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Special Observations in Skeletal Identification

From time to time new methods of observation become available in the identification of skeletal remains. There is often a marked delay between the publication of these methods and an awareness of them on the part of many people who are engaged in the actual identification procedures, because such papers may appear in relatively obscure journals. On the other hand, some anthropologists who have had extensive experience in skeletal identification have learned to weight their estimates in favor of certain indicators of biological status that have worked particularly well in their experience. These special observations based on experience are often unpublished and may remain unknown to many pathologists who might have occasion to utilize them. The purpose of this paper is to describe some of the special observations and techniques beyond those routinely used by anthropologists in identification that might be particularly useful in special circumstances or unusually difficult cases.

What can one ordinarily expect to find out from examining a skeleton? Most forensic pathologists can determine within reasonable limits several things from a relatively complete skeleton. First, whether it is human or not. The ability to do this depends largely on the experience of the individual in examining human skeletons of various sorts and, preferably, animal skeletons as well. Most pathologists can determine the approximate age at death by using the standard methods of Todd [*1*], Greulich and Pyle [*2*], McKern and Stewart [*3*], and the dental eruption in the remains of relatively young individuals. The determination of sex is generally uncomplicated provided the entire pelvis is present, and various methods for doing this have been outlined and incorporated in the standard techniques of identification. The forensic pathologist is usually better able to determine the presence of wounds or skeletal pathology than most physical anthropologists. The stature at the time of death can be determined with reasonable accuracy by the methods outlined by Rollet [*4*], Pearson [*5*], or Trotter and Gleser [*6,7*]. Standard methods for making these determinations have been described by various authors, and are well known among those who are engaged routinely in skeletal identification.

Several problems remain in the identification of skeletal remains. These are best handled by examiners who have had considerable experience in skeletal identification or by the application of special methods of observation and interpretation. The determination of race is rather difficult in many cases, and should be left to the expert whenever possible. It is hazardous for the inexperienced to attempt to assess probable race from the skeleton alone. Some fairly objective methods for this do exist, however, and will be discussed later.

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The incompleteness or fragmentation of a skeleton may take it out of the category of routine identification and make it an unusually difficult problem. If the skull is missing, or the portions appropriate for age determination are eroded or missing, or if major parts of the skeleton are badly fragmented or burned, it may be rather difficult to determine the biologic nature of the individual by standard procedures. Recently however several methods have become available for dealing with eroded, fragmented, or incomplete skeletal remains.

The commingling of two or more skeletons can cause problems for many examiners. The ability to segregate skeletal parts into individuals depends to a large extent on the familiarity of the examiner with the range of variation in human skeletons and on his experience in dealing with commingled skeletal remains.

The skeletal remains of an individual over forty years of age at the time of death may present a problem for the expert and novice alike, if only conventional methods are used to determine the age. Several special techniques have been described for the determination of age in indivuduals over thirty years of age, and these, too, will be discussed later. The pathologist is truly the expert at determining the time that has elapsed from death till examination of the remains, if the remains consist of the nearly intact body of a recently deceased individual. It is a little more difficult, however, to determine the time that has elapsed since death in purely skeletal remains, particularly if they have been buried or exposed for several months or even years.

Human or Not?

The standard methods for determining whether or not a skeleton is human depend upon the ability of the examiner to recognize human skeletal material on an anatomic basis. In most cases it is not difficult for the pathologist to do this. However there are some special hazards even in the determination of whether bones may be human or not, if the entire skeleton is not present. Unless the examiner has had experience in observing the bones of relatively large primates, such as gorillas or chimpanzees, he might find it difficult to distinguish some of the skeletal parts from those of man. Another hazard in identification arises when hunters kill a bear, skin it, and remove the claws and distal phalanges with the skin. The hands of a bear resemble those of man to a surprising degree, if only the skeletal parts are present. If the entire arm is present the examiner may become suspicious if he notices that the bones of the forearm are as long or longer than the humerus.

It is much more difficult to determine whether fragments of bone might be human or not than it is to reach the same conclusion from an entire bone. Techniques for such determination would include precipitin tests for fresh bone fragments and histologic examination for bone fragments of any age. The microscopic structure of many forms of non-human bone is distinct from the heavily osteonized bone of man, if a cross-section is examined from the diaphysis of a long bone [*8,9*]. The presence of the plexiform structure of most ungulate bone would distinguish it fairly readily from the compact osteonized bone of man. The reliability of these observations depends entirely upon the examiner and his experience.

Estimation of Age

Standard methods of estimating the age at the time of death are based upon dental eruption, the size and degree of maturity of bones, the ossification and fusion of the epiphyses [*10*], the fusion of the various elements of the sternum and sacrum [*11*], ossification of the bones of the hand and wrist [*12*], and changes that occur on the face of the pubic symphysis [*3,13*]. In cases where other indicators are not sufficient or present, the obliteration of the cranial sutures [*14*] and progressive buildup of bone around joint margins [*15*] can be used for the rough estimation of general age also. Special hazards in the estimation of age would include fragmented or incomplete skeletons with particularly informative areas missing, postmortem erosion, or an age at death in excess of forty years. In the case of female skeletons, an age in excess of thirty years is difficult to handle by conventional methods. There have been several special techniques reported in recent years for the estimation of age in fragmented, incomplete skeletons or those of individuals in the older age ranges. These include the histological examination and measurement of microscopic structures of the teeth [*16*], mandible [*17*], and long bones of the leg [*18–20*]. Methods of estimating the age at death by the regression of cancellous bone have been reported also [*21,22*]. While the best results are obtained using this method with hemisected long bones, either humerus or femur, radiographs of these areas can be used as general indications of the approximate age in older individuals.

The accuracy of age estimates varies considerably with the method applied. Cranial sutures offer little more than a rough guess and can be applied only to a relatively narrow age range [*23*]. On the other hand the combined state of dental eruption, hand-wrist ossification, symphyseal face and epiphyseal fusion may afford a reliable estimate within ±2 years through age twenty-five. The range of accuracy for histologic methods of age determination is ±5 years regardless of the age of the individual from birth through ninety-five years of age for all practical purposes. The reliability of the histologic methods of estimating age is fairly high and has been statistically established for each technique. In addition, fragmented or incomplete skeletons, or in some cases individual teeth, can be used for the estimation of age at death by microscopic methods.

Determination of Sex

Standard methods for the determination of sex from an examination of the skeleton are based on anatomic differences in the relative hip widths of males and females. These are reflected in the general shape of the pelvis, the shape of the sacrum, the width of the sciatic notch, and the appearance of the region of the pubic symphysis. In addition there are differences in the size of the brow ridges, shape of the frontal eminences of the skull, the size of the mastoid processes, the relative length of the sternum, the size of the condyles of the long bones, and the degree of apparent muscularity throughout the skeleton. Among the hazards encountered in the determination of sex, perhaps the greatest is the wide range of variability in terms of skeletal structure within each sex and the fairly large overlap in these respects between the sexes. In addition, the most reliable diagnostic criteria for sex determination are found in the region of the pelvis. If this is badly damaged, fragmented or missing entirely, the degree of reliability of sex determination decreases. Furthermore, any skeleton under the age of puberty is very difficult to sex, although Boucher [*24,25*] showed sex differences in fetal pelves. Most of the sex discriminating variations in skeletal structure begin at about the time of puberty and become more apparent as skeletal maturity is approached. It should be remembered, also, that sexual dimorphism is more pronounced in some genetic populations than in others.

Special techniques for putting the determination of sex on an objective basis include the measurement of the innominate bone to determine the ischio-pubic index [*26*], measurement of the femoral head diameter [*27*], and an assessment of specific anatomic configurations in the area of the pubic symphysis [*28*].

In modern societies, certain cultural marks may help indicate the sex of the individual. These would include in modern American skeletons the presence of pipe smokers' attrition and staining of the teeth as an indication of male sex and the medial corner notching of the medial incisors found in women who open bobby pins with their teeth. Another special observation has been reported as an indication of gestation [29-31]. These parturition pits are the result of pregnancy and the concomitant stress upon the abdominal musculature and symphyseal ligaments, and clearly distinguish between once-pregnant females and others if they are present. There have been some discriminate function statistical approaches reported as well [32,33]. These are generally based on the multivariate analysis by computer of a series of measurements to determine which combined measurements best discriminate between male and female. The statistical approach enables relatively inexperienced examiners to make reasonably reliable estimations of sex from standardized measurements and can be most useful where the pelvic area has been seriously damaged or is missing completely.

Race Determination

The determination of race is one of the most problematic observations in the identification of skeletal remains. Standard methods include the morphological variations in the skeletal structure of the facial area, the structure and appearance of head hair (when present), or the ratio of femur to tibia or humerus to ulna length. The reliability of race determination based on these variations depends greatly upon the experience of the examiner in looking at skeletal material of known race. The greatest hazards in the determination of race involve the inexperience of the examiner, incompleteness of the most crucial areas of the face, and cultural and biological discrepancies in the recorded race of the individual where the race designation may have been made more on an ethnic basis than on a biologic one. In addition, the great range of variation within any major race in terms of skeletal structure and the large area of overlap with regard to any racial characteristic make it difficult to be precise in the determination of race in some cases.

The most reliable areas of the skeleton for determining race are the facial skeleton, then the long bones of the arm and leg, and when it is present, the form of the head hair can be quite helpful. In recent years there have been some multivariate statistical methods reported for the determination of race from skeletons [34]. Like the discriminate function methods for determining sex, the multivariate statistical approach for the determination of race eliminates some of the problems that arise from a lack of experience on the part of the examiner. It should be pointed out however that these multivariate approaches are for specific breeding populations and may not apply widely to the determination of race in all skeletons. On the other hand, a physical anthropologist who is experienced in examining skeletal remains of people from different known racial groups can often determine the race of a skeleton with a high degree of reliability. His own expression of confidence or concern about the race of a particular skeleton is probably the best guide to the reliability of specific cases.

Marks of Cultural Identity

Occasionally in the remains of individuals of culturally primitive societies there may be marks on the skeleton that indicate identity in such primitive societies. These include cranial deformation [35,36], either intentionally produced by head-binding or accidentally produced by continuous cradle-board pressure, the occurrence of squatting facets on the bones of the leg, tooth wear or tooth mutilation [37], mutilation resulting in skeletal alterations, or the fleching marks of Indians who cut flesh from the bones prior to secondary burial. The major problem in utilizing the information of this sort is the lack of recognition of the significance of cultural marks, and the lack of uniformity of many of the markings so produced on the skeleton. There are relatively few special techniques for handling these cultural marks, but the use of the dissecting microscope to ascertain the nature of abrasions or cut marks, squatting facets or excessive tooth wear may be quite helpful. In cases of apparent trephination, or old healed cut marks, radiographs or even microradiographs may be particularly informative. The reliability of some of these cultural marks depends on the examiner's awareness of their range of variation in primitive and non-primitive societies.

When they are present, such things as artifacts in the form of tools or weapons of primitive manufacture, marked cranial deformation, dental filing or other mutilation, or excessive tooth wear may be reliable indicators of primitive status.

On the other hand, all primitive peoples who do not have chairs do not exhibit squatting facets, and it is probable that some people from some socially impoverished areas of the United States lack the use of chairs and may acquire the extended articular facets that result from spending much time in a deep squat during developing childhood and adolescence. Cut marks on bone need extremely careful interpretation, since these may be the result of postmortem fleching or may have occurred at the time of death. Physical anthropologists engaged in skeletal identification are generally aware of the cultural marks that can occur on the skeleton, whereas many forensic pathologists may not be.

Stature at Death

The reconstruction of the approximate stature at the time of death is achieved by measuring the overall length of the major long bones, particularly those of the leg, and applying reconstructive formulae that have been worked out by various investigators [*4–7*]. These measurements are fairly simple and easy to make, and the existence of tables for determining the approximate stature at the time of death from the length of each major long bone in the arm or leg makes it a very straightforward estimate for the inexperienced examiner to make. Special hazards in this estimation include, the incorrect estimation of sex or race and consequently the use of the wrong formula for reconstructing stature, and also the difficulty of measuring long bones in incomplete or fragmented skeletal remains. Special techniques for measuring the length of long bones have been reported by Trotter and Gleser [*6,7*] and offer the most accurate and reliable method for stature estimation available. In dealing with the remains of American Indians, the tables published by Genoves [*38*] for Indians of Mexico are the best available. It should be pointed out however, that all American Indians are not of the same general body build or do not belong to the same breeding populations. Steele [*39*] has published a method for dealing with fragmented remains. This method makes it possible to measure the length of broken long bones, parts of which are missing, and use them for the reconstruction of approximate stature at the time of death.

Time Since Death

One of the most difficult things to determine from skeletal remains is how long they have been buried, or how much time has elapsed since death. This is usually not difficult to determine in fresh, flesh-covered cadavers and can be rather precisely estimated. In purely skeletalized material, however, there may be little to go on if the individual has been dead for a period of only a few years. The postmortem conditions are quite variable from one case to the next. Standard methods of estimating the time since death include discoloration of the bone by ground water minerals, bleaching, friability, "weathering" cracks, erosion of the cancellous ends of bones, and infiltration by sand or soil and roots. The weight of the bones and degree of mineralization are often used to estimate the amount of fossilization that may have occurred. In some cases the bones of individuals who have been dead for a few hundred years may be quite heavy as a result of postmortem mineralization by the ground water. In other cases bones may be lighter than normal because of the leaching effects of acid soil in well-drained areas where ground water seeps in and out of bone. In some parts of the United States different bones of the same individual may be heavy or light depending on the level of the ground water table and the depth at which parts of the skeleton were buried.

There are many hazards in estimating the time of death from skeletal material. Most of these center around the great degree of variability of postmortem soil conditions, climate, depth of burial, degree of exposure to water, and so forth. In northern temperate areas there is a tendency for the repeated cycle of freezing and thawing to cause weathering cracks to appear throughout the bone. On the other hand, in moist tropic areas bones may tend to crumble away, presenting an eroded appearance at the end of the bones in a fairly brief period of years. In hot dry tropic areas remains may be reduced to little more than skeletons in a matter of a very few months. All of these factors make it extremely difficult to estimate the time since death with any degree of reliability for short periods of time. Some special observations can be made including X-ray diffraction studies of the mineral content of bone, or the fluorine content of bone, that is, the replacement of hydroxyapatite crystals by fluorapatite crystals, and the histologic examination of ground sections of bone. The microscopic appearance of old mineralized bone includes nonbiologically distributed calcium carbonate and ground water stain in some areas of a histologic section and decalcification in other areas caused in part by bacteria. These can be best evaluated by microradiography but can be seen by light microscopy. The leaching effects of bacteria may involve enlargement of the osteocytic lacunae and demineralization of osteon canal walls. In partly fossilized bone cancellous spaces may be filling in with large calcium carbonate crystals. In more recent skeletal remains the presence of dessicated soft tissues and the remnants of red blood cells may be an indication of very recent death.

The accuracy and reliability of estimates of time since death are open to serious question. If the estimate is made on the biological material only, the range of accuracy for the estimate gets larger with the passage of time since death. Recourse to histologic microradiographic and mineral content studies offers the greatest reliability. Since the forensic pathologist's interest in time since death is usually limited to rather recently deceased remains, the mere demonstration of mineralization or leaching in any appreciable degree is usually sufficient to determine that the remains of prehistoric man are well beyond the provenance of the law.

Commingling

In some cases the remains of more than one individual are intermingled. This is usually detected by the obvious duplication of skeletal parts. Occasionally however, missing parts of two or more incomplete skeletons may be accepted as one by the inexperienced examiner. The segregation of skeletal parts into individual skeletons is usually based on disagreement as to age, sex, race, stature, the degree of muscularity or the general configuration of the bones [*40*].

Although the color of different bones may indicate the possibility of commingling, it is not uncommon to find bones of slightly different color from one individual skeleton, due to the differences in very localized soil or clothing conditions. One of the major hazards in trying to separate commingled remains is the tendency to rely upon slight variations in color or slight skeletal asymmetry. The comparison of left and right side bones for marked similarities or dissimilarities in contour, texture, and surface topography is one of the best methods for determining whether or not a specific bone might represent the commingled remains of another individual. It is not always possible to make side-to-side comparisons if the opposing bone is missing or commingled bones in question are from the axial portions of the skeleton and not members of bone pairs. When the question of commingling arises in remains where no duplication of skeletal parts is present, one must rely on the circumstances of burial and recovery for additional information. The lack of precise data about burial relationships may lead to erroneous conclusions concerning the uniqueness of remains. Positive articulation is the most reliable method of detecting commingling, yet this is not always possible and depends quite a bit on the experience of the examiner in judging whether or not two bones actually did articulate. There are some special techniques that can be brought to bear on the problem of commingling, particularly where the question is an important one. Sometimes it is possible to examine bones under long wave ultraviolet light and detect differences in the fluorescence that help to separate the commingled bones into individual skeletons.

The interpretation of ultraviolet light fluorescence requires some care however since the results are variable [*41*]. Radiographs of individual bones may be helpful in separating the bones of individual skeletons on the basis of differences in the amount and pattern of cancellous bone at the ends of long bones and in the thickness of the cortex in individual bones. Where the commingling of skeletons poses serious problems, it may be possible to blood-type bones themselves [*42*]. However, there may be certain hazards in the interpretation of the blood-typing of bones where soil bacteria have had an opportunity to operate on the bones [*43,44*]. A more recent technique, neutron activation analysis, may prove quite useful in segregating commingled remains and can be applied to the bones of individuals or small fragments of bone.

Personal Identification

In some instances individuals will have sufficiently unique features recorded during life to permit positive personal identification. These range from particular configurations of crooked or crowded teeth that may be recorded by the dentist or apparent in close-up photographs to the presence of anomalous structures or specific patterns in the normal variations of cancellous bone that may be visible in pre-existing radiographs and can be compared with radiographs of the bone in question. It should be noted, however, that the pattern of cancellous bone varies only slightly between individuals, and one should be cautious in assessing these similarities unless direct radiographic overlays can be compared. In some cases one can overlay photographs taken during life on tracings of skeletal X-rays or photographs and eliminate the possibility of a misidentification, because there is an incompatibility in facial skeletal structure.

Sometimes soft tissue thickness has been reconstructed by measuring the thickness of specific areas of overlying soft tissue on dissecting room cadavers and building up these areas with clay to the appropriate thickness in unidentified skulls [*45*]. It is possible to reconstruct the general features of individuals by using this technique. The reconstruction of soft tissues and identification on that basis can be rather hazardous, however. In some cases, the reconstruction is misleading and may confuse the identification.

One of the major hazards to personal identification may be the tendency to overdiagnosis by retrospection, due to an over-zealousness in trying to obtain positive identification. Another is presented by incomplete remains, particularly where an anomaly or old fracture has been reported in a bone that is not present. Blood typing of bone is possible and may indicate the actual blood type of the individual during life, if the remains are quite fresh. It is also possible in most cases to determine the handedness of the individual by differences in the length of the clavicles, the general size and degree of muscular attachment of bones on left or right side, and the size of the nutrient foramina in paired left and right bones.

The degree of reliability of personal identification techniques depends on the nature of the technique used and ranges from positive identification in the case of X-ray overlays with absolute fidelity of trabecular pattern, cortical thickness, and other configurations to the probable appearance of an individual as suggested by soft tissue build-up. In the former case identification can be quite positive, in the latter it can be erroneous.

Summary

In summary, the standard techniques used in the identification of skeletal remains afford an uneven degree of accuracy and reliability, but conventional techniques are generally capable of providing reasonable identification. Special techniques for determining age from histologic examination of bones and teeth afford a much more accurate and reliable basis for the estimation of age. In dealing with wounds, skeletal pathology, the cause of death, and the interpretation of most skeletal anomalies, the forensic pathologist is quite capable and usually more proficient than the anthropologist. For the determination of race, marks of cultural identity, the time that has elapsed since death if the remains have been dead for more than a few weeks, and many marks of personal identification the anthropologist may have had more experience in interpretation. Stature and whether or not bones are human can usually be determined with good reliability by forensic pathologists, as can the sex of the individual provided the pelvic area is available.

The specialized techniques for dealing with such things as commingling, time since death and estimation of stature from fragmented skeletal remains extend our ability to identify skeletal human remains and make it possible for relatively inexperienced examiners to utilize these more objective methods of measurement and statistical interpretation to arrive at estimates of the biologic nature of an individual from the skeleton.

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