy, and, thus, many facts may remain undiscovered. The skeletal survey findings may substantiate or contradict the

findings at the death scene investigation by law enforcement personnel and allow the cause of death to be categorized as accidental or undetermined.

Although our study reveals the utility of high-detail postmortem radiography, limitations should be addressed. Two involve the materials and methods portion of the study. First, no fracture specimens were removed at autopsy to correlate with the radiographic findings. Thus, the findings of this study lack correlation with a gold standard. Second, not all radiographic studies were interpreted by the same pediatric radiologist. Although undesirable, this practice was unavoidable because of changes in personnel during the 2-year study period.

The third limitation of this study is one of logistics and expense. Although some centers provide funding for routine postmortem radiography, this was not the case in our study. Performing a postmortem skeletal survey is time-consuming, often requiring 30–45 min of a technologist's time and 30–45 min of radiography suite time. It also requires the commitment of a radiologist to evaluate all radiographs for adequate quality before the decedent is removed from the department. Not only is the study itself nonreimbursable from a technical and professional standpoint, additional revenue is lost because a substantial amount of time in a radiography suite is used, during which reimbursable studies could otherwise be performed. Further investigation with a true cost-to-benefit analysis may prove an interesting topic for future research about this subject.

Despite the aforementioned limitations, we support the routine use of high-detail postmortem radiography of neonates, infants, and children in the evaluation of unexpected death. Postmortem skeletal surveys provide additional information about the extent and

chronicity of extremity trauma that is not routinely documented by autopsy and should be performed in all cases of suspected child abuse in neonates, infants, and children. Normal findings on postmortem radiography may also contribute to the accurate classification of natural, accidental, and undetermined causes of death and ensure the proper handling of these cases by medical and law enforcement personnel.

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