Norman J. Sauer,[1] *Ph.D.; Robert E. Brantley,*[2] *M.D.; and David A. Barondess,*[1] *M.A.*

The Effects of Aging on the Comparability of Antemortem and Postmortem Radiographs

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ABSTRACT: To study the effects of aging on the ability to make positive identifications from radiographs of the postcranial axial skeleton, we collected early and later exposed abdominal X-rays from five patients whose period of treatment spanned from ten to twenty-three years. Corresponding lumbar vertebrae from each pair of radiographs were compared for similarities and differences in several of the criteria that have been reported as useful for individualization. These include shapes of the bodies, spinous processes, transverse processes, pedicles, and osteophytic extrusions. It is our conclusion that even though bone is a flexible tissue and changes constantly during life, aspects of the criteria chosen are quite stable and that even after two-and-a-half decades the ability to make positive identifications from postcranial axial material is not necessarily diminished.

KEYWORDS: physical anthropology, X-ray analyses, musculoskeletal system, human identification

In 1927, Culbert and Law reported in the *Journal of the American Medical Association* the identification of unknown human remains through a comparison of antemortem and postmortem X-rays [*1*]. Their comparison of nasal accessory sinuses and mastoid processes was, they claimed, the first application of roentgenography to the identification of decomposed remains. Since that time, the use of X-rays in skeletal identification has become well established and has been documented for a number of the elements or regions of the skeleton, including, of course, the dentition. Perhaps the best known historical case wherein X-rays were used for identification is the Ruxton case [*2*]. The Ruxton identification used an analysis of several postcranial elements. Subsequently, postmortem-antemortem X-ray comparisons have been reported for the calcaneus, the clavicle, the thorax, and the patella [*3–6*].

To establish the validity of using the postcranial axial skeleton for positive identification, Martel, et al. [*4*] conducted an experiment wherein a sample of fifty male and female posterior-anterior chest films was collected from hospital files to form a control group of known individuals. Two experienced radiologists were independently asked to match nine "unknowns" to members of the control sample. The unknown sample was actually made up of X-rays that were obtained from the individuals in the first sample but taken at different times. Both radiologists identified all nine specimens correctly. The authors felt that both spinous and transverse processes and the anterior extremities of the lower ribs (particularly

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[1]Associate professor and graduate student, respectively, Department of Anthropology, Michigan State University, East Lansing, MI.

[2]Radiologist, Department of Radiology, E. W. Sparrow Hospital, Lansing, MI.

calcified cartilage) were especially useful. In a similar study, Atkins and Potsaid [7] reported on the correct matching of one hundred control and unknown chest films.

In 1983, Birkby and Rhine [8] presented a systematic method for determining and reporting positive identification by X-ray comparisons of the axial skeleton. They discuss the usefulness of several features including rib contours and transverse processes, centra extrusions, and osteophytic extrusions on the vertebral column. Individual points of comparison were then applied to a simple formula to assess the probability of a correct positive identification.

X-rays of the postcranial axial human skeleton display a number of individual points that may be used for individualization. The purpose of the study discussed here is to evaluate the effects of timing and aging on the reliability of such techniques. We know, of course, that the structure of bone changes throughout the life of an individual, that bone is constantly being replaced, that the structural patterning of bone responds to the direction and magnitude of stress (Wolf's Law), and that degenerative bony changes are a normal consequence of the aging process. What is the cumulative effect of these modifications on the comparability of antemortem and postmortem X-rays?

Methods

To explore this issue, we collected from hospital files anterior-posterior abdominal radiographs of 5 different patients whose period of treatment spanned 10 to 25 years. Each of the subjects, 4 females and 1 male, was an adult (minimum age, 27) at the time the initial X-ray was taken.

For each case, one early and one or two later X-rays were selected and evaluated for similarities and differences in points of comparison. The structures or features associated with the points of comparison involved primarily the lumbar vertebrae and included the spinous and transverse processes, the pedicles, margins of the vertebral centra, spaces between neural arches, osteophytic extrusions, and intervertebral space.

Since we are not attempting to validate the use of vertebral radiographs for positive identification (that has been done [4, 7]), we do not feel compelled to conduct a blind study. Our goal is to illustrate some of the change and constancy associated with aging in various features that have been relied upon in the past and to argue that identification may still be possible even if two or three decades separate antemortem and postmortem radiographs. To this end, the data, photographic reproductions of X-rays, are reproduced here and provide the bases for our discussion.

Case Studies

Case 1

The first case is a female, who was 50 years of age in 1984 when the X-ray on the right was taken (Fig. 1). The initial film was exposed in 1961, when the subject was 27. In this set of X-rays, the spinous processes and pedicles are delineated quite well. An element-by-element examination of spinous processes reveals that a number of comparison points remain visible even after 23 years. Similarly features of the pedicles have also persisted over the 23-year span.

To clarify the features being discussed here we will use the first case to detail several of the comparison points. In Fig. 1, the lumbar vertebral bodies are labeled I-V. First, notice the outlines of the spinous processes on each of the segments (the spinous process of the second lumbar vertebra [L-II] is indicated in Fig. 1) and compare their outlines in the corresponding vertebrae in each of the radiographs (A and B). Second, study the right and left pedicles (the left pedicle of L-IV is indicated in Fig. 1). Third, consider the shape of the spaces be-

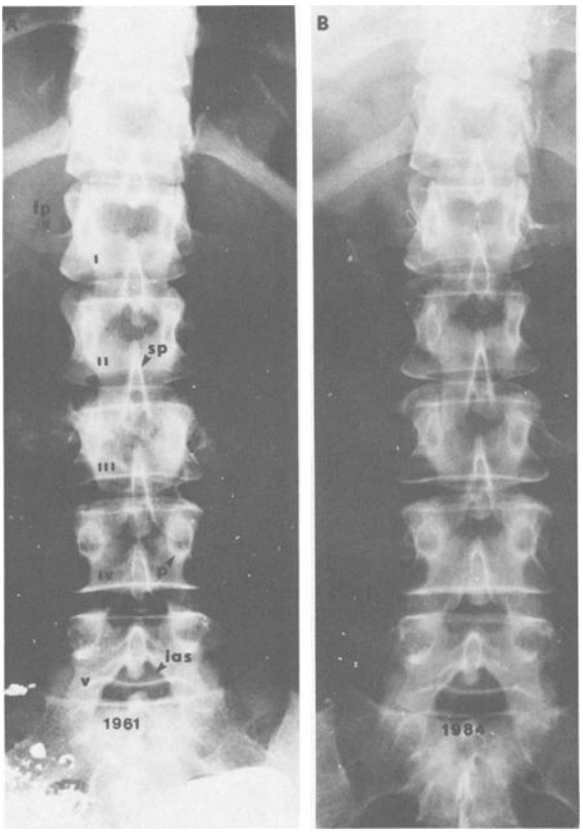

FIG. 1—*Female aged 27* (a) *and 50* (b). *Note the similarity in the centrum shapes and details of the corresponding transverse processes* (tp), *spinous processes* (sp), *pedicles* (p), *and interneural arch space* (ias).

neath the neural arches of vertebrae III, IV, and V (the interneural arch space of L-V is indicated in Fig. 1). Finally, compare the visible transverse processes to the right and left of each vertebral body (indicated in Fig. 1). There are a number of additional points and structures that could be used for identification.

Case 2

This case is also a female, aged 49 at the time of the second X-ray (Fig. 2). The first film was taken 17 years earlier. In this case, again the spinous processes and pedicles are especially clear, but also notice the transverse processes of lumbar vertebrae I and II. As in the first case, there are many points of comparison that have persisted between the early and later exposures.

Case 3

This case is a female, aged 38 in the first X-ray and 56 years in the second (Fig. 3). Between the 2 exposures 18 years elapsed. In both cases, the films are somewhat overexposed; however, there is sufficient detail to compare vertebral body shapes, spinous processes, and several of the pedicles and transverse processes.

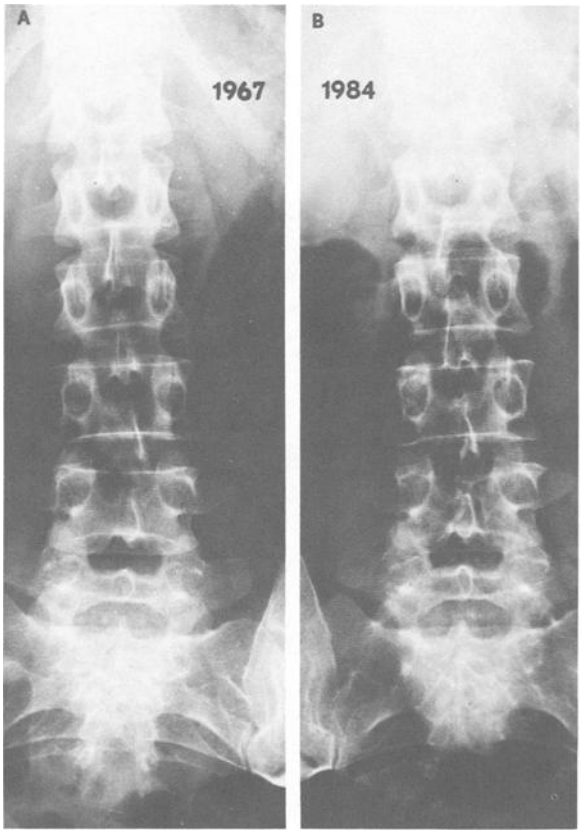

FIG. 2—*Female aged 32* (a) *and 49* (b). *Note the similarities in spinous processes, pedicles, body shapes, and transverse processes. Note also that this patient has six lumbar vertebrae.*

Case 4

These X-rays represent a female, 49 at the time of the 1984 X-ray (Fig. 4). Only a 10-year span is represented in this case, but again it illustrates very well the constancy of the criteria we have been discussing. Notice the body shapes, spinous processes, and transverse processes of the first and second lumbar vertebrae and pedicles. The inter-neural arch spaces are also illustrative in this case.

Case 5

This case is a male, who was 66 years old when the second film was taken (Fig. 5). The films represent a 10 year span. A laminectomy was performed before the first radiograph was exposed. Again looking at the vertebral centra and the pedicles, little significant change has taken place. Notice the anomalous spinous process and of L-V. This case displays a significant reduction in the intervertebral space and the development of significant osteophytic extrusions. Notice the lipping on the left side of the inferior and superior margins of L-II and L-III, respectively. Case 5 also illustrates the value of the sacrum and ilium and their orientation and articulation for identification.

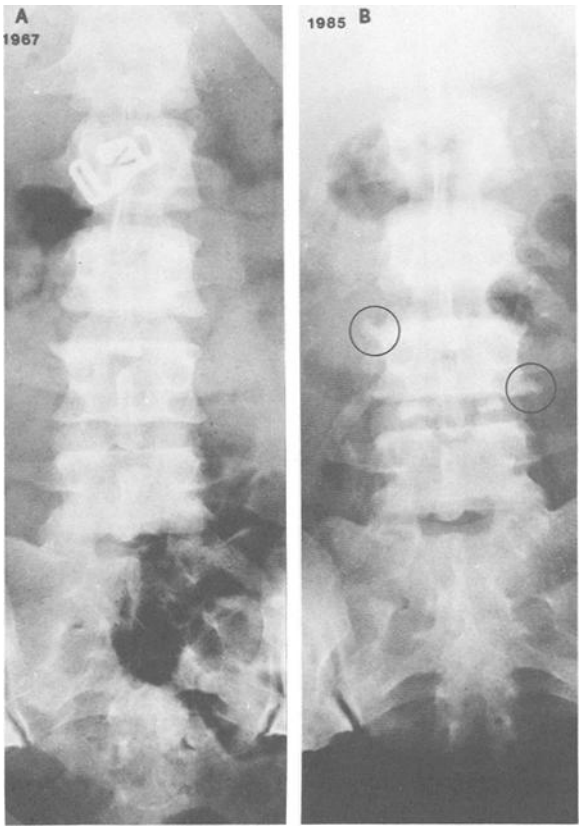

FIG. 3—*Female aged 38* (a) *and 56* (b). *Note the similarities in spinous processes, pedicles, and transverse processes. Note also the osteophytic lipping associated particularly with the body of L-4* (circled).

As in each of the previous cases, we feel that any of the changes that occurred in the structures under consideration were not sufficient to preclude positive identification.

Discussion

The purpose of this study was to evaluate the degree to which a number of different morphological structures, visible on postcranial axial radiographs and commonly used for positive identification, change with time. The cases presented here demonstrate that with the passing of from 10 to 23 years, the radiographic appearance of vertebral bodies, pedicles, and transverse and spinous processes in typical abdominal X-rays may not change significantly. Incidentally, these cases were not selected because they confirmed our initial expectations. They were selected simply because of the presence of comparable films that represented a 10 year or greater span of time.

In this project we considered two criteria of potential use in X-ray identification that are expected to change over time: intervertebral space and osteophytic lipping. Intervertebral space is complicated by the problem of orientation. Significant variation may be induced by the position of the X-ray source with respect to the subject. Nonetheless, we expected a less-

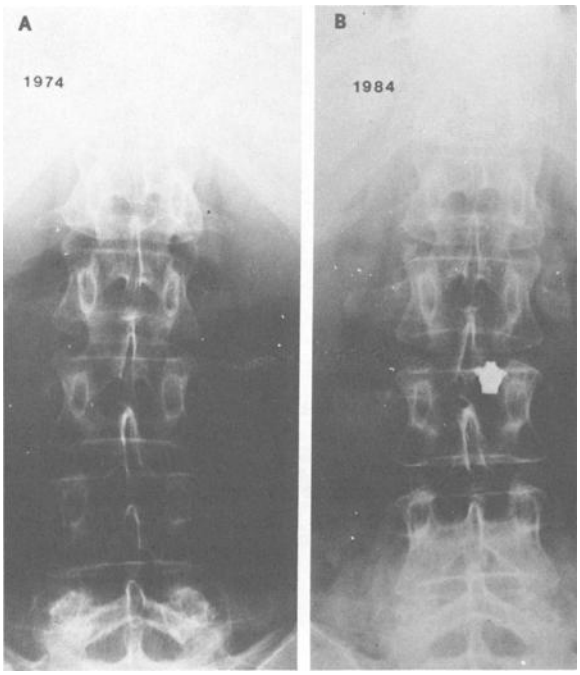

FIG. 4—*Female aged 39* (a) *and 49* (b). *Note the similarities in the spinous and transverse processes, pedicles, and vertebral body margins.*

ening of intervertebral distance with aging. The results were variable. Cases 1 and 5 display a consistent decrease in the distance between centra. In other cases, there appears to be no difference in intervertebral space between the earlier and later films. It is difficult to know how much of that variation is due to orientation.

In our sample, the expected accumulation of osteophytes was one of the consistent differences noted between the earlier and later radiographs (especially Cases 3 and 5). In cases where the antemortem X-rays were taken within several years of the time of death, osteophytes may be quite useful for identification [*8*], but their accumulation may lead to significant change over a longer period.

One limitation of our study was that we were required to use X-rays that were on hand and which were made for purposes other than for positive identification. In most actual identification cases, the radiologist would be able to study the antemortem X-ray while preparing the postmortem film. In those cases, attention could be paid to orientation and exposure and would greatly enhance the comparability of the two sets of films.

Conclusions

The study described in this paper demonstrates that skeletal changes that occur over the course of 2 or 3 decades do not necessarily diminish one's ability to make positive identifications through comparisons of antemortem and postmortem radiographs. In this project we dealt specifically with aspects of lumbar vertebral morphology. We reported on the effects of aging on the comparability of transverse processes, spinous processes, pedicles, spaces between adjacent neural arches, and the margins of vertebral centra. We demonstrated that in

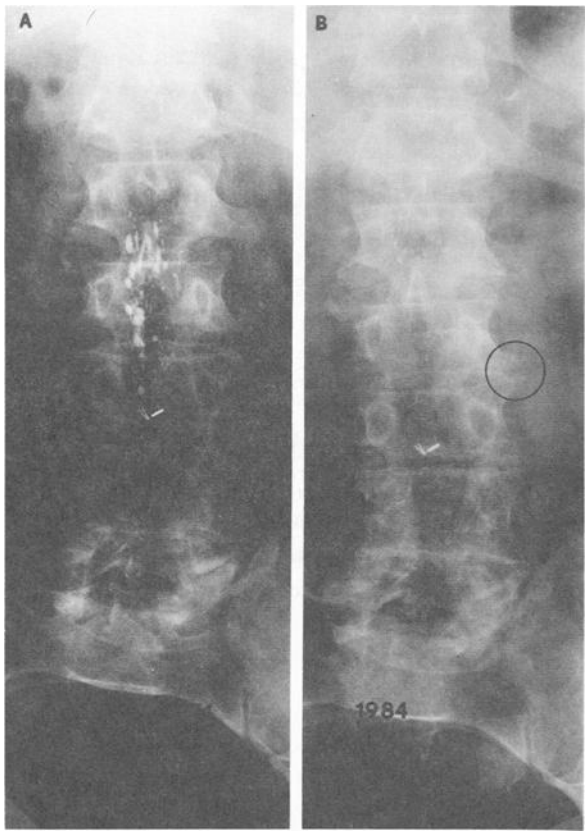

FIG. 5—*Male aged 56* (a) *and 66* (b). *Note the similarities in spinous processes, pedicles, transverse processes, and body morphology, the anomalous neural arch of L-5 and the orientation of the sacrum. This patient had undergone laminectomy surgery before the first available X-ray. Note also the osteophytic lipping especially on L-2 and L-3* (circled).

each of 5 cases, spanning 10 to 23 years, there is a sufficient retention of radiographic features to allow identification.

Osteophytic lipping, another feature cited as valuable for identification, represents a common degenerative process and should be avoided if more than a few years separate two sets of X-rays. Intervertebral space, affected significantly by orientation, does not appear to be very useful, especially since intervertebral space during life can only be estimated in disarticulated skeletonized remains.

In addition to these gross categories, actual radiographic comparisons involve a number of minute, randomly occurring opacities and radiolucencies. These substructural features are also apparent on the figures, and depending on the degree of specificity one applies, one may approach, for any case, an indefinite number of points of identity.

The significance of this research is severalfold. First, it provides a set of comparison X-rays that illustrates some of the features used for positive identification with the postcranial axial skeleton. Second, it illustrates the stability (and changes) that may be expected in radiographically discernable features over time. And third, it should make forensic scientists and investigators aware that the positive identification of decomposed remains may depend on obtaining medical records that date back two or three decades or even longer.

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Address requests for reprints or additional information to
Dr. Norman J. Sauer
Department of Anthropology
Baker Hall
Michigan State University
East Lansing, MI 48824