Legal Medicine 17 (2015) 167–171

Contents lists available at ScienceDirect

Legal Medicine

journal homepage: www.elsevier.com/locate/legalmed

Postmortem CT morphometry with a proposal of novel parameters for sex discrimination of the mandible using Japanese adult data

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ARTICLE INFO

Article history:
Received 3 July 2014
Received in revised form 28 November 2014
Accepted 28 December 2014
Available online 3 January 2015

Keywords:
Forensic anthropology
Sex discrimination
Mandible
Skeletal development
Japanese

ABSTRACT

Major human sex differences in the mandible after adolescence include the overall size as well as the shape of the chin and mandibular angle; however, objective interpretation of discrimination accuracy is difficult for these morphological indicators. The present study investigated measurements of the mandible for sex discrimination using postmortem CT morphometry in forensic autopsy cases of Japanese subjects after adolescence (age > 16 years; male, $n = 116$, and female, $n = 106$), including the proposal of novel parameters representing the overall mandibular size and shape. The distance between the gnathion and condylus (gn–cdl), and bigonial width (go–go), as well as the angle formed by bilateral gn–cdl lines (Agn–cdl), correlated with bicondylar breadth (cdl–cdl), independent of the body height, showing no significant sex difference. The distance from the gn to the cdl–cdl line (oblique length), the ratio of Agn–cdl to cdl–cdl, and the oblique triangular area formed by bilateral gn–cdl and cdl–cdl lines (Δobl), which were proposed as indicators of chin protrusion, showed significant sex differences ($p < 0.001$). Overall sensitivity and specificity at respective discriminating points for sex estimation were 0.72 and 0.78 at 105.0 mm for the oblique length, 0.73 and 0.83 at 0.49 for the Agn–cdl to cdl–cdl ratio, and 0.82 and 0.78 at 643 mm^2 for Δobl; the efficacy for females was greater in younger subjects. Although these parameters weakly depended on the body height ($p < 0.0001$), the correlations were insufficient for stature estimation. These findings suggest the efficacy of CT morphometry of the mandible for sex discrimination with quantitative assessment.

1. Introduction

The human mandible presents sex differences in the early stage of life [1,2], but the morphological characteristics vary among ethnic groups, modified by developmental processes involving lifestyle factors, food and skeletal muscle growth, as well as aging in adults [3–7]. Major sex differences in the mandible after adolescence include the overall size as well as the shape of the chin and mandibular angle depending on attached muscle development; however, objective interpretation of the accuracy of discrimination is difficult for these morphological indicators, showing substantial inter- and intraobserver differences [8–12]. Previous studies presented the usefulness of conventional measurements for sex discrimination in different ethnic populations [10,13–20]. Meanwhile, recent advances in forensic imaging including computed tomography (CT) have provided virtual radiographic procedures for skeletal measurement, which can be readily used in cases of various postmortem conditions, including advanced decomposition or severe destruction by fire [21–29]. These investigations suggest that radiographic osteometry will be applicable to sex and stature estimations in forensic identification without mechanical intervention or maceration once relevant radiographic databases have been established. CT morphometry may be particularly useful for the three-dimensional (3-D) analysis of skeletal robusticity involving sex-related differences [25,26,30–33].

From the observations described above, the present study investigated osteometric measurements of the mandible for sex

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http://dx.doi.org/10.1016/j.legalmed.2014.12.009
1344-6223/

discrimination by means of 3-D reconstruction using postmortem CT (PMCT) data in forensic autopsy cases of Japanese subjects after adolescence, and proposed novel parameters representing the overall mandibular robusticity, including the size and shape.

2. Materials and methods

2.1. Postmortem CT data

PMCT scans were routinely performed immediately before forensic autopsy at our institute, employing a scanner (ECLOS, Hitachi Medical Co., Tokyo, Japan; 120 kVp, 200 mA s, 1.25 × 16 mm collimation with a 1.25 mm slice thickness) within the framework of routine casework. From this autopsy database, CT data as well as demographic and physical data of 222 Japanese subjects after adolescence in forensic autopsy cases during August 2010–October 2014 (16–100 years of age; $n = 116$ and $n = 106$ for males and females, respectively) were collected retrospectively (Table 1). Birth year and age distributions are shown in Table 2. Cases with the fracture or destruction of the mandible were excluded.

2.2. Virtual measurement

Using a CT data analysis system, Volume Analyzer SYNAPSE VINCENT (FUJIFILM Medical Co., Ltd., Tokyo, Japan), a 3-D image of the mandible was reconstructed for virtual measurement of the distance between the gnathion and condylus (gn–cdl), bicondylar breadth (cdl–cdl), bigonial width (go–go), and the angle formed by bilateral gn–cdl lines (Agn–cdl), as well as the distance from the gn to the cdl–cdl line (oblique length), the ratio of Agn–cdl to cdl–cdl, and the oblique triangular area formed by bilateral gn–cdl and cdl–cdl lines (Δobl), which represent the protrusion of the chin as mandibular development (Fig. 1a and b). These virtual analyses were performed by a forensic dentist, two forensic pathologists and two radiological technicians. These measurements were performed twice to examine the reproducibility and calculate mean values for analysis with regard to the individual sex and stature (body height measured at autopsy). The data analyses were approved by our institutional ethics committee as part of our research project.

Table 1
Case profile and measurements.

Parameter	Male (M)/ female (F)	Range	Mean	Median
Age (years)	M	16–91	59	61
	F	18–100	61	64
Height (cm)	M	146–183	165	165
	F	134–171	154	154
Bicondylar breadth (cdl–cdl; mm)	M	113.1–141.9	128.4	128.9
	F	105.1–137.0	121.7	121.9
Bigonial width (go–go; mm)	M	72.1–117.2	102.9	104.1
	F	83.9–111.5	95.8	95.8
The distance between the gnathion and condylus (gn–cdl; mm)	M	113.8–136.0	125.2	124.9
	F	102.0–136.0	117.4	117.1
Angle formed by bilateral gn–cdl lines (Agn–cdls; degrees	M	54.9–67.9	61.5	61.8
	F	54.5–71.5	62.3	62.1
Mandibular angle (ago; degrees)	M	108.4–142.1	126.0	125.5
	F	116.2–149.6	129.8	130.2

Table 2
Birth year and age distribution.

	Range	Total ($n = 222$)		Male ($n = 116$)		Female ($n = 106$)	
		n	%	n	%	n	%
Birth year	1910–1929	27	12.3	8	7.0	19	18.1
	1930–1949	85	38.6	47	40.9	38	36.2
	1950–1969	69	31.4	44	38.3	25	23.8
	1970–1989	37	16.8	14	12.2	23	21.9
	1989–1995	4	1.8	3	2.6	1	1.0
Age at death	16–29	12	5.5	4	3.5	8	7.6
	30–49	54	24.5	29	25.2	25	23.8
	50–69	82	37.3	53	46.1	29	27.6
	70–89	68	30.9	29	25.2	39	37.1
	90–100	6	2.7	1	0.9	5	4.8

2.3. Statistical analyses

Regression equation analysis was used to study the relationships between pairs of parameters. Comparisons between individual groups were performed using the nonparametric Mann–Whitney U-test. These analyses were performed using Microsoft Excel, Statview (version 5.0, SAS Institute Inc., Cary). A p-value of <0.05 was considered statistically significant. In Fig. 3, the results of data analysis are shown as box-plots, for which 50% of the data are included in the box. The line in each box represents the median, and the lines outside each box represent the 90% confidence interval.

The sensitivity and specificity in distinguishing two groups using cut-off values were estimated by receiver-operating characteristics (ROC) analysis [34]. The cut-off value was determined by the Youden index, defined as maximum (sensitivity + specificity − 1). The areas under the curves were calculated and analyzed by one-tailed t test. The optimal compromise between sensitivity and specificity was determined graphically. The predictive value for sex estimation was calculated, dividing the number of cases above and below the cut-off values by the total number of cases in males and in females.

3. Results

Fluctuation in two independent trials and interobserver deviation were within 4.8% for each measurement. The measurements of the gn–cdl and go–go as well as Agn–cdl correlated with cdl–cdl ($r = 0.47$–0.62, $p < 0.001$). These parameters were independent of body height and showed slight sex differences (insignificant; Table 1). The oblique length, Agn–cdl to cdl–cdl ratio and Δobl slightly depended on body height; the correlation efficiencies were as follows: oblique length, $r = 0.38$, $p < 0.0001$ for males and $r = 0.29$, $p < 0.0001$ for females; Agn–cdl to cdl–cdl ratio, $r = -0.40$, $p < 0.0001$ for males and $r = -0.32$, $p < 0.0001$ for females; and Δobl, $r = 0.38$, $p < 0.0001$ for males and $r = 0.35$, $p < 0.0001$ for females (Fig. 2a–c). No age dependence was detected for each parameter on regression equation analysis; however, significant differences were detected between subjects of <60 and >60 years of age for the oblique length and Agn–cdl to cdl–cdl ratio ($p < 0.05$ and < 0.01, respectively) in Mann–Whitney U test.

These parameters showed significant differences between the sexes ($p < 0.001$; Fig. 3a–c). Using ROC analysis, the sensitivity and specificity at respective discriminating points for sex estimation were 0.72 and 0.78 at 105.0 mm for the oblique length, 0.73 and 0.83 at 0.49 for the Agn–cdl to cdl–cdl ratio, and 0.82 and 0.78 at 643 mm^2 for Δobl in all cases. The predictive values of sex estimation using the above-mentioned discriminating points were: 72.4% for males and 79.2% for females for the oblique length, 74.1% for males and 83.0% for females for the Agn–cdl to cdl–cdl ratio, and 81.9% for males and 78.3% for females for Δobl.