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Radiologic Examination of Anatomic Parts and Skeletonized Remains

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ABSTRACT: During a 28-month interval, the radiographs of eight cases of skeletonized remains were evaluated by a radiologist. Radiologic evaluation of limited anatomic parts (four cases) was used to establish human or nonhuman origin and was helpful in the assessment of the relative social importance of the part. Radiologic evaluation of more complete skeletons (four cases) contributed data toward estimation of sex, age, stature, and past medical history. It confirmed the presumptive identity in two cases, excluded two possible identities in a third, and could still be useful if a presumptive identity is ever established for the fourth. Therefore, radiologic evaluation of skeletonized remains by a trained observer may be a useful adjunct to a forensic science investigation.

KEYWORDS: pathology and biology, human identification, postmortem examinations, skeletal examinations, radiography, X-ray, musculoskeletal systems

During the identification of individuals who have died within its jurisdiction, a medical examiner's or coroner's office may need to investigate and identify individual bones and limited body parts as well as almost complete or complete skeletons. Traditionally, a forensic osteologist or anthropologist has contributed expertise in these cases. A large literature has developed to support this scientific endeavor, and these skills are respected. Through the presentation of our recent experience with the following cases, we hope to show that routine application of radiologic techniques to the scientific investigation of body parts and skeletonized remains is effective and easy.

Methods

We have collected the cases studied during the 28 months between March 1978 and June 1980. Each was investigated in the standard fashion by members of the medical examiner's office and the police. Radiographs were obtained as a standard part of the initial scientific examination. Each body part or bone was radiographed in one projection, and all radiography was performed in the medical examiner's office. Additional views were obtained later if required for specific comparison with premortem films.

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Case Reports

Body Parts

Case 1—In October 1978, a workman found a human hand on the second story flat roof of a commercial building. Pathologic examination suggested that the partially mummified hand came from a dark-skinned individual. No hemorrhage was found. The only lead that developed was a report that several hands had been stolen from a gross anatomy laboratory. These had been severed at the distal forearm, as had the recovered hand. Radiographs of the hand (Fig. 1) were compared with the forearms of those anatomic specimens with missing hands. It was clear that the recovered hand was not one of those missing. No further leads for the origin of this hand ever developed.

Case 2—In July 1979, a human skull was found in an ambulance garage parking lot. A portion of the skull was missing; in some areas the edges were sharp as from a saw blade, and in other areas the edges were irregular as from a fracture. The radiograph confirmed this appearance, and it was concluded that the skull must have come from a person

FIG. 1—*Case 1: Anterior radiograph of hand shows no unique features and no evidence of arthritis. The hand was severed obliquely from the forearm with a sharp instrument. The arrows indicate the smooth surface of the distal radius at the site of severance.*

previously autopsied. Further investigation determined that juveniles had desecrated a grave in a nearby cemetery a week previously.

Case 3—During January 1980, a group of bones was found in an old wooden box in the basement of a vacant house. Newspapers in the box were 30 years old. On inspection, it was apparent that some of the bones were from small animals and others from humans. Radiographs confirmed presence of a human ulna, tibia, humerus, femur, hemipelvis, and mandible. In addition, all the bones of a foot were present and had holes appropriate for wire fixation in anatomic position. It was concluded that the box of bones most likely constituted a set for the study of skeletal anatomy.

Case 4—In July 1979, on three separate days, a dog carried bones into its master's yard. The three bones were subsequently given to a policeman, who lived in the neighborhood, and he conveyed them to the medical examiner's office for investigation. Because portions of the bones had been destroyed by postmortem animal activity, determination of species was not accomplished. Radiographs (Fig. 2) of the three bones were obtained, reviewed, and determined to be from a young adult human. This information resulted in the search of a local

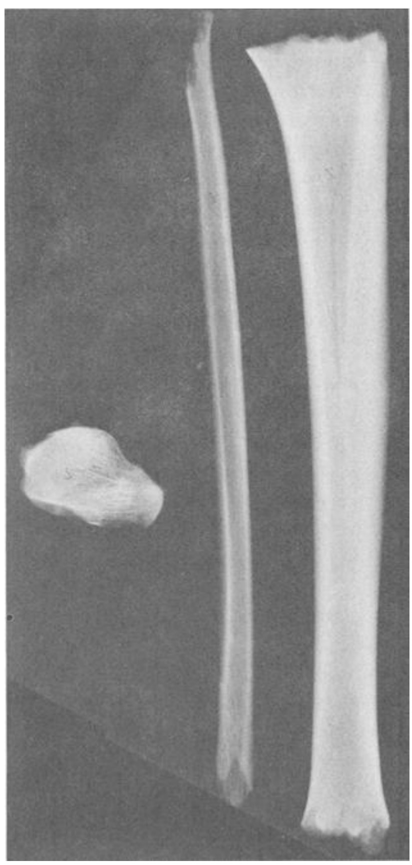


FIG. 2—*Case 4: Radiograph of three bones carried home by a dog shows them to be a human talus* (left), *fibula* (center), *and tibia* (right). *All bones have areas of surface irregularity from animal activity; otherwise, they are of excellent mineral content with thick cortices indicating that they probably came from a young adult.*

wooded area and the discovery of a bound, decomposed human body. Autopsy determined the probable cause of death to be a stab wound in the back.

Skeletonized Remains

Case 5—In May 1978, the U.S. Coast Guard recovered a partially skeletonized human torso from the Mississippi River. Disarticulation had occurred at the knees, shoulders, and the disk space between cervical spine segments five and six. The parts distal to the disarticulations were never recovered. Most of the thoracic soft tissues were absent, but the rib cage remained intact. The autopsy determined that the individual was most likely a white male between the ages of 25 and 40, approximately 1.8 m (6 ft) tall and weighing between 73 and 82 kg (160 and 180 lb). It did not establish a probable cause of death and revealed no information concerning prior illness or injury.

Radiographic examination showed bones of excellent mineralization without evidence of disease, probably those of a young adult. Subsequently, two possible identifications developed and both had premortem radiographs available. These were obtained and compared with appropriate radiographs of the torso. Comparison showed dissimilarity between the skeletal features of the possible identifications and the torso. One identification was convincingly excluded on the basis of anatomic differences in lumbar spine anatomy, as well as absence of evidence of previous surgery [*1*]. The other potential identification was excluded on the basis of anatomic and arthritic differences seen in cervical vertebrae six and seven (Fig. 3). Unfortunately, the identity of this torso remains unknown.

Case 6—In March 1980, a skeleton was discovered in a cave-like area between two buildings. No identifying papers were found, but a presumptive identification was established by the police. Relatives provided preliminary confirmation through recognition of an empty black vinyl wallet and a belt. This person had a long arrest record for alcoholism and several hospital admissions for trauma.

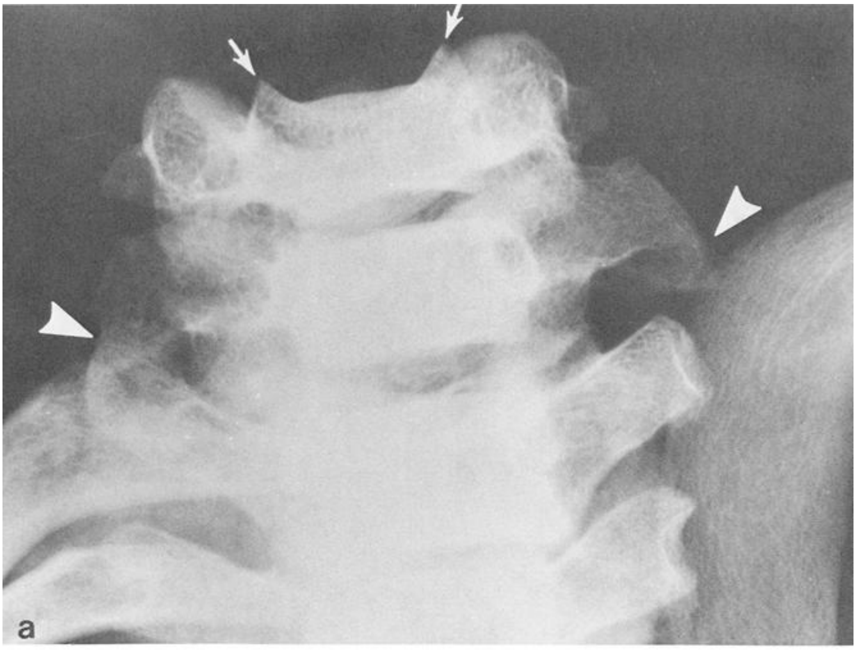
Review of the radiographs of the skeleton revealed many previous fractures including those of the occipital bone, most of the ribs, and the right hemipelvis as well as a scapula, radius, ulna, tibia, and fibula (Fig. 4a). Comparison with premortem radiographs confirmed many of the fractures (Figs. 4b and c) and showed concordance of several other distinctive skeletal features (Fig. 4a). Thus, study of premortem and postmortem radiographs established a firm scientific identification.

Case 7—In March 1980, while hunting for aluminum cans, two boys found a skeleton wrapped in plastic bags and located in a deep ditch about 9 m (30 ft) from a road. A presumptive identity was established soon after a televised announcement of the discovery. Although dental and prosthodontic procedures had been done, those records had all been destroyed.

Radiographs of the skeleton demonstrated excellent mineralization, closed epiphyses, and no evidence of trauma or disease, findings that suggested that the individual was between 18 and 25 years of age (later established at 22 years). Taking long bone length measurements from the radiographs, we estimated the stature to be less than 178 cm (5 ft, 10 in.). Anthropologic measurement of the actual bones yielded an estimate of 175 cm (5 ft, 9 in.) and, once identified, the alleged stature was 168 cm (5 ft, 6 in.).

Premortem medical radiographs were traced and included a skull series. The victim's skull was then positioned to match the premortem anterior skull film and radiographed. All skull details, including frontal sinus pattern, matched (Fig. 5). In addition to the skull findings, many other areas of the skeleton provided identical comparison of minute osseous detail (Fig. 6). These radiological studies established a firm scientific identification.

Case 8—In April 1980, a human skeleton was found in a debris-filled second-floor room of a vacant building. Death was apparently from natural causes and no presumptive identity was ever established.



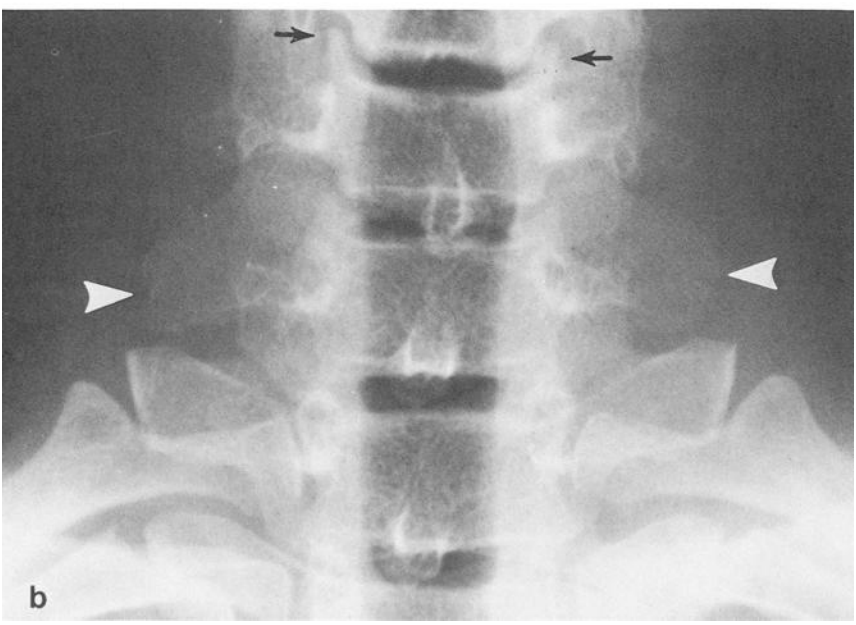


FIG. 3—*Case 5:* (a) *An anterior view of the remaining sixth and seventh cervical segments from the torso shows that the uncinate processes* (arrows) *of the sixth segment are sharp and of normal contour. The transverse processes of the seventh cervical segment are long and pointed* (arrowheads). (b) *Comparisons of similar anatomy from a clinical cervical spine study done premortem on a now-missing person shows thickened arthritic C6 uncinate processes* (arrows) *and short rounded C7 transverse processes* (arrowheads). *These discordances are sufficient to exclude the presumptive identification.*

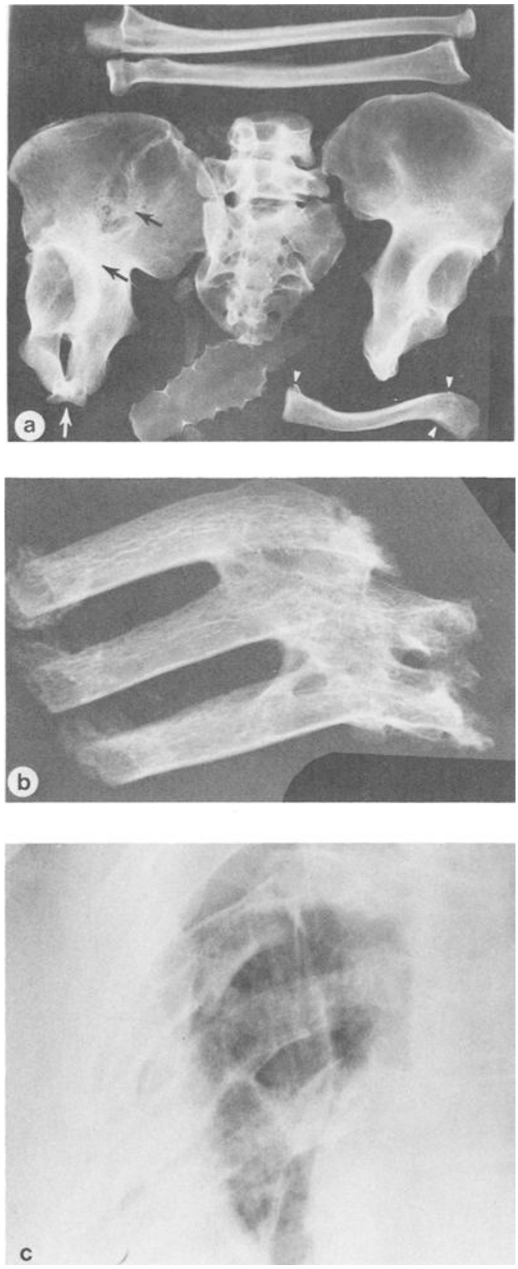


FIG. 4—*Case 6:* (a) *This photograph is representative of films of skeletal remains presented for interpretation. The image includes a radius, ulna, clavicle, sternum, sacrum, the last two lumbar vertebrae, and both innominate bones. The innominate bone on the left has a healed fracture through the iliac wing, the acetabulum, and the ischium* (arrows). *Both innominate bones have narrow sciatic notches, a characteristic of males. The three tiny spurs arising from the distal clavicle* (arrowheads) *were identified in a premortem clinical chest film and thus were additional unique skeletal features for scientific confirmation of identity.* (b) *Detail of rib fragments from the skeleton shows portions of three ribs fused together after previous fractures.* (c) *Close-up photograph of a region from a premortem clinical chest film shows the same three fused ribs, one of many unique similarities between premortem radiographs and postmortem films of the skeleton.*

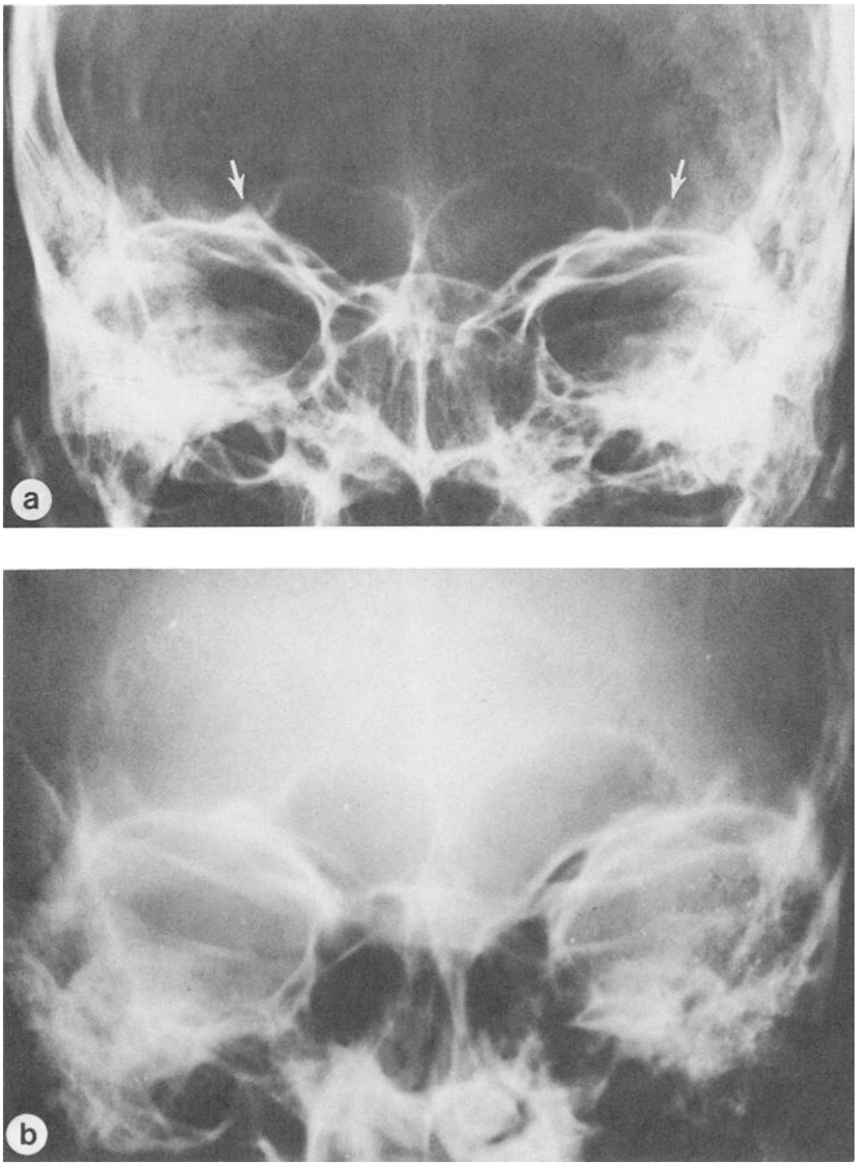


FIG. 5—*Case 7:* (a) *Postmortem radiograph of carefully positioned skull shows small, smoothly curved frontal sinuses with tiny lateral air cells* (arrows). (b) *Comparison with premortem clinical radiograph demonstrates identical features.*

Radiographs of the skeleton showed a narrow sciatic notch and costochondral calcifications (Fig. 7) characteristic of a male. By direct measurement of long bone length from the radiographs, and application of Trotter's equations [*2,3*], stature was estimated at 180 cm (5 ft, 11 in.) (standard deviation 5 cm [2 in.]) if white and 170 cm (5 ft, 7 in.) (standard deviations 6 cm [2.5 in.]) if black. Race could not be accurately assessed. Age was estimated at 60 years.

The skeleton was independently evaluated by a forensic osteologist whose opinion was that

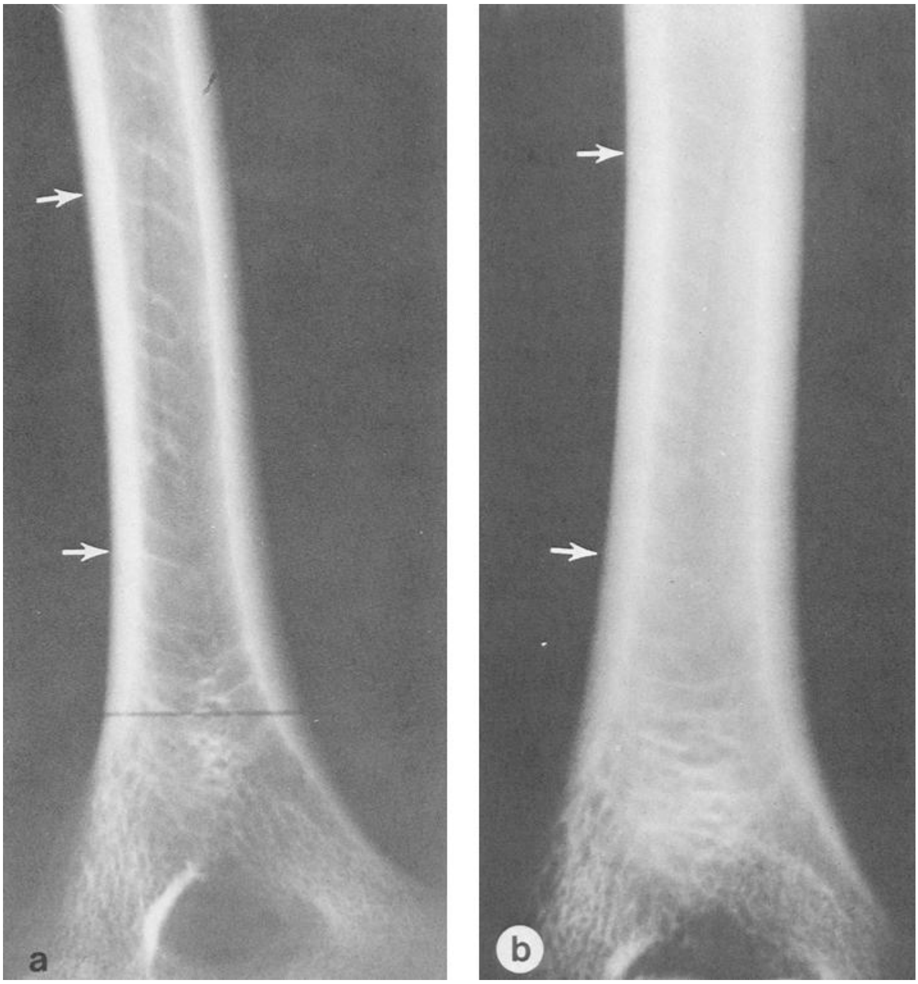


FIG. 6—*Case 7:* (a) *Postmortem radiograph of distal humerus shows many linear "growth" lines in the medullary region* (arrows). (b) *Comparison with a premortem view of the same humerus, which happened to be included on a radiograph taken of the rib cage, demonstrates identical features. (The arrows have been placed at identical sites to facilitate comparison.)*

the individual had been a black male, approximately 45 to 50 years old and 169 to 173 cm (5 ft 6½ in. to 5 ft 8 in.) tall.

Many other skeletal features were observed by both the radiologist and the anthropologist. Principal among these were osteophytes of the spine and fusion of one sacroiliac joint. While the osteologist interpreted these as evidence for ankylosing spondylitis, the radiologist thought they were unrelated and saw no evidence of ankylosing spondylitis. The radiological appearance of the calvarium suggested sickle cell disease or other anemia to the anthropologist but was within the range of normal in the radiologist's experience.

Discussion

These cases show that radiologic techniques can provide important contributions to the investigation of human body parts and skeletonized remains. However, the contributions are somewhat different for body parts than for more complete skeletons.

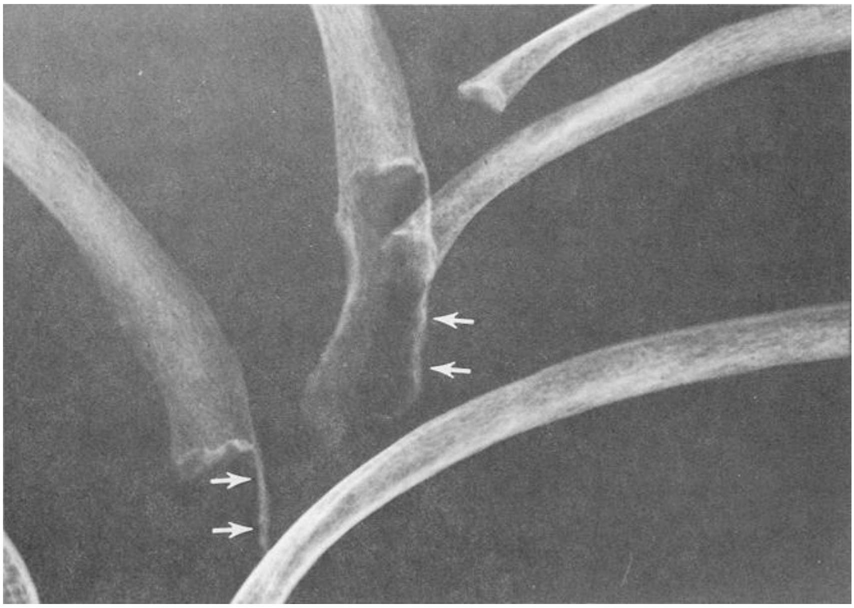


FIG. 7—*Case 8: Detail of the ribs from the skeleton shows peripheral ossification at the costochondral junction* (arrows) *characteristic of males.*

Radiologic investigation of body parts can confirm or establish the human or nonhuman origin of a bone or apparent human part. It can also contribute information regarding the source of the part and may help indicate the social significance of the parts. For example, in Case 4 radiologic investigation clearly established the three bones as human and stimulated a police investigation that discovered a homicide victim. On the other hand, in Case 3 the radiological opinion contributed to the decision that no further investigation was warranted.

When a partial or complete skeleton is discovered, there is rarely a question concerning whether or not it is human. However, major questions arise as to its identity. Much as radiologic techniques can be effective in the study and ultimate scientific identification of nonskeletonized human remains [*1*], these same techniques can be effective for the study and identification of skeletons. Radiologic investigation may provide information toward estimation of sex, age, stature, and past medical history. In general, these estimates are based on the radiological correlates of standards developed by physical anthropologists [*2-4*]. For example, it is possible to estimate stature by taking direct linear measurements of long bone length from radiographs. These measurements can then be entered into Trotter's equations and a stature estimate with a standard deviation obtained [*2,3*].

Similarly, sex can be estimated if appropriate bones are available and then positioned properly for the radiographs. One feature well known to radiologists, but apparently not as prominently discussed in the forensic science literature, is the sex difference of costochondral cartilage calcification. The predictive value of this particular radiologic feature for sex estimation is greater than 90% [*5*]. If several features are combined, the radiological sex estimate should be very good.

Age estimates in adults are difficult by any technique. However, radiological estimates can be made and may supplement those derived from other disciplines.

Confirmation or exclusion of identity depends on establishment of a presumptive identity. Information generated by study of the radiographs from a skeleton may prove helpful. Following development of a potential identification, the medicolegal investigator must trace and obtain whatever premortem radiographs exist. These are often readily available as they are generally kept at least five years as part of a person's medical record. If original films are not available, microfilmed copies, or at least reports, may be. Any of these may be useful in confirmation of identity.

Comparison of premortem and postmortem films is very effective for scientific identification [*1*] and has at least two major advantages over forensic anthropology. First, a direct comparison is made radiologically while the osteologist is limited to conjecture. Second, the X-ray can study the internal architecture of bone, while osteology is generally limited to surface analysis. Similarly, radiology has major advantages not available to forensic odontology. First, medical records and medical X-rays are usually preserved in a more standard fashion and are generally more readily available than dental films and records, and second, the entire skeleton is available for scientific scrutiny rather than a limited region and number (32 or less) of teeth.

Radiological evaluation of skeletonized remains should not replace osteological evaluation by a forensic anthropologist or dental examination by a forensic odontologist. These disciplines should be complementary and when they give similar results, confirmatory. The differences of opinion apparent in the interpretation of skeletal findings in Case 8 simply reflect differences in training and professional experience with human diseases. Such differences should be numerically small and may provide a certain "check and balance" system for these somewhat subjective opinions. We think that radiological evaluation is optimized by consultation with an interested radiologist. Radiologic training facilitates study of normal and variant anatomy and the effects of disease and surgery on the human skeleton.

Summary

Radiologic consultation can provide important information during the investigation of body parts and skeletonized remains and is particularly effective for the scientific confirmation of identity following presumptive identification. It is best performed by an interested radiologist and should be complementary to osteological evaluation by a forensic anthropologist.

Acknowledgments

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References

[*1*] Murphy, W. A., Spruill, F. G., and Gantner, G. E., "Radiologic Identification of Unknown Human Remains," *Journal of Forensic Sciences*, Vol. 25, No. 4, Oct. 1980, pp. 727-735.

[*2*] Krogman, W. M., *The Human Skeleton in Forensic Medicine*, Charles C Thomas, Springfield, Ill., 1978.

[*3*] Stewart, T. D., *Essentials of Forensic Anthropology Especially as Developed in the United States*, Charles C Thomas, Springfield, Ill., 1979.

[*4*] Kelley, M. A., "Sex Determination with Fragmented Skeletal Remains," *Journal of Forensic Sciences*, Vol. 24, No. 1, Jan. 1979, pp. 154-158.

[*5*] Navani, S., Shah, J. R., and Levy, P. S., "Determination of Sex by Costal Cartilage Calcification," *American Journal of Roentgenology, Radium Therapy and Nuclear Medicine*, Vol. 108, No. 4, April 1970, pp. 771-774.

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