An Evaluation of the Arcus Corneae For Age Estimation

Boonsak Hanterdsith

ABSTRACT

Although the arcus corneae (AC) has long been used as an age indicator for forensic purposes, its diagnostic value has not been evaluated. To evaluate the AC as a predictor of chronological age, the author has studied the correlation of AC with respect to age of the deceased. A cross-sectional study was conducted of 342 Thai corpses at the Maharat Nakhon Ratchasima Hospital, Thailand. AC was graded into three levels: no AC, incomplete ring, and complete ring. One-way analysis of variance, chi-square test, binomial logistic regression, sensitivity, specificity, predictive values, and likelihood ratios were used for analysis. The Cohen's kappa was used to determine the intraobserver and interobserver reliability. The prevalence of AC and the probability of complete AC were significant higher in corpses aged 60 years and above than in those under 60 years. Consequently, this study confirmed that the prevalence of AC was significantly correlated with the age of Thai individuals. If the complete AC is used as an indicator of age of 60 years and above, complete AC has high sensitivity (92.56%) but low specificity (72.85%), low positive predictive value (65.12%), but high negative predictive value (94.71%). For diagnostic value, the presence of AC can be used for age screening but not for absolute confirmation. The absence of AC indicates young age, incomplete AC indicates middle age, and complete AC indicates old age. The high intraobserver and interobserver reliability provides assurance of the value of AC as a means to estimate personal age. *Acad Forensic Pathol.* 2019 9(3-4): 155-162

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As per Journal Policies, ethical approval was not required for this manuscript

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KEYWORDS

Forensic pathology, Arcus corneae, Age estimation, Postmortem examination, Identification

INFORMATION

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INTRODUCTION

Age estimation of unknown deceased individuals remains a challenge for medicolegal postmortem examination. Several physical appearances are helpful for estimation of age such as skin wrinkling, gray hair, arcus corneae (AC), bone osteophytes, teeth eruption and teeth changes due to age, bone age in children, and skull sutures. The AC can be easily and quickly examined as a part of identification during postmortem examination of a nonskeletalized body and, along with other features, provides useful information for an unknown deceased. Accordingly, previous studies have shown that AC increases with ages in both genders of Caucasians (1-5), Middle East (6), and Indian ethnic groups (7, 8). It is rarely seen in people under 60 years (9) and never seen in people under 20 years (3). However, the prevalence of AC within some ethnic groups varies even in the same region (10-12). There have been few such studies in an Asian population (13). None of the previous studies of the Thai population have used AC for age estimation, and reference data from European countries cannot be used due to racial difference (2, 9, 14-16). To date, there has been no clear diagnostic study of AC as a means to estimate the age of persons. To address this gap in understanding, the author has studied the correlation of AC with respect to the chronological age to evaluate the value of AC for the prediction of chronological age.

MATERIALS AND METHODS

Definition and Terminology

Arcus corneae is an irreversible lipid deposition. It is defined as a gray-white opaque ring, 1 to 1.5 mm wide located near the periphery of the corneae, but separates from the limbus by a clear zone, 0.3 to 1 mm wide (3, 5, 12, 17). However, AC has to be distinguished from a corneal limbus (a dense white ring on the rim of the corneae).

Cardiovascular disease (CVD)-related death is defined as any death from cardiovascular diseases including acute myocardial infarction, coronary heart disease (CHD), cerebrovascular disease, and ruptured aortic aneurysm.

The author conducted a cross-sectional study of randomly selected Thai medicolegal corpses from January 1, 2017, to June 30, 2018, at the Maharat Nakhon Ratchasima Hospital, Thailand. Three hundred forty-two corpses were eligible for the study. Most of the cases were examined within one day of their death. Some cases were kept refrigerated for postmortem examination. A postmortem interval longer than 24 hours, putrefied corpses, cases with eye injury or an eye condition, and unknown cases were excluded from the study. The eyes were carefully examined by visual inspection and documented with photos during the routine postmortem examination under adequate autopsy room light. Arcus corneae was evaluated separately for both eyes and graded into three levels: no AC, incomplete ring (any degree of presentation of AC but not circumferential ring), and complete ring based on its circumferential extension (**Image 1**). To analyze intraobserver reliability and interobserver reliability, the author evaluated AC of the eyes from the taken photos one month after the first examination and the same photos were sent to another doctor, respectively. The corpses were grouped into CVD and non-CVD. The general characteristics of the sample were analyzed with one-way analysis of variance and chi-square test. With regard to AC, gender, and the cause of death, the predicted probability for each age group (under 45 years, 45-59 years, 60 years and above) was analyzed with the binomial logistic regression model. Sensitivity, specificity, predictive values, and likelihood ratios were used for diagnostic analysis. The Cohen's kappa was run to determine the intraobserver and interobserver reliability. The Stata SE version 12.0 was used for statistical analysis. A *p* value of less than 0.05 was considered statistically significant.

RESULTS

All cases included had clear corneae. The general characteristics of corpses are shown in **Table 1**. Age ranged from 7 to 95 years (average: 50.67 years). The prevalence of AC and the probability of complete AC were significantly higher in the corpses aged 60 years compared with those under 60 years (**Table 2**). AC was not seen in corpses aged 33 years and under and some corpses aged above 60 years.

Image 1: The degrees of arcus corneae. **A)** No arcus corneae. **B)** Incomplete arcus corneae: the arcus corneae is presented only on the upper pole of the cornea. **C)** Complete arcus corneae: the arcus corneae is obviously presented as a complete ring on the margin of the cornea.

There was no difference in AC between the right and the left eye. For the incomplete AC group, the crescent-shaped AC was found only on the upper pole or both upper and lower poles of the corneae. It was never found on the medial or lateral pole.

Based on **Table 2**, if the complete AC is used as a diagnostic indicator of age 60 and higher, complete AC has a sensitivity of 92.56%, specificity of 72.85%, a positive predictive value of 65.12%, a negative predictive value of 94.71%, a likelihood ratio positive of 3.41, and a likelihood ratio negative of 0.10. A high

Table 1: General Characteristics of the Study Sample

Characteristic	No AC (n=119)	Incomplete AC (n=51)	Complete AC (n=172)	p-value
Mean age (SD)	29.05 (12.10)	50.69 (8.06)	65.62 (12.42)	<0.001*
Male	98 (82.4%)	42 (82.4%)	121 (70.4%)	0.033†
CVD-related death	4 (3.4%)	9 (17.6%)	40 (23.3%)	<0.001†

AC - Arcus corneae

SD - Standard deviation

* One-way Analysis of variance: There is a statistically significant difference in each pair of AC groups.

† Chi square test

Table 2: The Prevalence and Probability of Arcus Corneae, Gender, and Cause of Death to Age In Decades

Age Group (Years)	Arcus Corneae				Gender		Cause of death	
	No AC (n=119)	Incomplete AC (n=51)	Complete AC (n=172)	Probability of Complete AC	Male (n=261)	Female (n=81)	CVD-related* (n=53)	Non-CVD-related† (n=289)
0-9	2	0	0	0.00	1	2	0	3
10-19	28	0	0	0.00	28	2	0	30
20-29	37	0	0	0.00	30	5	0	35
30-39	26	3	2	0.08	30	6	2	34
40-49	19	18	16	0.34	42	8	6	44
50-59	5	23	42	0.57	57	18	16	59
60-69	2	6	47	0.92	38	15	13	40
70-79	0	1	42	0.98	24	17	11	30
80-89	0	0	20	1.00	10	8	4	14
90-99	0	0	3	1.00	1	0	1	0

AC - Arcus corneae

CVD - Cardiovascular disease

* Acute myocardial infarction and coronary heart disease, 41 cases; cerebrovascular disease, 3 cases; other CVD-related death such as ruptured aortic aneurysm, 9 cases.

† Traffic injury, 106 cases; any cancer, 14 cases; sudden unexplained death syndrome, 11 cases; poisoning, 11 cases; other injuries including hanging and drowning, 60 cases; other natural diseases, 80 cases; other, 7 cases.

negative predictive value and a low likelihood ratio negative indicate that the absence of complete AC is strongly associated with age under 60 years. The Cohen's kappa demonstrated high intraobserver reliability (right eye: kappa = 0.9271; left eye: kappa = 0.9271) and interobserver reliability (right eye: kappa = 0.8440; left eye: kappa = 0.8828).

Figure 1 demonstrates that the higher probability of complete AC corresponds with higher age. **Table 3** demonstrates that male and CVD-related death also correlates with a higher probability for the presentation of AC other than age. For instance, the predicted age for an individual who has no AC, was male, and died of non-CVD related death is below 45 years with the probability of 0.91.

DISCUSSION

This study confirms that, for Thai individuals, the prevalence of AC is significantly correlated with chronological age, but it does not confirm that AC is rarely seen in the age under 60 years (**Tables 2 and 3** and **Figure 1**), unlike the previous mention (9). If AC is negative or incomplete, age being under 60 years has a predictive value of 94.71%. Conversely, if AC is complete, being 60 years or above has a positive predictive value of only 65.12%. The predictive value was only calculated to distinguish between the corpses aged over and under 60 years because 60 years is the threshold for old age in Thailand and many countries in the world. Moreover, our findings strongly contradict the statement that "AC is rarely seen in the age under 60 years." Therefore, this study provides

Figure 1: The logistic regression model for the probability of complete arcus corneae by chronological age.

a screening tool able to distinguish between older and younger persons. This distinction has very useful practical applications. For example, a situation where a distinction has to be made in a double death between two people of different ages (one has complete AC, one has no AC), then AC may be of considerable use. Another situation might be an old age person missing from home. Examination of the AC in any unknown body could readily rule in or rule out the body as relevant to the investigation. However, as AC was graded into three levels, the practical value of AC for age estimation is that the absence of AC indicates young age, incomplete AC indicates middle age, and complete AC indicates old age (**Table 3**). The high intraobserver and interobserver reliability promotes the high value of AC for personal age estimation.

Previous studies have reported associations between AC and several factors other than age, such as high serum lipid levels (5, 11, 13, 16), diabetes mellitus (4, 5, 18), male gender (5, 6, 11), CHD (14, 19), high diastol-

ic blood pressure (negative correlation) (20), high systolic blood pressure (positive correlation) (6), smoking (6, 21), alcohol intake (4), and obesity (negative association) (4). Dyslipidemia was the most common factor to be examined. Although some studies showed that AC was associated with high LDL-cholesterol concentration (5, 14, 21, 22), others showed that AC was not significantly associated with cholesterol level (4, 23, 24). In addition, the factors mentioned above such as CHD and smoking might not be associated with AC (4, 5, 20). In this study, male gender and CVD-related death were significantly related to AC (**Tables 1 and 3**). Therefore, age estimation using AC should be interpreted along with data on gender and cause of death.

In previous studies, the eyes have previously been examined by various methods including naked eyes (1, 5, 10, 11, 15, 16, 19, 21, 25, 26), photography (8, 20), and slit-lamp examination (3, 6, 7, 20, 24). In this study, the author used the naked eye method for easy and prompt examination under adequate room light. A

Table 3: Binomial Logistic Regression of the Highest Predicted Probability For Each Age Group Stratified by Arcus Corneae, Gender, and Cause of Death

Arcus Corneae	Gender	Cause of Death	Age (Years)	Predicted Probability	p-value
No AC (n=119)	Male	CVD-related death	<45	0.72	<0.001
		Non-CVD-related death		0.91	<0.001
	Female	CVD-related death		0.54	0.007
		Non-CVD-related death		0.81	<0.001
Incomplete AC (n=51)	Male	CVD-related death	45-59	0.73	<0.001
		Non-CVD-related death		0.60	<0.001
	Female	CVD-related death		0.70	<0.001
		Non-CVD-related death		0.65	<0.001
Complete AC (n=172)	Male	CVD-related death	>59	0.67	<0.001
		Non-CVD-related death		0.60	<0.001
	Female	CVD-related death		0.77	<0.001
		Non-CVD-related death		0.72	<0.001

AC - Arcus corneae
CVD - Cardiovascular disease

corneal limbus may be misinterpreted as AC; thus, the eye examination had to be done very carefully. The study confirmed that the nature of the AC formation progresses with age initially from the upper and lower poles of the corneae to form a complete ring.

CONCLUSIONS

This paper provides data that show significant correlation between AC and chronological age and provide high sensitivity and high negative predictive value of AC for personal age estimation. However, the diagnostic value of AC should be used for screening of aging only, not for confirmation. AC is a useful indicator of aging. Even a single eye provides a good indication because no difference in presentation of AC was found between the right and the left eyes. In case-work, when an unknown individuals is found dead, the presence of AC is an easy early indicator of age. A scene investigator or doctor could estimate the age of an unknown corpse with a high confidence using this method and trace back the corpse's relatives. In addition, this method is potentially useful as an additional data point for age estimation in the context of a mass disaster in which all deceased are Thai people. Although this data is specific for a Thai population, it provides data for forensic identification for Asian population and can be used as part of a larger data set in future studies.

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