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TECHNICAL NOTE

Jennifer C. Love,[1] *Ph.D. and Luis A. Sanchez,*[1] *M.D.*

Recognition of Skeletal Fractures in Infants: An Autopsy Technique

ABSTRACT: Complete recognition and documentation of injury pattern is crucial in the diagnosis of child abuse. Skeletal fractures regarded as highly specific to nonaccidental injury in infants include posterior rib, scapular, metaphyseal, and spinous process fractures. These injuries are often occult, especially when acute, to standard radiologic and autopsy procedures. The presented autopsy technique requires incising and reflecting skeletal muscles to expose the bones and costal osseous joints *in situ*, increasing the opportunity to recognize skeletal injury. Fractured or atypical appearing bones are removed and processed for complete evaluation. The bones are processed by macerating the soft tissue in a water soap bath at an elevated temperature. To aid in reconstruction of the decedent, long bones are replaced with wooden dowels and the chest cavity is packed with the organ bag. The technique is invasive and recommended for cases in which the pathologist has reasonable suspicion of acute or remote trauma.

KEYWORDS: forensic science, forensic pathology, forensic anthropology, autopsy techniques, skeletal injury, classic metaphyseal lesions

Complete recognition and documentation of skeletal injury pattern is critical for an accurate determination of child abuse. Several fracture types are regarded as highly specific to nonaccidental injury in infants and include posterior rib, scapular, metaphyseal, and spinous process fractures (1–12). Radiologic detection of these injuries is difficult in infants, especially when acute (1–12). For example, a classic metaphyseal lesion (CML) creates a transverse radiolucency in the subphyseal region; however, without sufficient trabecular bone disruption the regional bone density may not be altered enough to appear atypical on radiograph (1–12). Forces associated with CML rarely disrupt the periosteum, failing to generate significant hemorrhage when acute or subperiosteal new bone formation when remote. Therefore, these injuries are often occult to standard autopsy and radiograph techniques.

This article describes an autopsy technique that enables the pathologist to grossly examine the ribs, scapulae, and long bones, including the costal osseous junctions (COJ), increasing the likelihood of fracture recognition. The technique requires reflection of the muscles, pleura, and periosteum exposing the bone, epiphysis, and COJ for visual inspection. The proposed technique is invasive and labor intense. Complete application may elongate an already exhausting autopsy by as much as 2 h. However, the skeletal examination is crucial in identifying injuries missed by standard methods (see Case Studies below).

Method

For the extremities, once the skin and subcutaneous fat is reflected the posterior long bone muscle groups are incised and reflected. The muscle groups and joint ligaments are detached from the metaphyses and epiphyses to expose the COJs and the epiphyses. The periosteum is incised along the longitudinal axis of the bone and lifted off the bone using a crushing periosteal elevator or other flat-edged instrument. The elbow is flexed to inspect the olecranon fossa. The infraspinatus and supraspinatus are cut from the medial surface of the scapula and the scapular spine, and are reflected laterally to expose the scapula. The periosteum is removed from the scapula. Once the muscle and periosteum is removed, the shaft of the long bone is inspected for fractures and subperiosteal new bone formation and the COJ for CML (Fig. 1).

For the ribs, the pleura is stripped and the internal intercostal muscles are cut from the internal surface of the rib. The periosteum is incised and reflected (Fig. 2). Posterior rib fractures might appear as very subtle lines along the rib head and subperiosteal new bone formation as a very thin layer of lacy bone.

Once all the bones and COJs are exposed, photographic documentation is recommended. Skeletal elements with suspect injury are removed for additional analysis (Fig. 3). At this point, the injury can be evaluated histologically or grossly. Histologic preparation is outside the scope of this article; consult a histotechnology textbook for standard methods (13). For gross analysis, all soft tissue is removed from the bone. Multiple methods are available for macerating specimens for removal of bone. A very gentle method is to place the bone in a 1:2 ratio of Foremost 1553-ES Super Kleen® (Delta Foremost Chemical Corporation, Memphis, TN) and water. Super Kleen® is a concentrated liquid cleaner with alkaline builders. Elevating the temperature of the water soap bath to 60°C for *c.* 24 h facilitates easy removal of the soft tissue from the underlying bone. The process can be repeated for another 12–24 h, if necessary. An incubator elevated and maintains the bath temperature evenly without creating hotspots, a common problem with the use of hotplates. The dried bone specimen is then available for gross inspection for trauma and signs of healing.

Grossly, an acute CML presents as exposed trabecular bone (Fig. 4). A healing CML is characterized as an irregular metaphyseal surface (Fig. 5). Subperiosetal new bone formation presents as a fine lacy blanket of woven bone (Fig. 6). These lesions are relatively easy to differentiate from the regular uniformed appearance of atraumatic bone.

[1]Harris County Medical Examiner's Office, 1885 Old Spanish Trail, Houston, TX 77054.

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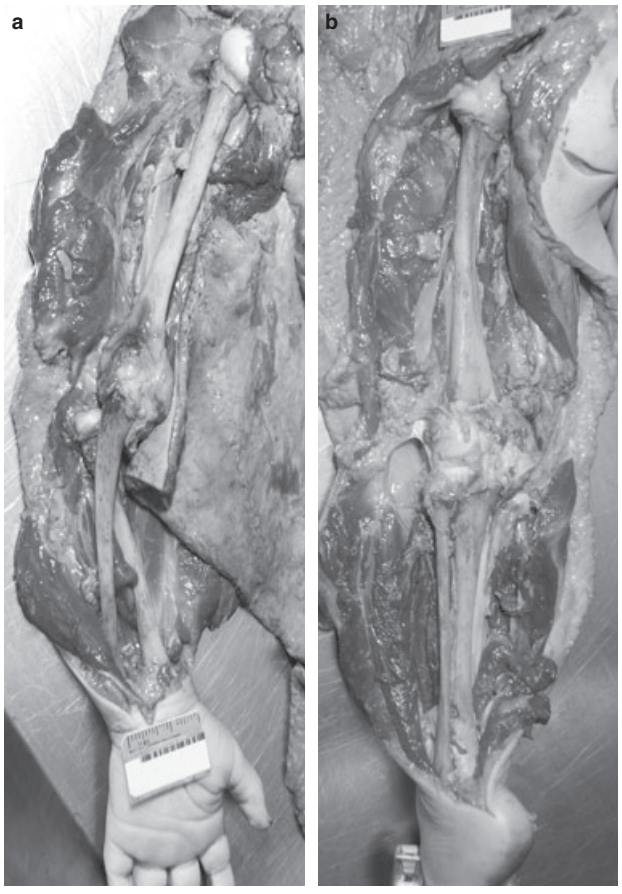

FIG. 1—*Images illustrating the exposed shafts, metaphyses, and epiphyses of the long bones after reflecting the skeletal muscles and periosteum. Scale is in inches.*

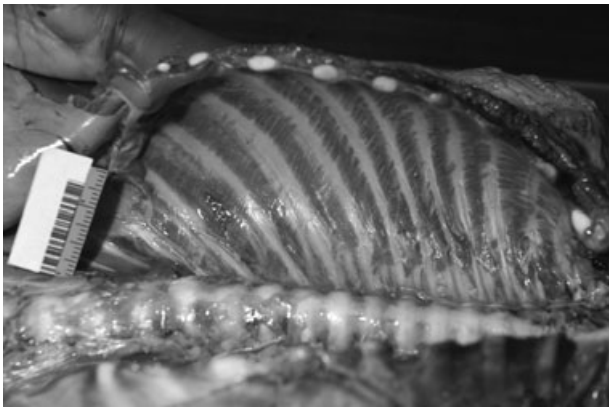

FIG. 2—*Image of ribs after pleura is stripped and the intercostal muscles and periosteum is removed. Scale is in inches.*

Results

Two recent cases investigated by the Harris County Medical Examiner's Office underscore the success of this technique for recognition of occult skeletal fractures.

Case Study 1

A 27-day-old Hispanic male was found unresponsive while cosleeping with his father and 2-year-old sibling. Fire department personnel responded to the scene and found the infant asystolic and

FIG. 3—*An injured left humerus postremoval. The arrow is pointing to fracture through the epiphyses. Scale is in inches.*

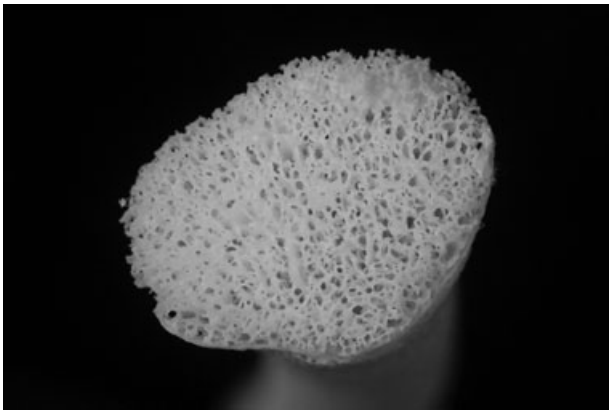

FIG. 4—*A complete classic metaphyseal lesion.*

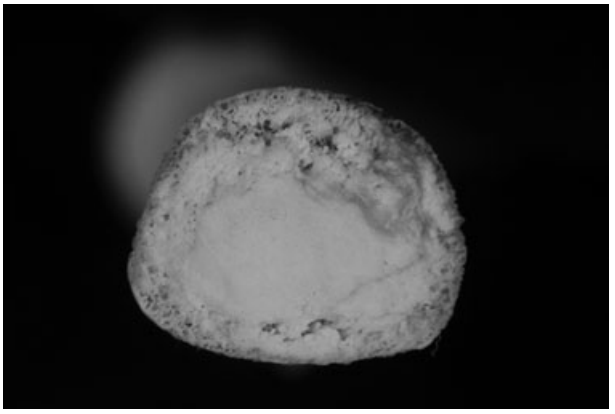

FIG. 5—*Healing classic metaphyseal lesion of distal fibula.*

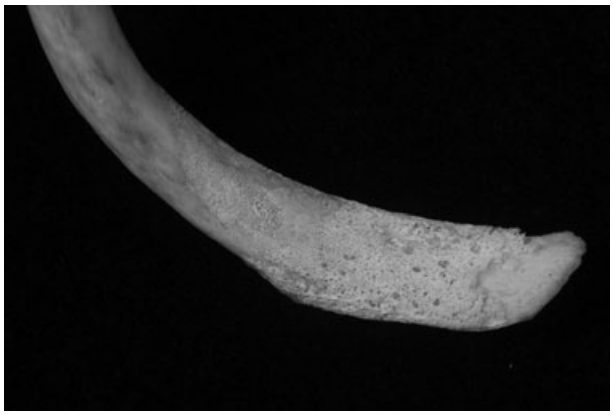

FIG. 6—*Subperiosetal new bone formation of a rib head.*

apneic. Cardiopulmonary resuscitation (CPR) was initiated and the infant was transported to the hospital. CPR continued at the hospital until the decedent was pronounced dead 28 min after arrival. No skeletal abnormalities were observed in a postmortem skeletal survey conducted by the hospital radiology department. The death investigator reported the residence was filthy with minimal infant supplies. During the reenactment of the events surrounding death, the father became very irritable and handled a teddy bear representing the infant roughly. The father also had a history of consuming alcohol the evening prior to the discovery of the decedent and responding police officers reported that he smelled of alcohol.

During the autopsy, minor head trauma was noted including several contusions and abrasions of the face and scalp, petechial hemorrhages of the left eye, and focal subarachnoid hemorrhages of the right frontal lobe of the brain. Additional anatomic findings included visceral petechial hemorrhages of the lungs and heart. The death investigator report and observed trauma escalated the index of suspicion enough to warrant the skeletal examination. During the skeletal examination, an acute CML of the right proximal and left distal fibulae was identified. The bones were removed, processed, photographed, and retained as evidence.

Ultimately, all toxicological, bacterial, and metabolic tests were negative. The cause and manner of death were classified as undetermined based on the uncertainties about the circumstances surrounding the death and uncertainties and interpretation of the autopsy findings.

Case Study 2

An 11-week-old infant presented to the emergency department with a history of falling from his mother's arms *c.* 5 ft onto a tile floor and being shaken while in a car seat. Two linear fractures of the left parietal bone and a subdural hematoma were observed during a head computed tomography scan. The radiographic skeletal survey was negative for additional skeletal trauma.

During the skeletal examination numerous acute and remote fractures were noted on the ribs and long bones (Table 1). The traumatized specimens were retained and processed. The fracture pattern and stages of healing observed on the retained elements were consistent with a minimum of two traumatic events. The ages of injury, based on stages of healing, were estimated at 2–4 weeks and several days (approximately the date of admission to the hospital) prior to death, respectively. Additional pathologic findings included extensive blunt trauma to the head and torso including scalp contusions, complex skull fractures, epidural and subdural hemorrhage, brain lacerations with associated subarachnoid hemorrhage, innumerable bilateral retinal hemorrhages, and contusions of the torso. The cause of death was classified as blunt trauma of head with skull fractures and subdural hemorrhage; the manner of death was classified as homicide.

TABLE 1—*Antemortem and perimortem injuries identified in case 2.*

Antemortem Injuries	Perimortem Injuries
Sternal rib end fractures (right ribs 5–6)	Skull fractures (left parietal)
SPNBF (shaft left tibia)	Posterior rib fractures (right ribs 1–11 and left ribs 1–7)
CML (distal left tibia, proximal left fibula)	CML (right and left distal radii)

SPNBF, subperiosetal new bone formation; CML, classic metaphyseal lesion.

Discussion

Fractures highly specific for nonaccidental injury in infants are often occult, especially when acute to standard radiologic and autopsy techniques (1–12). Kleinman et al. (10) recommended removing and histologically examining radiologically normal but high-risk metaphyses in suspect child abuse cases. Complicating the analysis, CMLs are challenging to recognize histologically and may be seen as faint metaphyseal separation (3,4,10). Gross examination of dry bones provides a diagnostic view of a CML; however, a threshold under which the injury is only visible histologically may exist. Sectioning a bone, prior to fixing and decalcifying it, for both gross and histologic examination may provide the greatest information.

Although potentially very informative, the proposed technique is also highly invasive and discretion in its application is warranted. The authors recommend it only when there is a high index for suspicion resulting from inconsistencies in the history or scene, significant involvement of Child Protective Services, and/or unexpected, traumatic findings in the soft tissues. An excellent example is Case Study 1 in which the initial impression was a death resulting from cosleeping, but the death investigator report and soft tissue finding elevated the suspicion of trauma and warranted the skeletal examination.

The retention of bones as evidence and notification to the family of bone retention are dependent on the standard practices of an office and the procedure used for the retention of organs should be followed. Under Texas law the performance of an autopsy includes the taking of body fluid samples, tissues, or organs in order to ascertain the cause of death or whether a crime has been committed. Texas law also permits the inclusion of a forensic anthropologist in the effort to establish the cause, manner, and time of death. In the cases presented, the forensic pathologists and anthropologists deemed that the retention of bones was necessary for the determination of cause and manner of death in accordance with the Texas Code of Criminal Procedures. Removed long bones can be replaced with dowels of appropriate length, following standard tissue procurement procedures, and chest cavities can be packed to approximate the thorax, assisting funeral homes in the reconstruction and preservation of the body. Alternatively, the presented maceration process is relatively fast allowing the bones to be processed, analyzed, and returned to the body in approximately 24 h. An important point to emphasize is that the proposed technique does not require incisions in addition to the dissection of the back,

buttocks, upper arms, and lower extremities advised in all cases of suspected child abuse.

Conclusion

The autopsy technique presented in this paper increases the opportunity for recognition of fractures highly specific for nonaccidental injuries in infants that are often occult to standard radiologic and autopsy techniques (1–12). A very gentle maceration process prepares the specimen for gross examination and photographic documentation of the injury.

Acknowledgments

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Additional Information—reprints not available from author:
Jennifer C. Love, Ph.D.
Forensic Anthropology Director
Harris County Medical Examiner's Office
1885 Old Spanish Trail
Houston, TX 77054
E-mail: jennifer.love@meo.hctx.net