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นิพนธ์ต้นฉบับ

การระบุเพศด้วยการใช้ภาพเอกซเรย์คอมพิวเตอร์ระบบ 3 มิติ ของกะโหลกศีรษะในคนไทย

Sex Identification By Using 3D Computerized Tomography Image of skull in Thai

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ศราวุฒิ สุจริตธรรม พ.บ.
กลุ่มงานนิติเวชคลินิก กองนิติวิทยาศาสตร์บริการ สถาบันนิติวิทยาศาสตร์ กรุงเทพฯ ประเทศไทย 10210

Abstract

Objective : To determine the criteria for sex identification from Thai's skeleton by 3D computerized tomography skull imaging.

Method : Study 100 samples of 3D computed tomography skull image taken by Aquilion Lightning (16-row helical CT system). The samples were categorized into those of male and female, 50 each, and collected during 2017-2018 from autopsy process. Each skull was measured at 18 different positions by using Vitrea program (Vital Images, Inc.). The discriminant function analysis was used to calculate the equation for sex identification of each variable, while the leave-one-out cross-validation method was used to calculate the percentage accuracy of sex identification.

Result : The discriminant function analysis indicated that the single variable (br-mas) resulted in the average percentage accuracy of sex identification at 84% and that the multiple variables (br-mas and rhi-in) resulted in the average percentage accuracy of sex identification at 88% (original) and 87% (cross-validation). Consequently, the equation for discriminant function was -32.013+0.115(br-mas) + 0.85(rhi-in) with cutting point = 0.

Conclusion : The result shows the potential of using 3D computerized tomography imaging in forensic anthropology. The data, hence, should be categorized for further study of larger population and the further study of standard for bone measurement and standardized scanning protocol should be conducted for the purpose of more convenient data collection and future research.

Keywords : skull, forensic anthropology, discriminant analysis, computed tomography image

บทคัดย่อ

วัตถุประสงค์ : เพื่อหาหลักเกณฑ์เพื่อใช้ในการระบุเพศของโครงกระดูกคนไทยโดยการใช้ภาพถ่ายรังสีระบบ 3 มิติของกะโหลกศีรษะ

วัสดุและวิธีการศึกษา : ศึกษาจากภาพถ่ายรังสีจากเครื่องเอกซเรย์คอมพิวเตอร์ระบบ 3 มิติ จากเครื่อง Aquilion Lightning (16-row helical CT system) ของกะโหลกศีรษะ จำนวนทั้งหมด 100 ตัวอย่าง แบ่งออกเป็นเพศหญิงและเพศชายอย่างละ 50 ตัวอย่าง ย้อนหลังในช่วงปี พ.ศ 2560 ถึง พ.ศ.2561 ที่เกิดขึ้นจากกระบวนงานผ่าชันสูตรศพ ทำการวัดตำแหน่งของกะโหลกศีรษะจำนวนทั้งหมด 18 ตำแหน่ง โดยใช้โปรแกรม Vitrea (Vital Images, Inc.) วิเคราะห์ข้อมูลด้วยสถิติ discriminant function analysis เพื่อคำนวณหาสมการในการระบุเพศของแต่ตัวแปรในการวัด จากนั้นทำการหาร้อยละความแม่นยำในการระบุเพศของสมการโดยใช้วิธี Leave-one-out cross-validation

ผลการศึกษา : จากสถิติ discriminant analysis พบว่ากลุ่มตัวแปรการวัดตัวแปรเดียว br-mas มีค่าเฉลี่ยของความแม่นยำในการทำนายเพศร้อยละ 84 และจากการทดสอบด้วยการใช้ตัวแปรหลายตัวแปรพบว่า การใช้ตัวแปร br-mas ร่วมกับ rhi-in เพียงสองตัวแปร จะให้ความแม่นยำในการทำนายเพศสูงสุดถึงร้อยละ 88(original) และร้อยละ 87 (cross-validation) ซึ่งสามารถสร้างสมการ discriminant function ได้คือ

-32.013+0.115(br-mas) + 0.85(rhi-in) โดยมีค่า cutting point = 0

สรุป : จากผลการวิจัยแสดงให้เห็นถึงศักยภาพในการนำข้อมูลภาพ 3D Computerized Tomography Image มาใช้ในงานนิติมานุษยวิทยา ในอนาคตควรมีการจัดหมวดหมู่ของข้อมูลเพื่อการศึกษาในกลุ่มประชากรที่ใหญ่ขึ้น ทำการศึกษาเพิ่มเติมในการกำหนดมาตรฐานของการวัดของกระดูกแต่ละตำแหน่งรวมถึงมาตรฐานข้อกำหนดของเทคนิคการใช้เครื่อง CT (standardized scanning protocol) เพื่อให้การเก็บข้อมูลมีความสะดวกและเหมาะสมต่อการศึกษาวิจัยในอนาคต

คำสำคัญ : กะโหลกศีรษะ, นิติมานุษยวิทยา, สถิติวิเคราะห์จำแนกกลุ่ม, ภาพเอกซเรย์คอมพิวเตอร์

INTRODUCTION

Body identification is a task of Central Institute of Forensic Science to identify the body of deceased and return to their family. Furthermore, it is prescribed in Section 154 of Criminal Procedure Code that the official performing the autopsy shall identify the deceased, and sex identification is one of the person identification processes. Generally in case of complete body, the sex can be identified by reproductive organ. In case of incomplete body with only skeleton or skull left, however, it is required to examine the characteristics of the remaining skeleton or bones in order to identify the sex.

The characteristics of male and female bone are different due to the level of testosterone(1) which is the hormone helping develop the physical characteristics. Therefore, the male bone structure is different from female one at many position, especially the skull which can be well used to sex identification. It is found that male bones are bigger than female ones. Some studies were conducted which concluded that the sex can be identified by bone measurement.(2, 3)

Nowadays the computed tomography scan is used in forensic field(4, 5) to analyze the cause of death without undertaking autopsy in some case, as well as in forensic anthropology for sex identification from the bone by indicating the position for measurement. Thus, for the most efficient usage of computed tomography scanner of Central Institute of Forensic Science and for setting an example for other Thai forensic medical agencies, it is necessary to determine the criteria in order to use such tool for the accurate body identification.

METHOD

Calculate sample size by using quantifying the precision of a discrimination(6) and setting 100 sample, 50 for male and 50 for female. Select 3D computed tomography skull image taken by Aquilion Lightning, 16-row helical CT system (120 kVp, 150 mAs, 0.5 mm. slice thickness) during 2017-2018 from autopsy process. The sample criteria were that the deceased must be over 18 years old at the time of death without any irregularity, break or deformation of skull. Measure the skull from 18 different positions (Table1 and Figures 1-3) by using Vitrea version 4.1.52 (Vital Images, Inc.). (Figure 4) Bony landmarks and abbreviation of each measurement are originally from Rooppakhun S, et al.(7) and Cordeiro BA, et al.(8)

The collected data was analyzed by SPSS version 19 (SPSS Inc., Chicago, IL, USA) and the selected statistics were descriptive statistics for finding standard deviations of each measured position, t-test analysis for comparing the average of male and female measurement, discriminant function analysis for calculating the equation used for sex identification of each variable, and cross validation (Leave-one-out) method for calculating percentage accuracy of sex identification

RESULT

The descriptive statistics (Table2) used to find the mean and standard deviations of each variable indicated that the male average was higher than female one, while the t-test analysis indicated that the average of each variable was significantly different at every position ($p<0.05$).

The discriminant analysis (Table 3) indicated that the Wilk'lamda value of every variable was significantly different at every position ($p<0.05$). The most accurate value for female sex prediction was br-mas (90% for original and cross-validation) while br-mas and rhi-in were the most accurate values for male sex prediction (both 78% for original and cross-validation) and the most accurate value for both male and female sex prediction was br-mas (84% for original and cross-validation). Consequently, the equation for discriminant function was -27.655+0.179(br-mas) with cutting point = 0.

The sex prediction with 2 variables indicated that if br-mas and rhi-in were used together, the highest accuracy value for both male and female sex prediction was 84% for original and 87% for cross-validation. Consequently, the equation for discriminant function was -32.013+0.115(br-mas) + 0.85(rhi-in) with cutting point = 0. The sex prediction with 3-5 variables indicated that the sex prediction was not more accurate (Table 4). Finally, the sex prediction with 18 variables indicated that the equation was 93% accurate for original but only 85% accurate for cross-validation (Table 4).

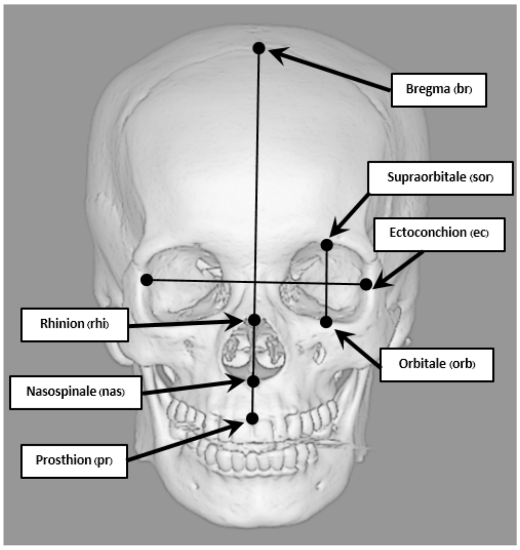

Figure 1 Showing anterior measurement landmark

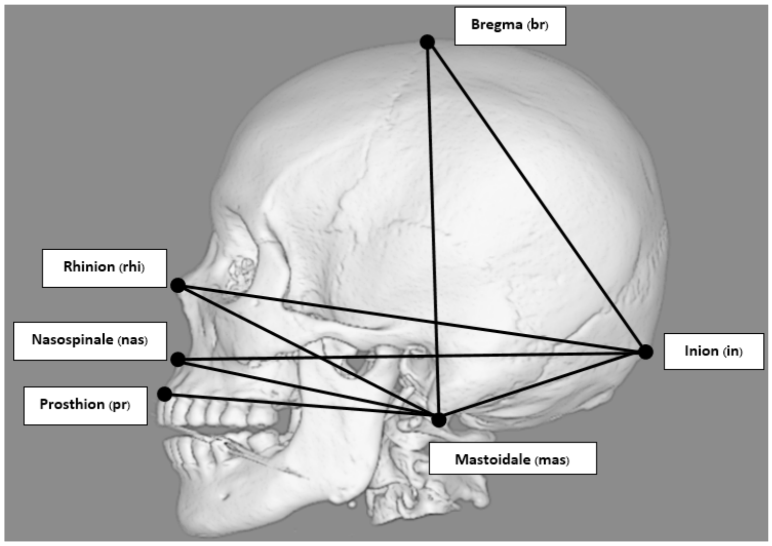

Figure 2 Showing lateral measurement landmark

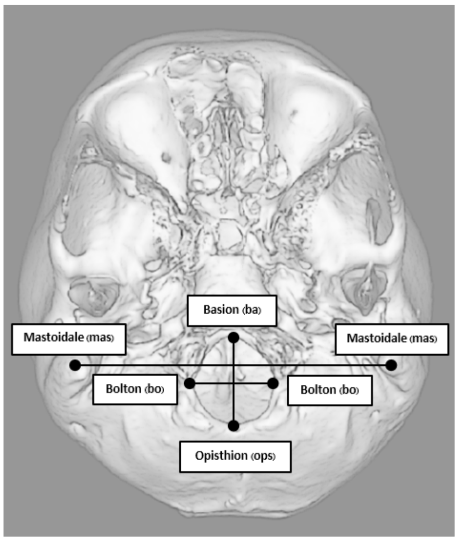

Figure 3 Showing inferior measurement landmark

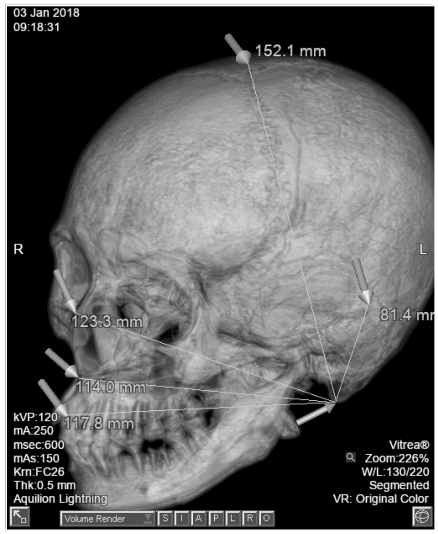

Figure 4 Showing digital caliper by using Vitrea

DISCUSSION

The sex identification of the body is an important process in autopsy. General it is easy with complete body but it turns more difficult with incomplete or partial body and sometimes only partial head is left. Therefore, the skull can be well used to identify sex, following pelvic bone(9)by morphological assessment which requires the skill and expertise of the assessor. The simpler method is morphometric analysis of skull. In some previous researches, the researchers determined the criteria for sex identification by measuring dried skull with caliper.(10, 11) However, the limitation of such researches was that there are only few agencies in Thailand preserving many skulls with systematic registration. The CT scanner has been recently used at Central Institute of Forensic Science in autopsy to identify the cause of death and the author think that the 3D computed tomography imaging can apply to forensic anthropology.

Studying to determine the criteria for sex identification from Thai's skeleton by 3D computed tomography skull imaging, the t-test analysis with 18 variables indicated the significant sexual dimorphism ($p<0.05$) while the discriminant analysis indicated that the single variable (br-mas) resulted in the average percentage accuracy of sex identification at 84% and that the multiple variables (br-mas and rhi-in) resulted in the average percentage accuracy of sex identification at 88% (original) and 87% (cross-validation). Consequently, the equation for discriminant function was -32.013+0.115(br-mas) + 0.85(rhi-in) with cutting point = 0. This research showed that using more than 2 variables in the equation did not affect the accuracy of sex prediction but increased time spent on measurement. Furthermore, the sex prediction with 18 variables indicated that the equation was 85% accurate for cross-validation, which was less accurate than the prediction using br-mas and rhi-in together resulting in 87% accuracy (cross-validation). When comparing with the result of the previous research(12-15)conducted by Kajanoja(12)studying the skull of Finnish population, the accuracy of sex prediction was 80%, while the research conducted by Deshmukh and Devershi(13)indicated the accuracy at 87.84%, the research conducted by Franklin et al.(14) studying the skull of South African population indicated the accuracy at 80%. and the research conducted by Saini et al.(15)indicated the accuracy at 85.5%. Therefore, the mentioned equation can be used for sex prediction.

Generally 3D computed tomography imaging is used for medical diagnosis(16)or engineering(17)and it has been recently used in forensic anthropology.(18, 19)The result of this study shows the potential of 3D computed tomography imaging in forensic anthropology for the purpose of research and sex prediction from bone. The database is in digital file (DICOM) and the dried bone is no longer required for analysis, resulting in no large space required for preservation. Accordingly, the author has the opinion that if the bone data is properly collected and categorized, it can be useful for future research.

CONCLUSION

The result shows the potential of using 3D computerized tomography imaging in forensic anthropology. The data, hence, should be categorized for further study of larger population and the further study of standard for bone measurement and standardized scanning protocol should be conducted for the purpose of more convenient data collection and future research.

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Table 1 Description of each skull measurement and abbreviation

No.	Measurement	Abbr.	No.	Measurement	Abbr.
1	The distance from Bregma to Rhinion	br-rhi	10	The distance from Bregma to Inion	br-in
2	The distance from Bregma to Nasospinale	br-nas	11	The distance from left Mastoidale to Inion	mas-in
3	The distance from Bregma to Prosthion	br-pr	12	The distance from Rhinion to left Mastoidale	rhi-mas
4	The distance from Rhinion to Nasospinale	rhi-nas	13	The distance from Nasospinale to left Mastoidale	nas-mas
5	The distance from Rhinion to Prosthion	rhi-pr	14	The distance from Prosthion to left Mastoidale	pr-mas
6	The distance from Supraorbitale to Orbitale	sor-orb	15	The distance from Bregma to left Mastoidale	br-mas
7	The distance from left and right Ectoconchion	ec-ec	16	The distance from left and right Mastoidale	mas-mas
8	The distance from Rhinion to Inion	rhi-in	17	The distance from Basion to Opisthion	ba-ops
9	The distance from Nasospinale to Inion	nas-in	18	The distance from left and right Bolton	bo-bo

Table 2 Descriptive statistics and t-test of each skull measurement in females and males

Variables	Female (N=50)		Male (N=50)		t	p-value
	Mean (mm.)	SD	Mean (mm.)	SD		
br-rhi	130.4700	4.23885	136.0020	5.96659	-5.345	0.000
br-nas	152.8860	3.95227	159.8540	5.83642	-6.990	0.000
br-pr	168.5200	5.57633	174.3340	6.78175	-4.682	0.000
rhi-nas	29.0560	2.36817	32.1580	2.81230	-5.966	0.000
rhi-pr	44.7020	3.91374	46.9760	3.92925	-2.899	0.005
sor-orb	34.3220	1.85641	35.8000	2.26184	-3.572	0.001
ec-ec	94.8080	3.73133	99.0000	4.33204	-5.184	0.000
rhi-in	163.0480	6.13954	173.7860	7.37843	-7.910	0.000
nas-in	159.6620	7.04910	169.9760	7.50501	-7.083	0.000
br-in	145.3500	6.46984	152.3340	6.40273	-5.425	0.000
mas-in	83.8940	6.21514	90.8540	6.09249	-5.655	0.000
rhi-mas	118.0440	4.19193	125.9120	5.07606	-8.451	0.000
nas-mas	110.3100	3.60296	115.9460	4.00949	-7.393	0.000
pr-mas	114.7220	4.82977	119.6360	5.02706	-4.984	0.000
br-mas	150.1540	4.59797	159.4820	6.44508	-8.331	0.000
mas-mas	102.1040	4.22248	107.6620	4.35299	-6.481	0.000
ba-ops	33.1560	1.82401	35.3440	2.31492	-5.250	0.000
bo-bo	28.3260	1.87571	29.7440	2.19686	-3.471	0.001

Table 3 Wilk's lamda and accuracy of classification for the univariate discriminant function analysis

Variables	Wilk's lamda (* = p<0.05)	Discriminant function (cutting point= 0)	Predicted group membership for original (%)		Predicted group membership for cross-validation (%)		Average accuracy for original (%)	Average accuracy for cross-validation (%)
			Female	Male	Female	Male		
br-mas	0.585*	-27.655+0.179(br-mas)	90	78	90	78	84	84
rhi-in	0.610*	-24.814+0.147(rhi-in)	82	78	80	78	80	79
rhi-mas	0.578*	-26.203+0.215(rhi-mas)	84	72	84	72	78	78
ba-ops	0.781*	-16.435+0.480(ba-ops)	80	72	80	72	76	76
br-nas	0.667*	-31.373+0.201(br-nas)	82	68	82	68	75	75
nas-in	0.661*	-22.638+0.137(nas-in)	78	74	76	74	76	75
mas-mas	0.700*	-24.458+0.233(mas-mas)	76	74	76	74	75	75
mas-in	0.754*	-14.198+0.162(mas-in)	76	72	76	72	74	74
rhi-nas	0.734*	-11.773+0.385(rhi-nas)	78	68	76	68	73	72
ec-ec	0.785*	-23.969+0.247(ec-ec)	76	66	76	66	71	71
nas-mas	0.642*	-29.680+0.262(nas-mas)	68	76	66	76	72	71
br-in	0.769*	-23.125+0.155(br-in)	72	68	72	68	70	70
br-rhi	0.774*	-25.744+0.193(br-rhi)	70	68	70	68	69	69
br-pr	0.817*	-27.612+0.161(br-pr)	68	64	68	64	66	66
sor-orb	0.885*	-16.945+0.483(sor-orb)	66	64	66	64	65	65
pr-mas	0.798*	-23.771+0.203(pr-mas)	64	66	64	66	65	65
rhi-pr	0.921*	-11.689+0.255(rhi-pr)	64	64	64	64	64	64
bo-bo	0.891*	-14.215+0.49(bo-bo)	70	56	70	56	63	63

Table 4 Wilk's lamda and accuracy of classification for the multivariate discriminant function analysis

Variables	Wilk's lamda (* = p<0.05)	Discriminant function (cutting point= 0)	Predicted group membership for original (%)		Predicted group membership for cross-validation (%)		Average accuracy for original (%)	Average accuracy for cross-validation (%)
			Female	Male	Female	Male		
br-mas/rhi-in	0.500*	-32.013+0.115(br-mas) + 0.85(rhi-in)	92	84	92	82	88	87
br-mas/rhi-in/rhi-mas	0.482*	-32.861+0.93(br-mas)+0.54(rhi-in)+0.77(rhi-mas)	90	84	90	82	87	86
4 variables	0.454*		90	84	90	80	87	85
5 variables	0.454*		90	84	90	78	87	84
All variables	0.333*		96	90	94	76	93	85