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Mineralization of the Costal Cartilages as an Indicator of Age: Preliminary Observations

REFERENCE: McCormick, W. F., "Mineralization of the Costal Cartilages as an Indicator of Age: Preliminary Observations," *Journal of Forensic Sciences*, JFSCA, Vol. 25, No. 4, Oct. 1980, pp. 736-741.

ABSTRACT: Soft X-ray examination of costal cartilages from 210 cadavers indicated a roughly linear increase in mineralization with advancing age. A cabinet X-ray machine and mammography film were used. Detectable mineralization was not found before the age of 15 and was rarely marked before the age of 50. Similar degrees of mineralization over a wide age span during middle years seriously limits the value of this method of age estimation while the ease, rapidity, and relative inexpensiveness of this procedure on intact or partially decomposed bodies recommends its use, especially where an expert physical (forensic) anthropologist is not readily available.

KEY WORDS: physical anthropology, human identification, musculoskeletal system

The ability to age partially or totally skeletonized human remains as well as "fresh" cadavers of unknown age is of obvious importance in forensic medicine. In the past, a number of suggested methods have been published, some of which have now been abandoned because of obvious lack of precision. The rate and pattern of tooth eruption, the closure of epiphyseal plates, and the appearance of centers of ossification have been most useful in aging with considerable precision skeletal remains from infants and children [1-4]. Pubic symphysis morphology, cranial suture closure, and wear-and-tear changes in bones and teeth (dental abrasions, osteophytic lipping of vertebrae, arthritic changes in joints, and so forth) have all been used in estimating age of postpubital skeletal finds [1-7]. In relatively recent years, microscopic methods of bone age estimation have proven to be more precise [8-10]. The possibility of relatively precise determination of age by examining the ratio of racemization of aminoacids seems to show exciting promise [11].

However, the fact remains that most or all of these techniques offer precision only in the hands of experts. A significant percentage of forensic autopsies in this country are done by hospital-based pathologists with relatively little training in forensic pathology and virtually none in forensic anthropology. Moreover, most pathologists, forensic or hospital-based, rarely have the opportunity to study many skeletonized remains. Above all else, suitable experience is necessary for real expertise in the "classical" methods of age determinations in current use. The number of individuals truly expert and experienced in forensic anthropology is few, and it is often difficult for the busy practitioner of

Received for publication 14 Dec. 1979; revised manuscript received 11 March 1980; accepted for publication 1 April 1980.

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pathology to use their services correctly and fully. Thus, any method that gives acceptable accuracy while obviating the need for great expertise or expense is worthwhile.

The following simple, readily available technique for the approximation of age at death of partially or completely skeletonized human material is inexpensive and requires little expertise. For these reasons, it would seem to be of some value in spite of its lack of great precision.

Material and Methods

The "chest plate," consisting of the sternum, the costal cartilages, and the terminal 2 to 5 cm of ribs, was removed at the time of autopsy and X-rayed in a closed unit² at 30 kV peak at 2 mA for 1.8 to 2.0 min with Kodak X-Omat TL film "Ready Pack." The degree of mineralization of the costal cartilages was arbitrarily graded from absent (0) to 4+ (Fig. 1). Two hundred ten sternums and attached costal cartilages from cadavers of known age ranging from three months to 86 years were used. The race and sex of each specimen were also known.

To determine the resistance of costal cartilage to decay and degeneration, 20 chest plates (consisting of the sternum, costal cartilages, rib ends, and attached soft tissues) obtained at autopsy were placed in an enclosed outdoor environment for up to four months. Some of the specimens were placed in open sun, others in dense shade, and still others partially or completely buried beneath gravel, sand, or grass. The specimens were removed only for photographing and X-raying at two- to three-week intervals. The study period was summer, when the temperature ranged from a low of 21°C (70°F) to a maximum of 33°C (92°F). The total rainfall during this period was approximately 610 mm (24 in.). No attempt was made to keep insects from the specimens but large animals were excluded.

Results

Costal Cartilage Calcification

Calcification of the costal cartilages was first seen on X-ray in a 15-year-old Mexican-American boy and is quite uncommon before the age of 20. Calcification in females appears to be somewhat slower to develop and was first seen in a 21-year-old. Mineralization was usually first detectable in the six, seventh, and eighth cartilages adjacent to the sternal borders. At least a "trace" of mineralization was evident within the costal cartilages in all cadavers over the age of 25 years. Moderate mineralization, here arbitrarily graded as 2+ to 3+, was rare before the age of 40 and was usual after the age of 60. Dense mineralization, here graded 3 to 4+, was encountered in only two individuals below the age of 55 (Fig. 2).

Conversely, however, mild to moderate (1 to 2½+) mineralization was frequently encountered in cadavers over the age of 50, even to advanced age (80+ years).

Resistance of Costal Cartilage to Decay

Figure 3 illustrates the effect of three months of summertime exposure of costal cartilage to the environment. This figure is representative of the specimens studied and demonstrates the relative stability and utility of this X-ray method even in such largely to totally skeletonized material.

²Faxitron 43805N (Hewlett-Packard).

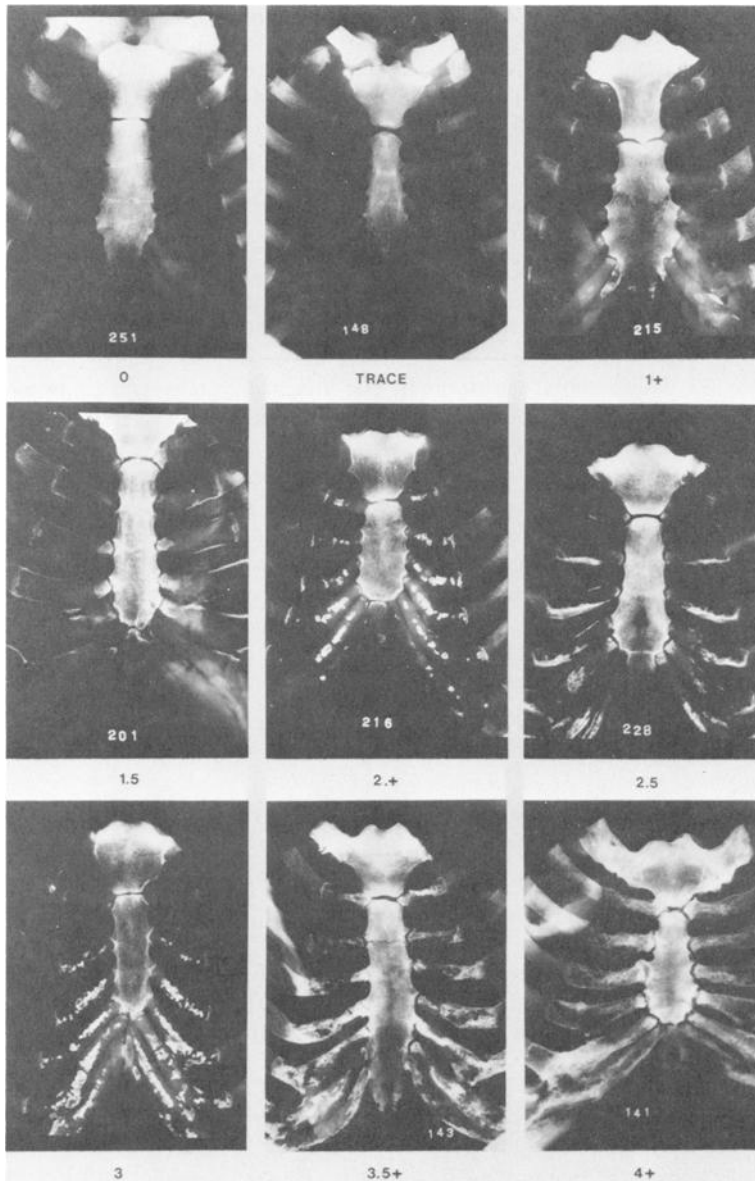


FIG. 1—X-rays of chest plates with grading of mineralization of costal cartilages from 0 (none visible) to 4+ (very severe). This nine-point grading system was used to develop Fig. 2.

Discussion

X-ray studies of the degree of mineralization of the costal cartilages in human necropsy material is a very simple and inexpensive technique. It does not require extensive training and experience either to perform or to interpret such studies. With only insignificant modifications, they can be carried out in any hospital. Unlike the single known old study of costal cartilage calcification in the living [12], the resolution obtained with this technique

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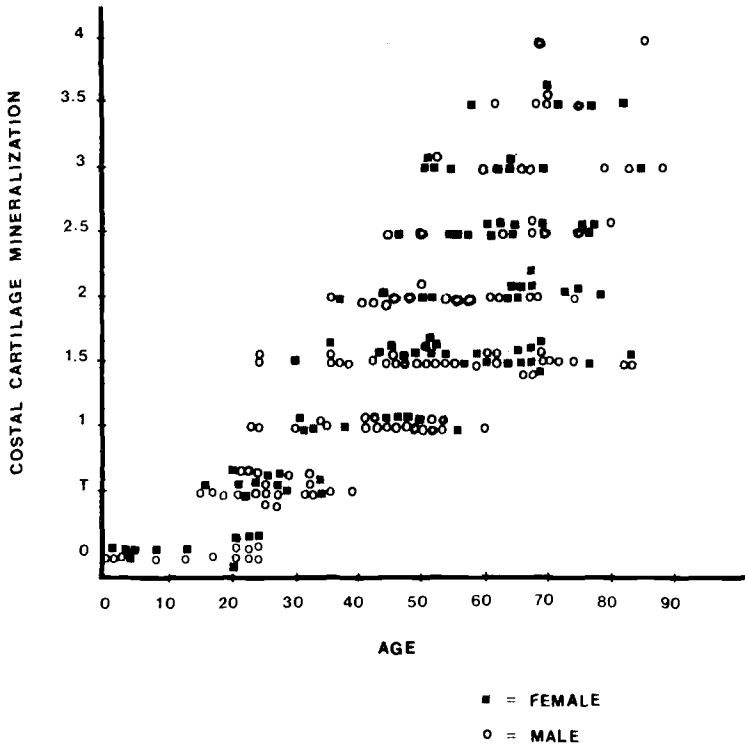


FIG. 2—Graph demonstrating the relationship of age and degree of cartilage mineralization utilizing the system illustrated in Fig. 1.

is excellent because of the type of X-ray film and the very low voltage necessary to obtain excellent resolution. The technique is very rapid and the developed X-ray film can be in the hands of the interpreter within minutes. Thus, the desirable features of low cost, rapidity of obtaining the results, ready availability of adequate facilities, and the lack of need for great experience and expertise are all readily met.

Certain generalizations appear to be warranted by this preliminary study. Briefly stated they are these:

1. Mineralization of the costal cartilages is a common event in adults and is roughly age-related, with every specimen older than 25 having at least slight mineralization. This is in absolute agreement with the observation of Fully and Dehouve [13]. However, mineralization is very uncommon before puberty and is rarely present in more than trace amounts before the age of 25 years.

2. Dense mineralization of the costal cartilages appears to be very unlikely before the age of 50 and is relatively uncommon before the age of 60.

3. Relatively small amounts of mineral can be found even in the elderly, making age estimation based only on relatively light mineralization (1.5 to 2+) of costal cartilages suspect.

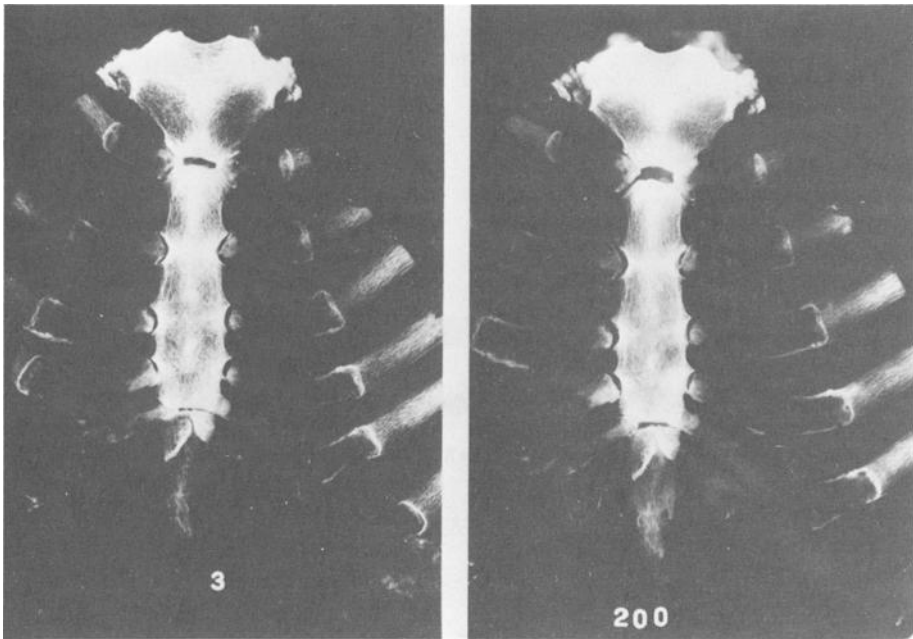


FIG. 3—X-ray of "fresh" chest plate (5 h postmortem) and later X-ray of the same specimen after three months of outside summertime exposure. All important features are still visible.

4. This method does not allow the degree of precision that can be obtained by experts experienced in the evaluation of skeletal remains. In this regard, it best can be likened to a screening test. It would seem to have its greatest use in (a) decaying adult bodies of indeterminate age (by usual gross autopsy methods), (b) when some reasonable estimation of age range is urgent, or (c) in mass disasters.

These data, based as they are on limited numbers of bodies, clearly need further expansion. The effects of sex and race on rate and degree of mineralization are not yet clear. Preliminary data suggest somewhat earlier and more marked mineralization of costal cartilages in men than in women and in Mexican-Americans than in blacks and whites. The study of 120 cadavers by Fully and DeHouve [13] also found somewhat heavier ossification in men. More precise quantification of the density and extent of mineralization of the costal cartilages is now underway in this laboratory. It is possible that these methods will prove significantly superior to the 0 to 4 grading system. Fusion of the sternomanubrial joint has been found to be of no value in predicting age in this limited study, in keeping with the observation of others [5]. The fusion of sternebra to give rise to the typical adult pattern is of use in cadavers less than 20 years of age [13].

Conclusions

A simple, rapid, and inexpensive X-ray technique for broad estimation of age based on rib cartilage mineralization, using either skeletonized or fresh human costal cartilages, is presented. While less precise than some other methods currently available, its ease of performance, low cost, ease of storage of the single X-ray film, and lack of need for considerable personal experience and expertise in evaluating skeletal materials recommend

its use as a "second-best" method. Costal cartilages are sufficiently resistant to decay to allow their use for X-ray studies for many months after death.

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