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Age Estimation from the Rib by Phase Analysis: White Males

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ABSTRACT: The determination of age at death is an important part of physical and forensic anthropology. Techniques now in use vary from direct observation of a bone to microscopic examination of a given segment. This study introduces the sternal end of the rib as a new site for age estimation by direct observation. The sample consisted of 118 white male ribs of verified age, sex, and race. The ribs were assigned to one of nine phases (0 through 8) based on changes noted at the costochondral junction. These included the formation of a pit, its depth and shape, configuration of the walls and rim surrounding it, and the overall texture and quality of the bone. Statistical analysis indicated that these changes were age related. It was further revealed that metamorphosis was most rapid and uniform from the mean age of 17 to 28 years (Phases 1 through 4). The rib morphology was more varied after age 39 (Phase 5) resulting in a wider range for the predicted age. Our study concluded that the sternal rib end may yield a similar degree of accuracy to the pubic symphysis and perhaps better than that for cranial sutural closure. Our technique also enables the forensic scientist to use the rib for corroboration with age estimations obtained by traditional methods.

KEYWORDS: physical anthropology, human identification, musculoskeletal system, sternal rib, white males, age determination

The estimation of age is an essential part of all forensic science investigations involving skeletal remains of unknown individuals. This estimation is especially difficult after adulthood is reached [*1-3*]. Methods in use today are fairly successful [*4*], but are limited to only a few parts of the skeleton. Therefore, new techniques are still needed for cases where available methods are inadequate or inappropriate and corroborative evidence is necessary. The present study is an attempt to develop a technique using the sternal extremity of the rib as a new site for the determination of age.

Forensic and physical anthropologists currently use two types of methods for estimating age in adult skeletons. The traditional approach is based on gross morphologic changes in the bones. The best known of these include the time sequence of cranial sutural closure [*5,6*] and metamorphosis in the pubic symphysis [*7,8*]. A newer approach involves microscopic analysis of changes at the histologic level, such as osteon counting in a segment of long bone [*9,10*].

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Both morphologic and microscopic approaches are differentially preferred. They also have their limitations and present certain difficulties.

Microscopic analysis has been criticized on two counts. First, cross-sectioning necessitates some destruction of the bone. Bone coring has reduced, but not entirely eliminated this problem [*10*]. Secondly, a great deal of time, specialized equipment, and skill are needed to produce and analyze thin sections. Very few forensic scientists, including anthropologists, have the training and equipment to carry out this complex procedure. In forensic science cases, where time is of the essence, it is important to provide a preliminary description as soon as possible.

Morphologic examination does offer a more rapid estimation of age. However, there are also limitations here too. The pubic symphysis cannot be used accurately to estimate age in males beyond the mid-fifties [*7, 11*], and only slightly older in females [*8*]. Cranial sutural closure had been used for many years until repeated criticism, based on the high degree of individual variation encountered there, led experts to seriously question the reliability of this method [*1, 7, 11*].

Todd [*12, 13*] first claimed that the pubic symphysis was more reliable, and his accuracy in the estimation of age was further improved by Brooks in her 1955 study. The main criticism of Todd's phase analysis of the pubic symphysis came from McKern and Stewart [*7*]. They felt that Todd's phases considered each bone static, and thus, could not account for variability. To help eliminate this problem, McKern and Stewart [*7*] proposed a Sheldonian type component analysis in which each bone was examined from three different perspectives. This method was later adopted by Gilbert and McKern [*8*] in their work on the pubic symphysis in females. This same component model was also used by Loth and associates [*14*] in their initial study of the rib.

While Suchey [*15*] has mentioned problems of interobserver error, the accuracy of component analysis has not been seriously challenged. The major criticism of this system is that it is rather complicated to apply. It is especially unwieldy and inconvenient for forensic anthropologists and pathologists who need to make a rapid estimation of age at a crime scene since it involves the assessment of each component and calculation of their combined scores. Thus, Todd's phase analysis is easier to learn and more convenient for fieldwork.

For this present study, the rib was chosen because radiographic and histologic research and direct morphologic observation of the sternal extremity indicated that this area showed changes throughout life [*9, 16–19*]. Osteologically, Kerley [*9*] noticed that the sternal extremity of the rib is billowy in adolescence, cup-shaped with sharp margins in middle age, and irregular in later years. The authors [*14*], in their preliminary studies, confirmed Kerley's observations and developed a system in which each rib was analyzed on the basis of changes noted in three components, a method similar to that used on the pubic symphysis [*7*]. The aim of our current research is to develop a phase analysis system, analogous to that of Todd [*12*], with the expectation that this technique is as rapid and easy to use as that based on the pubic symphysis.

Materials and Methods

To implement this study, the sternal end of the right fourth rib was collected from 118 white males autopsied at the Broward County Medical Examiner's Office. The fourth rib was chosen since it can be easily obtained during a routine postmortem examination, thus, better enabling us to build a larger data base. All specimens came from individuals of known age, sex, and race. The ribs were separated from the adherent soft tissue by first soaking them in water for several weeks, then boiling gently for 10 to 15 min. At this time, all soft tissues, including the costal cartilage, were easily removed from the bone yielding clean, undamaged specimens.

Our initial observations revealed that the first morphologic changes, beyond an increase in size, were not seen in the sternal extremity of the rib until after the age of 16 years. This may signify the cessation of growth, and thus would indicate that maturity in the rib is reached by the end of the 16th year. Therefore, the younger ribs ($N = 10$) were put in the 0 phase and only specimens 17 years and older were included in the statistical analysis. The mean age of the sample was 41 years, with a range of 17 to 85 years. Table 1 shows the frequency distribution of specimens in each age interval. Individuals over the age of 50 years accounted for 30% of the sample. The highest concentration by decade was in the 20s (32%).

Each rib was examined with special attention to features where changes were most apparent. Based on metamorphoses of these features, the specimens were separated into nine groups (Phases 0 through 8). The phases were then statistically analyzed by Statistical Package for the Social Sciences (SPSS) subroutines CROSSTABS, BREAKDOWN, and ONEWAY analysis of variance [*20,21*].

The Phase Method

The distribution of specimens into phases was based on changes noted in the form, shape, texture, and overall quality of the sternal rib. This metamorphosis begins with the formation of an indentation (pit) in the medial articular surface. Special attention is paid to the depth and shape of the pit along with the walls and rim surrounding it. Initially, the pit is merely an amorphous but noticeable indentation in the once almost flat, billowy endplate. As the pit deepens, the indentation between anterior and posterior walls takes on a V-shaped appearance that gradually widens into a U as the walls become thinner. With increasing age the pit becomes wider and deeper. Along with further pit development, the rim progresses from a regular, rounded border to a scalloped, but still fairly regular edge, and over the years, grows increasingly sharp and irregular. The overall texture and quality of the bone itself, dense, smooth and solid in youth, deteriorate until the bone becomes very thin, brittle, and porous in the elderly. Nine phases (0 through 8) were developed based on the aforementioned changes in the rib. The phases are defined as follows:

Phase 0: The articular surface is flat or billowy with a regular rim and rounded edges. The bone itself is smooth, firm, and very solid (Plate 1: Fig. 0*a*, *b*, and *c*).

Phase 1: There is a beginning amorphous indentation in the articular surface, but billowing may also still be present. The rim is rounded and regular. In some cases scallops may start to appear at the edges. The bone is still firm, smooth and solid (Plate 1: Fig. 1*a*, *b*, and *c*).

Phase 2: The pit is now deeper and has assumed a V-shaped appearance formed by the anterior and posterior walls. The walls are thick and smooth with a scalloped or slightly wavy rim with rounded edges. The bone is firm and solid (Plate 1: Fig. 2*a*, *b*, and *c*).

Phase 3: The deepening pit has taken on a narrow to moderately U-shape. Walls are still fairly thick with rounded edges. Some scalloping may still be present but the rim is becoming more irregular. The bone is still quite firm and solid (Plate 2: Fig. 3*a*, *b*, and *c*).

Phase 4: Pit depth is increasing, but the shape is still a narrow to moderately wide U. The walls are thinner, but the edges remain rounded. The rim is more irregular with no uniform

TABLE 1—*Frequency and percentage distribution of specimens by age intervals.*

Age Intervals (in Years)	*N*	%
0-16	10	8.5
17-19	6	5.1
20-29	38	32.2
30-39	15	12.7
40-49	15	12.7
50-59	11	9.3
60-69	12	10.2
70 and over	11	9.3
Total	118	100.0

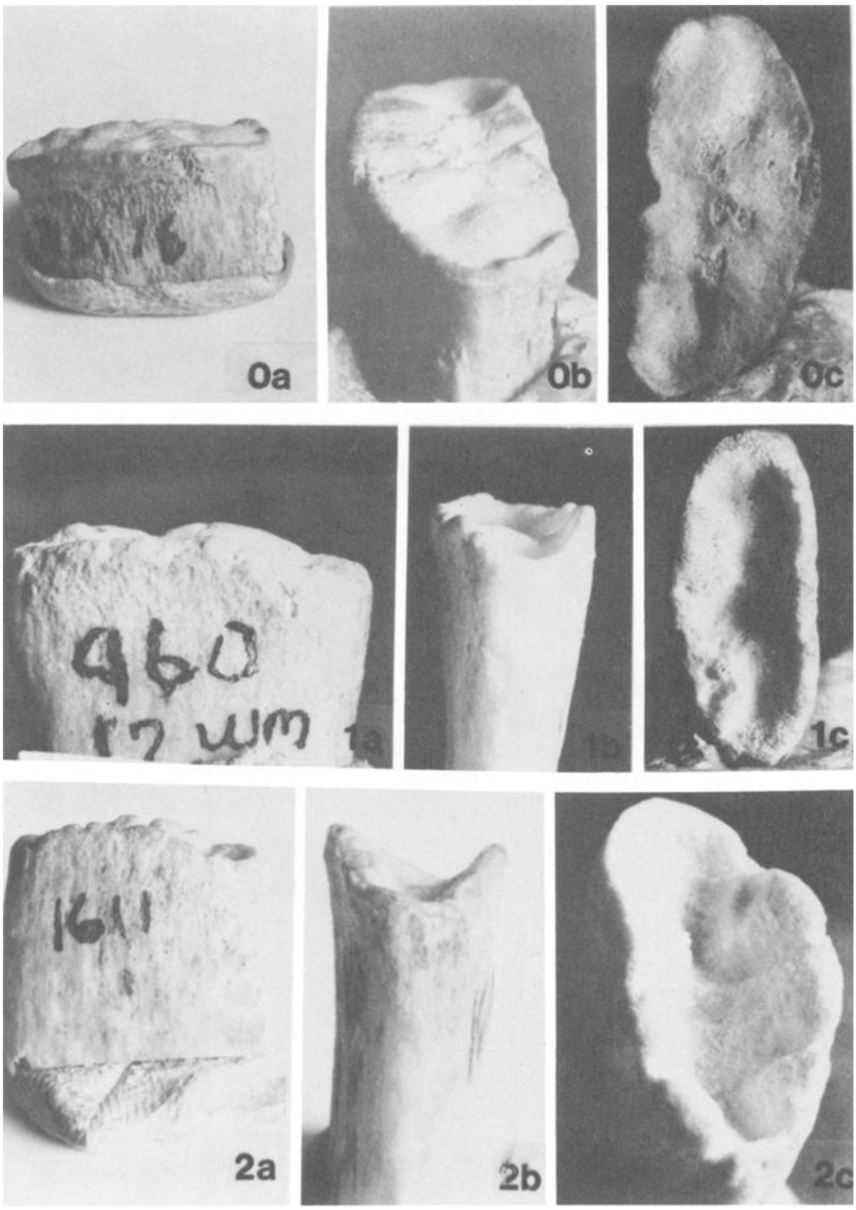

PLATE 1—(PHASES 0-2): Phase 0—*The smooth, regular, rounded rim shown in this frontal view (Fig. 0a) is typical of the adolescent rib. Note the billowy articular surface with no pit formation (Fig. 0b and c).* Phase 1—*Rim is still smooth and rounded, but is slightly wavier (Fig. 1a).* Figure 1b *and* c *show the initial indentation of the pit, along with some billowing still present on the articular surface.* Phase 2—*Figure 2a shows the scalloped rim with smooth rounded edges first seen in this phase. A side view of the U-shaped pit can be seen in Fig. 2b, while 2c shows the increased depth of the pit surrounded by thick walls.*

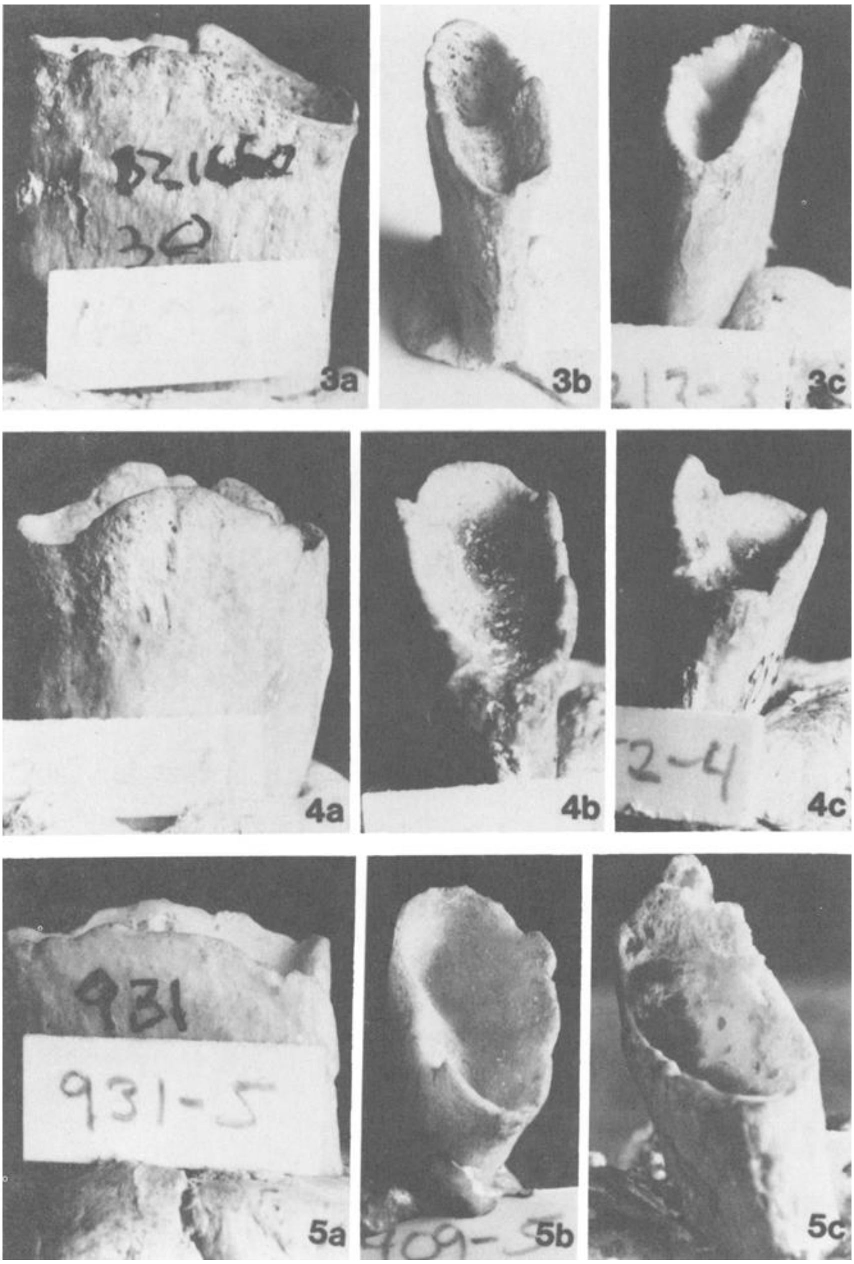

PLATE 2—(PHASES 3-5): Phase 3—*The rim is becoming more irregular with only a little scalloping remaining (Fig.* 3a*). The deepening pit has taken on a narrow U-shape with fairly thick walls and rounded edges (Fig.* 3b *and* c*).* Phase 4—*Regular scalloping pattern is gone from the increasingly irregular rim (Fig.* 4a*). Figure* 4b *and* c *show the moderately wide U-shaped pit with slightly thinner walls whose edges are still rounded.* Phase 5—*Rim is slightly more irregular (Fig.* 5a*). Note the deep, moderately wide U-shaped pit with thinner walls and sharper edges (Fig.* 5b*). Figure* 5c *shows evidence of porosity and some deterioration of bone inside the pit.*

scalloping pattern remaining. There is some decrease in the weight and firmness of the bone, however, the overall quality of the bone is still good (Plate 2: Fig. 4*a*, *b*, and *c*).

Phase 5: There is little change in pit depth, but the shape in this phase is predominantly a moderately wide U. Walls show further thinning and the edges are becoming sharp. Irregularity is increasing in the rim. Scalloping pattern is completely gone and has been replaced with irregular bony projections. The condition of the bone is fairly good, however, there are some signs of deterioration with evidence of porosity and loss of density (Plate 2: Fig. 5*a*, *b*, and *c*).

Phase 6: The pit is noticeably deep with a wide U-shape. The walls are thin with sharp edges. The rim is irregular and exhibits some rather long bony projections that are frequently more pronounced at the superior and inferior borders. The bone is noticeably lighter in weight, thinner, and more porous, especially inside the pit (Plate 3: Fig. 6*a*, *b*, and *c*).

Phase 7: The pit is deep with a wide to very wide U-shape. The walls are thin and fragile with sharp, irregular edges and bony projections. The bone is light in weight and brittle with significant deterioration in quality and obvious porosity (Plate 3: Fig. 7*a*, *b*, and *c*).

Phase 8: In this final phase the pit is very deep and widely U-shaped. In some cases the floor of the pit is absent or filled with bony projections. The walls are extremely thin, fragile, and brittle with sharp, highly irregular edges and bony projections. The bone is very lightweight, thin, brittle, friable, and porous. "Window" formation is sometimes seen in the walls (Plate 3: Fig. 8*a*, *b*, and *c*).

Results

Descriptive statistics and ONEWAY analysis of variance can be seen in Tables 2 and 3. Our results show a consistent increase in mean age per phase spanning a range of 17 to 72 years. This increase was approximately three years per phase in Phases 1 through 4 and extends to about 10 years per phase for Phases 5 through 8. The width of the 95% confidence interval also increased within each phase, widening from about a year and a half in Phase 1 to a maximum of 13 years in Phase 8. This range was less than 4 years for Phases 1 through 4 and averaged 11 to 12 years in Phases 5 through 8 indicating greater variability and slower rate of change in the higher phases largely composed of older individuals. It was also evident that the greatest rate of change, noticeable within a few years, occurred in the first four phases (mean ages 17 to 28).

In Table 3, which summarizes the results of the analysis of variance, η^2 refers to the proportion of variance in age explained by the metamorphoses defining the phases. Thus, 85% of the changes occurring with age can be accounted for by the characteristics chosen to delineate the phases. Furthermore, the F ratio for the analysis of variance indicated that the difference between phases is statistically significant at the $P < 0.001$ level.

The CROSSTABS procedure (Table 4) was carried out to assess the statistical significance of the distribution of individuals by age and phase. This analysis revealed that in Phases 1 through 4 and 8 at least 75% of specimens came from one decade. In the remaining phases, over 65% of the specimens came from two decades, and of these, Phase 6 showed the greatest variability.

Table 4 also shows that the decades spanning the largest number of phases were the 20s, 30s, and 40s, each being represented in four phases. However, the third decade is the only group having at least 20% of its population in each of the four phases, and thus, showed the greatest variability. Decades 1, 5, 6, and 7 had over 80% in two phases or less. The X^2 value for the distribution of specimens by age and phase was statistically significant at the $P < 0.001$ level.

Discussion

We have claimed that observation of a particular anatomic site could be improved if variation at that site was systematically accounted for. Based on this concept and the relative practicality of the phase technique we modified and adapted this system for use on the ribs. Statistical analysis of the results of the study indicates that there is a causal relationship between age and phase. All of our data support the suitability of the sternal extremity of the rib as a site for

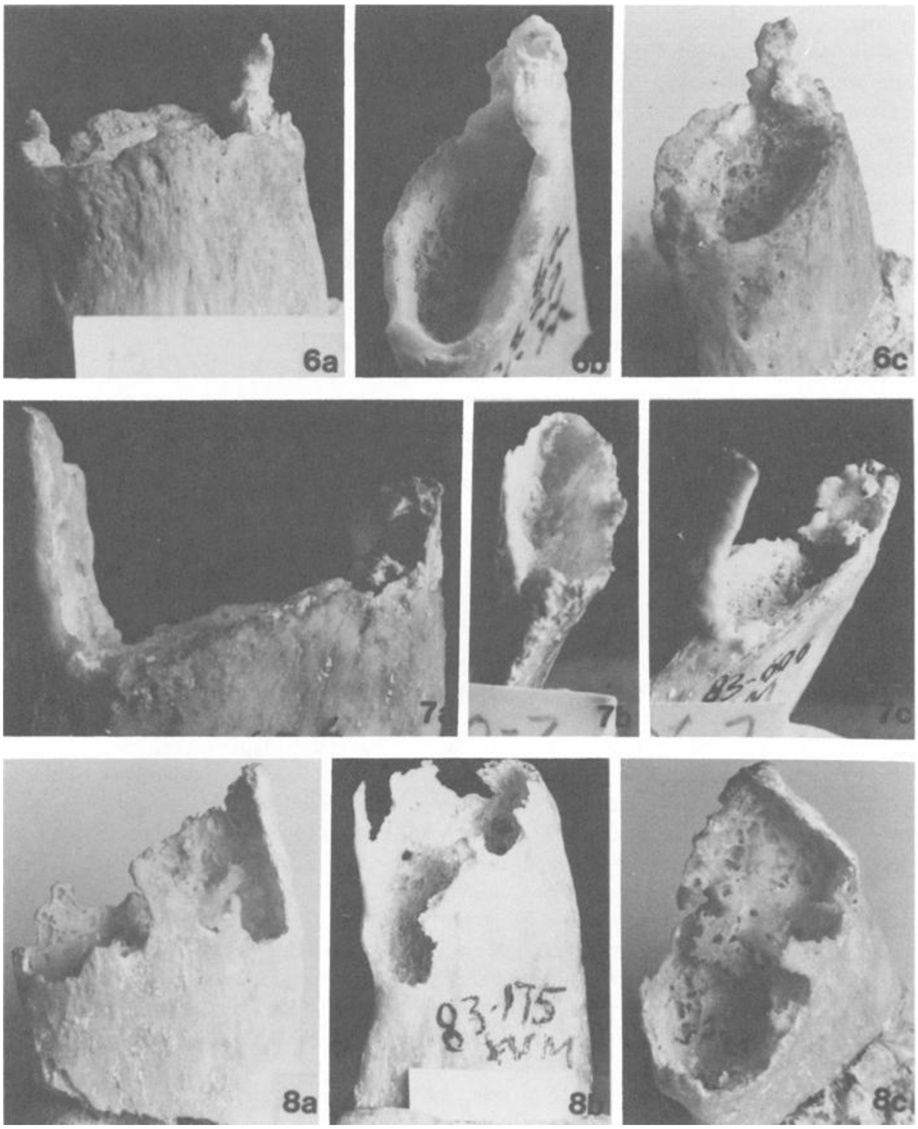

PLATE 3—(PHASES 6-8): Phase 6—*Note the bony projections arising from the superior and inferior borders of the rib (Fig.* 6a*). Figure* 6b *and* c *show the noticeably deep, widely U-shaped pit, thinning walls, and sharper edges. Increased porosity and deterioration of bone can also be seen inside the pit.* Phase 7—*Figure* 7a *shows the irregular rim with long bony projections. Porous, deteriorating bone can be seen in a deep, widely U-shaped pit surrounded by noticeably thin, fragile walls with sharp edges (Fig.* 7b, *and* c*).* Phase 8—*Figure* 8a *and* b *show the extremely irregular rim with sharp, brittle projections of bone. "Window" formation can be seen in Fig.* 8b, *along with the very thin walls surrounding a very deep pit. Bony projections can also be seen arising from the floor of the very widely U-shaped pit (Fig.* 8c*). The inside of the pit shows extreme porosity and obvious deterioration.*

TABLE 2—*Statistics of phases.*

Phase	N	Mean	SD	SE	95% Confidence Interval	Age Range
1	4	17.3	0.50	0.25	16.5–18.0	17-18
2	15	21.9	2.13	0.59	20.8-23.1	18-25
3	17	25.9	3.50	0.85	24.1-27.7	19-33
4	12	28.2	3.83	1.11	25.7-30.6	22-35
5	14	38.8	7.00	1.93	34.4-42.3	28-52
6	17	50.0	11.17	2.71	44.3-55.7	32-71
7	17	59.2	9.52	2.31	54.3-64.1	44-85
8	12	71.5	10.27	2.97	65.0–78.0	44-85
Total	108	41.0	7.51	0.72	39.6-42.4	17-85

TABLE 3—*ONEWAY analysis of variance.*

Source of Variation	df	Mean Squares	F Ratio	η^2
Between phases	7	4546.46	80.56[a]	0.85
Within phases	100	56.44	...	...
Total	107	...	...	...

[a]Significant at $P < 0.001$ level.

the accurate estimation of age, and the phase method as a viable technique. They also reconfirm the findings of our earlier work on the rib [*14*].

Histologic and radiographic studies have also confirmed that lifelong age related changes do occur in the rib. In their histologic studies, Sedlin et al [*16*] investigated changes in the cross-sectional area of the cortex of the rib and found that it increased rapidly until skeletal maturity, and then declined sharply from age 20 to 35 years with a continued, but more gradual decline thereafter. Epker and associates [*17*] later revealed that while the cortex became thinner with age, there was an increase in the overall diameter of the rib because of the continuous deposition of periosteally produced bone. These histologic patterns agreed with our observations of pronounced changes in bone density and weight in the later phases, and also correlated with the rapid rate of change we noted in the 20s.

Another significant factor that affects the sternal extremity of the rib might be the lifelong periosteal deposition of new bone [*16,17,22*], possibly accompanied by perichondral mineralization [*23,24*]. This makes it very likely that what appeared to be the "deepening" of the pit was actually a buildup of periosteally produced bone. Endosteal resorption, which Epker et al [*17*] found to outpace periosteal deposition also contributes to the thinning of the bone and may be responsible for the complete erosion of the floor of the pit seen in Phase 8.

Completion of growth in the rib must also be considered. Sedlin et al [*16*] found this to occur prior to age 20, and we observed that the initial change was a transition from a nearly flat articular surface to a cup-shaped structure. Since cartilage has greater resistance to mechanical and intermittent or pulsating pressure than does bone [*22*], ossification of the growth cartilage at maturity may leave the bone susceptible to reshaping around the costal cartilage with which it articulates. This change was first noted to begin at age 17.

Radiographic studies have focused mainly on the increased mineralization in the costal cartilages noted with advancing age [*18,19*]. As McCormick [*19*] pointed out radiographic methods can provide only a rough correlation with age. Furthermore, since radiographic analysis requires the entire, intact sternal rib cage, this would preclude its use on completely skeletonized, disarticulated, and disturbed forensic science cases. However, the researchers have agreed that this anatomic site has the potential for accurate age determination [*18,19*].

Statistical analysis of our results supported the validity of our assumption that the sternal extremity of the rib undergoes continuous metamorphosis as a normal part of the aging pro-

TABLE 4—*Frequency distribution of phases by age intervals.*[a]

	Age Interval							
Phases	17-19	20-29	30-39	40-49	50-59	60-69	70-85	Total N
8	...	...	...	6.7[b]	...	16.7	81.8	
				8.3[c]		16.7	75.0	
				(N=1)		(N=2)	(N=9)	12
7	...	...	...	23.5	23.5	47.1	5.9	
				26.7	36.4	66.7	9.1	
				(N=4)	(N=4)	(N=8)	(N=1)	17
6	...	...	17.6	29.4	35.3	11.8	5.9	
			20.0	33.3	54.5	16.7	9.1	
			(N=3)	(N=5)	(N=6)	(N=2)	(N=1)	17
5	...	7.1	50.0	35.7	7.1			
		2.6	46.7	33.3	9.1	...		
		(N=1)	(N=7)	(N=5)	(N=1)		...	14
4	...	83.3	16.7					
	...	26.3	13.3	...	...	...		
		(N=10)	(N=2)				...	12
3	5.9	76.4	17.6					
	16.7	34.2	20.0	...	...	...		
	(N=1)	(N=13)	(N=3)				...	17
2	6.7	93.3						
	16.7	36.8	...	...	...	...		
	(N=1)	(N=14)					...	15
1	100.0							
	66.7	...	...	...				
	(N=4)				...	...	...	4
Total N	6	38	15	15	11	12	11	108

[a] $\chi^2 = 258.74$ with 42 degrees of freedom (significant at $P < 0.001$ level).
[b] Row percentage.
[c] Column percentage.

cess. It was interesting to note that the rate of change closely paralleled that found by McKern and Stewart [7] in the pubic symphysis. The present study was also comparable to that of McKern and Stewart [7], Gilbert and McKern [8], and Todd [12,13] in terms of accuracy. While our sample size was about the same as the other studies, the primary deviation stemmed from our much greater age range of 17 to 85 as opposed to, for example, 17 to 50 for McKern and Stewart [7].

It is important to keep in mind that several factors should be considered when one uses a method of age estimation from the skeleton. These include interobserver error, human variability, occupation, general health, and the effects of disease. Common sense dictates that a more experienced observer will give a better estimation than a neophyte. Suchey [15] dealt with this problem and found this statement to be true. It should also be noted that many conditions are known to affect bone remodelling, and thus, may alter the expected pattern of aging in the ribs [25-31]. These include endocrine disorders, chronic lung disease, medication, sex and racial differences, diet, degree of physical activity, and intercostal variations [18,23,32-37].

Two of these factors are particularly pertinent to this study. Intercostal variation may come into play because this study was based on the fourth rib. Semine and Damon [18] addressed this issue and stressed that the first rib changes much faster than the lower ones. It was also shown that while intercostal variation does exist between the lower ribs, it is more gradual. Therefore, it is probable that there may not be much difference between the third, fourth, and fifth ribs. This matter, along with the possibility of side differences, have not yet been tested.

The second consideration deals with variation between males and females [18,23,34,36,38-41]. Differences in hormonal production can account for unequal rates of change in the rib, but biomechanical differences may also be involved [18,23]. This leads us to the next phase of our research in which we plan to develop a new standard for females.

Acknowledgments

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References

[1] Krogman, W. M., *The Human Skeleton in Forensic Medicine*, Charles C Thomas, Springfield, IL, 1962.

[2] Stewart, T. D., *Essentials of Forensic Anthropology*, Charles C Thomas, Springfield, IL, 1979.

[3] Rogers, S. L., *The Aging Skeleton: Aspects of Human Bone Involution*, Charles C Thomas, Springfield, IL, 1982.

[4] Kerley, E. R., "Recent Developments in Forensic Anthropology," *Yearbook of Physical Anthropology*, Vol. 21, 1978, pp. 160-173.

[5] Todd, T. W. and Lyon, D. W., "Endocranial Suture Closure, Its Progress and Age Relationship. Part I. Adult Males of White Stock," *American Journal of Physical Anthropology*, Vol. 7, No. 3, 1924, pp. 325-384.

[6] Todd, T. W. and Lyon, D. W., "Cranial Suture Closure, Its Progress and Age Relationship. Part II. Ectocranial Closure in Adult Males of White Stock," *American Journal of Physical Anthropology*, Vol. 8, No. 1, 1925, pp. 23-45.

[7] McKern, T. W. and Stewart, T. W., "Skeletal Age Changes in Young American Males," Technical Report EP-45, U.S. Army Quartermaster Research and Development Center, Environmental Protection Research Division, Natick, MA, 1957.

[8] Gilbert, M. B. and McKern, T. W., "A Method for Aging the Female Os Pubis," *American Journal of Physical Anthropology*, Vol. 38, No. 1, 1973, pp. 31-38.

[9] Kerley, E. R., "Estimation of Skeletal Age: After About Age 30 Years," in *Personal Identification in Mass Disasters*, T. D. Stewart, Ed., National Museum of Natural History, Washington, DC, 1970, pp. 57-70.

[10] Thompson, D. D., "The Core Technique in the Determination of Age at Death in Skeletons," *Journal of Forensic Sciences*, Vol. 24, No. 4, Oct. 1979, pp. 902-915.
[11] Brooks, S. T., "Skeletal Age at Death: The Reliability Cranial and Pubic Age Indicators," *American Journal of Physical Anthropology*, Vol. 13, No. 4, 1955, pp. 567-597.
[12] Todd, T. W., "Age Changes in the Pubic Bone," *American Journal of Physical Anthropology*, Vol. 3, No. 3, 1920, pp. 285-334.
[13] Todd, T. W., "Age Changes in the Pubic Bone," *American Journal of Physical Anthropology*, Vol. 4, No. 1, 1921, pp. 1-70.
[14] Loth, S. R., İşcan, M. Y., and Wright, R. K., "Estimation of Age by Component Analysis of Sternal Rib End Metamorphoses," *American Journal of Physical Anthropology*, Vol. 60, No. 2, 1983, p. 220 (abstract).
[15] Suchey, J. M., "Problems in the Aging of Females Using the Os Pubis," *American Journal of Physical Anthropology*, Vol. 51, No. 3, 1979, pp. 467-470.
[16] Sedlin, E. D., Frost, H. M., and Villanueva, A. R., "Variations in Cross-section Area of Rib Cortex with Age," *Journal of Gerontology*, Vol. 18, 1963, pp. 9-13.
[17] Epker, B. N., Kelin, M., and Frost, H. M., "Magnitude and Location of Cortical Bone Loss in Human Rib with Aging," *Clinical Orthopedics*, Vol. 41, 1965, pp. 198-203.
[18] Semine, A. A. and Damon, A., "Costochondral Ossification and Aging in Five Populations," *Human Biology*, Vol. 47, No. 1, 1975, pp. 101-116.
[19] McCormick, W. F., "Mineralization of the Costal Cartilages as an Indicator of Age: Preliminary Observations," *Journal of Forensic Sciences*, Vol. 25, No. 4, Oct. 1980, pp. 736-741.
[20] Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., and Bent, D. H., *SPSS*, McGraw-Hill, New York, 1975.
[21] Hull, C. H. and Nie, N. H., *SPSS Update 7-9*, McGraw-Hill, New York, 1981.
[22] Ortner, D. J. and Putschar, W. G. J., *Identification of Pathological Conditions in Human Skeletal Remains*. Smithsonian Institution Press, Washington, DC, 1981.
[23] King, J. B., "Calcification of the Costal Cartilages," *British Journal of Radiology*, Vol. 12, 1939, pp. 2-12.
[24] Nishino, K., "Studies on the Human Rib-Cartilage," *Kekkaku*, Vol. 44, 1969, pp. 131-137.
[25] Murray, P. D. F., *Bones: A Study of the Development and Structure of Vertebrate Skeleton*, Cambridge University Press, London, 1936.
[26] Lacroix, P., *The Organization of Bones*, Blakiston, Philadelphia, 1951.
[27] Bourne, G. H., Ed., *The Biochemistry and Physiology of Bone*, Academic Press, New York, 1956.
[28] Frost, H. M., *Bone Remodelling Dynamics*, Charles C Thomas, Springfield, IL, 1963.
[29] Hall, B. K., *Developmental and Cellular Skeletal Biology*, Academic Press, New York, 1978.
[30] Raisz, L. G. and Kream, B. E., "Regulation of Bone Formation, Part 1," *New England Journal of Medicine*, Vol. 309, 1983, pp. 29-35.
[31] Raisz, L. G. and Kream, B. E., "Regulation of Bone Formation, Part 2," *New England Journal of Medicine*, Vol. 309, 1983, pp. 83-89.
[32] Rist, E., Gally, L., and Trocmé, C., "L'Ossification des Cartilages Costaux dans L'Espèce Humain," *Presse Medicale*, Vol. 41, 1928, pp. 641-644.
[33] Riebel, F., "Ossification of the Costal Cartilages: Their Relation to Habitus and Disease," *American Journal Roentgenology and Radium Therapy*, Vol. 21, 1929, pp. 44-47.
[34] Michelson, N., "The Calcification of the First Costal Cartilage Among Whites and Negroes," *Human Biology*, Vol. 6, 1934, pp. 543-557.
[35] Heudtlass, A. P. and Garré, O., "La Calcificación de los Cartílagos Costales en la Evolución de la Tuberculosis Pulmonar," *Prensa Medica Argentina*, Vol. 27, 1940, pp. 365-369.
[36] Fischer, E., "Verkalkungsformen der Rippenknorpel," *Fortschritte auf dem Gebiete der Röntgen Strahlen und der Nuklear Medizin*, Vol. 82, 1955, pp. 474-481.
[37] Lichtenstein, L., *Diseases of Bone and Joints*, C. V. Mosby, St. Louis, 1975.
[38] Falconer, B., "Calcification of Hyaline Cartilage in Man," *Archives of Pathology*, Vol. 26, 1938, pp. 942-955.
[39] Horner, J. L., "Premature Calcification of the Costal Cartilages: Its Frequent Association with Symptoms of Non-organic Origin," *American Journal of Medical Science*, Vol. 218, 1949, pp. 186-193.
[40] Elkeles, A., "Sex Differences in the Calcification of the Costal Cartilages," *American Geriatrics Journal*, Vol. 14, 1966, pp. 456-462.
[41] Navani, S., Shah, J. R., and Levy, P. S., "Determination of Sex by Costal Cartilage Calcification," *American Journal of Roentgenology*, Vol. 108, 1974, pp. 771-774.

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