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Research Paper

Analyzing Morphometrics of Sella Turcica, Foramen Magnum and Mastoid Processes Using Head and Neck Computed Tomography for Sex Determination in Egyptian Adults

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ABSTRACT

Background: Recognition of unknown individuals is an essential element in forensics. This study aims to analyze the morphometrics of the sella turcica, foramen magnum (FM), and mastoid process in adult sex determination. In addition, to identify from the previously mentioned parts which is the most efficient single parameter in adult sex determination. In addition, we look forward to correlating the significant efficacy of the previously mentioned parts in sex determination using two or all of them together compared to using one bony part alone.

Methods: In this cross-sectional study, 60 Egyptian adults (30 men and 30 women) with multislice computed tomography (MSCT) bone window scans of the head and neck obtained for different purposes were included to obtain cranial measurements of the sella turcica, FM, and mastoid triangle area.

Results: The Sella turcica anterior-posterior (A-P) diameter of the adult male cases had a Mean±SD of 14.015±2.15 mm compared to 12.851±1.904 mm among adult female cases. The mean maximum FM width (FMW) of men was 32.183±2.126 mm, while that of women was 30.169±2.530 mm. The men's FM area (FMA) had a Mean±SD of 885.606±124.665 mm^2; In women, the Mean±SD were 784.179±140.997 mm^2. The mastoid triangle area's Mean±SD were 778.559±87.218 mm^2 among men compared to a mean of 645.215±88.733 mm^2 among women.

Conclusion: This study determined that sella turcica A-P diameter, mastoid area, FMW, FMA, the maximum length of the right and left occipital condyle (LROC), and length of the left occipital condyle (LLOC) showed significantly higher measures in adult Egyptian males. The best single parameter determining the adult sex was the mastoid triangle area with a cut-off level of 647.22 mm^2. The sella turcica A-P diameter, LLOC, and mastoid triangle area represent the best combination of all measured parameters for determining sex in adults. A predictive formula was performed using the best combination in adult cases with an accuracy of 87% in sex determination.

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Introduction

The identification of unknown individuals is a crucial milestone in forensic medicine. Each unknown should be identified according to sex, age, and race [1].

The skull basicranium is the main component used for identification. It resists the destructive effects of inhumation and body mutilation, and its location at the skull base supports this strength. In addition, the thickness and amount of soft tissue covering it provide additional protection [2].

Multislice computed tomography (MSCT) provides information that is usually consistent with cranial measurements detected using a caliper [3].

Sella turcica, from Latin for "Turkish saddle", can be used to determine skull morphological characteristics. It is located in the middle cranial fossa. It also projects to the inner aspect of the sphenoid bone [4].

The foramen magnum (FM) is a hole within the skull connecting the base of the skull to the neck. Several crucial nerves and vessels pass through the FM, which has been suggested to be relied upon in individuals' identification [5].

The mastoid process is conical in shape. It is a projection of the temporal bone that lies posterior to the external auditory meatus. It is preferred for sex determination because it is not frequently subjected to damage and is protected by its location [6].

Only a few research projects have studied the dimensions of Sella turcica, FM, and mastoid process among Egyptians. In addition, no studies in the literature have compared these aspects regarding the efficacy of sex determination.

This study aims to analyze the morphometrics of Sella turcica, FM, and the mastoid process in sex determination in adults. Also, it also aims to identify the most efficient single parameter in adult sex determination from the previously mentioned parts.

Materials and Methods

This was a cross-sectional study conducted in the Radiology Department Ain Shams University Hospitals, on 60 adult Egyptian patients aged >18, divided into 30 men and 30 women.

Inclusion criteria

The inclusion criteria included Egyptian adults with MSCT bone window scans of the head and neck obtained for different purposes and high-quality reconstructed images free from any pathological abnormalities that may cause skull deformities.

Exclusion criteria

The exclusion criteria included unclear images with artifacts, non-Egyptian adults, cases younger than 18 years old, and images of participants who had previous head trauma, surgery, or other pathologic anomalies that may cause cranial deformity.

Imaging

All MSCT examinations were performed using an optimum computed tomography (CT) 660 64-slice CT scanner (General Electric [GE] healthcare company]). The technique for performing MSCT of the head is volumetric helical acquisition. Measurements were taken from axial plane cuts, the multiplanar resolution (multiplanar reformatted [MPR]) images, and three-dimensional (3D) volume-rendered images using "RadiAnt DICOM Viewer software version 2020.2 (Jul 19, 2020). Two radiologists with at least ten years of clinical experience performed all measurements while completely blinded to the subjects' ages and sex. Inter-observer variability was evaluated, and the average value of the two measurements was obtained.

Measurements

A. Cranial measurements (mm) of the sella turcica

1. Sella turcica length: Measured by a line extending from tuberculum sellae (TS) to dorsum sellae.

2. Sella turcica depth: The distance from the deepest point of the sella turcica and extending with the sella turcica length.

3. Anterior-posterior (A-P) diameter: Line between TS and the most posterior point of the inner aspect of the posterior wall of the pituitary fossa (Figure 1).

B. Cranial measurements (mm) of FM

1. The maximum FM length (FML): Determined anteroposteriorly across the main axis of the FM in the mid-sagittal plane.

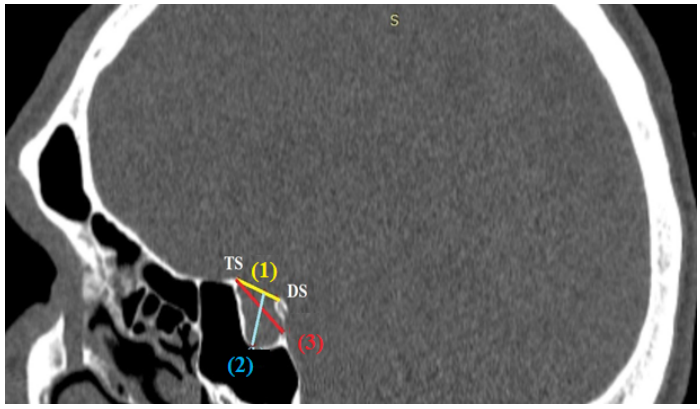


Figure 1. Measurements of the sella turcica; 1) Length, 2) Depth, 3) Antero-posterior dimension

DS: Diaphragma sellae; TS: Tuberculum sellae.

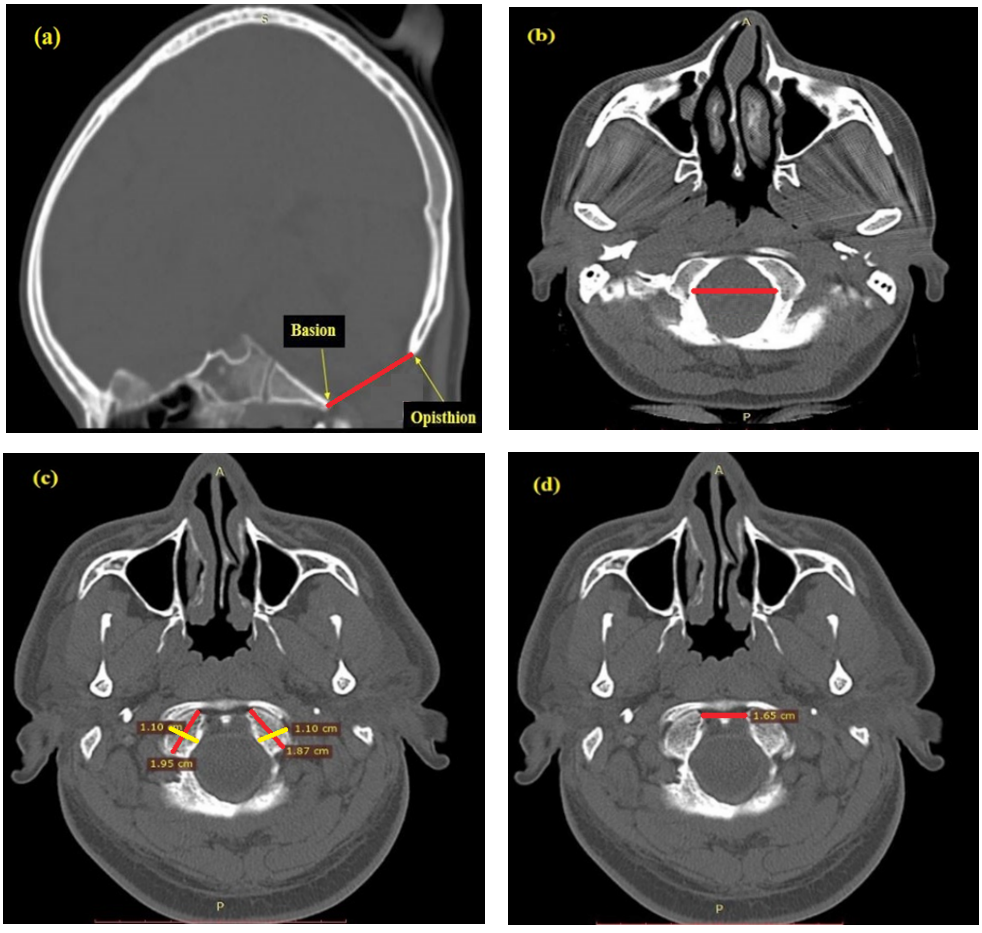


Figure 2. CT scan images of FM showing the studied parameters in bone window

a) The length of FM in midsagittal plane, b) The width of FM in axial plane, c) The length (red line) and width (yellow line) of occipital condyles on both sides in axial plane, d) The minimum intercondylar distance

CT scan: Computed tomography scan; FM: Foramen magnum.

2. The maximum FM width (FMW): The largest horizontal measurement of the FM in the axial plane.

3. The FM area (FMA): Measured in millimeters square (mm^2), calculated using Radinsky's formula: $(1/4) \times \pi \times FMW \times FML$ [7].

4. The maximum length of the right occipital condyle (LROC): Determined with the line from the edges of the articular surface.

5. The maximum length of the left occipital condyle (LLOC): Determined with the line from the edges of the articular surface.

6. The maximum width of the right occipital condyle (WROC): Determined with a line lies perpendicularly from articular edges.

7. The maximum width of the left occipital condyle (WLOC): Determined with a line lies perpendicularly from articular edges.

8. The minimum intercondylar distance (MID): Direct line that extends between the most medial points of the two occipital condyles (Figure 2).

C. Cranial measurements (mm) of right and left mastoid processes using three craniometrical landmarks

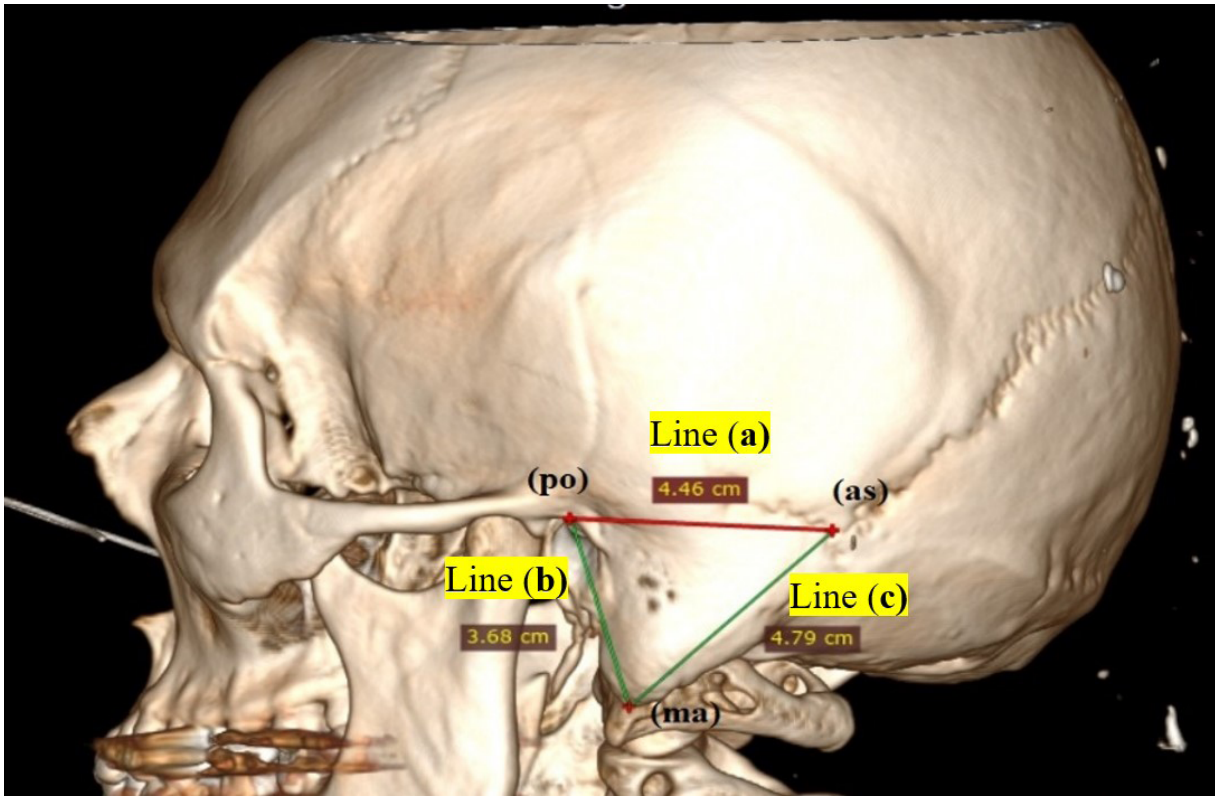
1. Porion (po): The peak of the center of the marginal part of the external auditory meatus.

2. Mastoidale (ma): The deepest part of the mastoid process.

3. Asterion (as): The intersecting point of the lambdoid, occipitomastoid and parietomastoid sutures.

We then measured the lengths of the lines between the three craniometric landmarks in the right and left mastoid processes (Figure 3).

The mean lengths of the three lines of right and left mastoid processes were subjected to "Heron's formula" to estimate the mastoid triangle area (Equation 1) [8]:



International Journal of
Medical Toxicology & Forensic Medicine

Figure 3. Measurement of the mastoid triangle area using the three craniometrical Landmarks in 3D volume-rendered images: Porion (po), asterion (as) and mastoidale (ma)

Line (a): Between po and as, Line (b): Between po and ma, Line (c): Between ma and as.

1. Area (m^2) = $\sqrt{}$ s (s - a) (s - b) (s - c)

"s" is half the perimeter, or (a + b + c) / 2.

Sample size

The required sample was determined based on PASS® version 11 program by reviewing previous study results [9]. Sixty patients were included in the study.

Data management

The collected data was updated, encoded, and structured for statistical analysis using SPSS software, version 24.

In addition, the Jamovi desktop software, version 2.3.21, was used to perform logistic regression to determine the parameter that best-predicted sex in each studied group. An Excel computer program was used to tabulate and graphically represent the results.

Results

Table 1 summarizes the age distribution and cranial measurements of both sexes. Using the student's t-test, the only studied parameters that showed a statistically significant ($P<0.05$) difference between men and women are the mean of sella turcica anterior-posterior (A-P) diameter, FMW, FMA, LROC, LLOC, and the mastoid triangle area.

As shown in Table 2, the best single parameter measured in the current study to determine the sex of adult cases was the mastoid triangle area. The best combination of the measured parameters for determining sex in adults is the A-P diameter of the sella turcica, LLOC, and mastoid triangle area.

Table 3 presents two logistic regression Equations "a" and "b" for predicting sex based on the significant parameters measured in the study group.

Equation "a" is a logistic regression analysis applied to predict sex using the parameters that showed a significant statistical difference between males and females by t-test.

Equation "b" is a logistic regression analysis applied to predict sex using the parameters that showed the best combination for determining sex.

In both equations, male is predicted if the "X" value of the equation is equal to or greater than the cut-off level, and female if it is less than the cut-off level.

Table 4 and Figure 4 show the cut-off values. The cut-off level for equation Ib in adult cases was 0.471, with the highest accuracy of 87%.

Discussion

This study revealed that Sella turcica A-P diameter was significantly higher among men. Consistent with the present study, studies conducted among Egyptian patients and Eastern Asian populations found that the A-P diameter and width were significantly different between men and women [10, 11]. In contrast, Turamanlar et al. reported no significant difference in depth or A-P diameter in 101 Turkish patients aged 17-70. In contrast, the sella turcica length showed significant differences between both sexes [12].

In addition, we found that men showed significantly higher measures of FMW, FMA, LROC, and LLOC than women. Several studies agreed that FMA and FMW are the only significantly different parameters between men and women [13-16]. In addition, Madadin et al. found that FML was significantly higher among Egyptian men in their study than among women [17]. Similarly, FML, FMW, and FMA were significantly higher among British men [18]. Based on the results of Darwish et al., the increased measures of FM in male skulls compared to female skulls are explained by the fact that the principal neurovascular bundles, which include "the cervical spinal cord, vertebral arteries, nerves, and meninges flowing through the skull base", are larger in men than in women [19]. Previous studies have reported that all measurements of the occipital condyle are significantly greater in men [2, 20-22].

However, in contrast to this study, other research concluded that no significant difference was observed between men and women regarding FML and FMW [23, 24]. The early maturation and fusion of FM compared to other skeletal elements may explain why there was not as much difference in FM length and width between men and women. This means that there was not much response to secondary sexual changes [20]. Furthermore, biomechanical mechanisms associated with loading stresses may affect the manifestation of dimorphic characteristics of the occipital condyle [18].

Regarding the measures of the mastoid process, we found that the area was significantly higher among men

Table 1. Student's t-test comparing men and women regarding age and cranial measurements

Variables	Sex		t	P
	Male (n=30)	Female (n=30)		
Age	45.467±15.03	41.033±14.782	1.152	0.254
Sella turcica length (mm)	10.933±1.956	10.138±2.011	1.552	0.126
Sella turcica depth (mm)	8.459±1.865	8.244±1.701	0.467	0.642
Sella turcica A-P diameter (mm)	14.015±2.150	12.851±1.904	2.221	0.030*
FML (mm)	34.972±3.563	32.983±4.258	1.962	0.055
FMW (mm)	32.183±2.126	30.169±2.530	3.339	0.001*
FMA (mm^2)	885.606±124.665	784.179±140.997	2.952	0.005*
LROC (mm)	20.22±2.583	18.851±2.119	2.244	0.029*
LLOC (mm)	20.008±2.535	17.831±3.049	3.008	0.004*
WROC (mm)	9.610±1.532	9.408±1.912	0.452	0.653
WLOC (mm)	9.493±1.512	8.98±1.346	1.388	0.171
MID (mm)	13.225±2.49	12.977±2.232	0.406	0.686
Mastoid triangle area (mm^2)	778.559±87.218	645.215±88.733	5.870	<0.001*

International Journal of Medical Toxicology & Forensic Medicine

Abbreviations: A-P: Anterior-posterior; FMW: Foramen magnum width; FMA: Foramen magnum area; LROC: Length of the right occipital condyle; LLOC: Length of left occipital condyle; FML: Foramen magnum length; WROC: Width of the right occipital condyle; WLOC: Width of the left occipital condyle; MID: Minimum intercondylar distance.

*Significant (P<0.05).

than among women. This was consistent with the results of Helmy et al., who concluded that the mastoid triangle area was helpful for the identification of unknown skulls [25]. Moreover, this was consistent with several studies among Asian and European populations, where significant differences were found between sexes in the mastoid triangle area [17, 26-29]. In contrast, Galdames et al. indicated that the determination of sex based on this dimension yielded low accuracy when estimating the female sex, hence being less useful in practice [30]. Men have a larger mastoid process due to stronger muscular activity of the following muscles: Sternocleidomastoid, posterior belly of the digastric, splenius capitis, and longissimus capitis muscles [31]. Moreover, there is variability in the growth patterns of mastoid cells, which creates a hollow inner aspect of the mastoid process [32].

Using univariate logistic regression analysis, the best single parameter measured in the current study for determining the sex of adult patients was the mastoid triangle area. Using multivariate logistic regression analysis, we found that the best combination of the measured parameters for determining sex in adults was the A-P diameter of the sella turcica, LLOC, and mastoid triangle area.

To the best of our knowledge, no study has discussed the best combination for determining the sex of adults by comparing the three bony parts used in our study: Sella turcica, FM, and mastoid process.

Some researchers have developed formulas that may be used to determine the sex of the skull according to the anatomy of the occipital bone and FM. The most prevalent approach is Fisher's approach [33-35].

Amores-Ampuero and Alemán found that basicranium's discriminant analysis accuracy was 78.2%, while the percentages were higher with logistic regression analysis (85.7% for basicranium) [36].

Table 2. Univariate and multivariate logistic regression for the cranial measurements

Parameters	Univariate Logistic Regression				Multivariate Logistic Regression		
	Estimate	SE	P	Rank	Estimate	SE	P
Sella length (mm)	0.208	0.137	0.129		-0.4344	0.353	0.219
Sella depth (mm)	0.07	0.148	0.636		-0.0600	0.373	0.872
Sella turcica A-P diameter (mm)	0.292	0.14	0.037*	4	0.7652	0.214	0.043*
FML (mm)	0.139	0.075	0.065		0.0816	0.159	0.608
FMW (mm)	0.373	0.129	0.004*	5	0.2048	0.209	0.327
FMA (mm^2)	0.285	0128	0.042*	3	0.5871	0.298	0.788
LROC (mm)	0.977	0.252	0.033*	6	-0.0395	0.230	0.863
LLOC (mm)	0.282	0.111	0.008*	2	0.7107	0.260	0.006*
WROC (mm)	0.07	0.154	0.648		0.4810	0.294	0.102
WLOC (mm)	0.263	0.193	0.174		-0.7712	0.400	0.054
MID (mm)	0.046	0.111	0.68		-0.0845	0.238	0.723
Mastoid triangle area (mm^2)	0.248	0.117	<0.001*	1	1.6054	0.486	<0.001*

International Journal of
Medical Toxicology & Forensic Medicine

Abbreviations: A-P: Anterior-posterior; FMW: Foramen magnum width; FMA: Foramen magnum area; LROC: Length of the right occipital condyle; LLOC: Length of left occipital condyle; FML: Foramen magnum length; WROC: Width of the right occipital condyle; WLOC: Width of the left occipital condyle; MID: Minimum intercondylar distance; SE: Standard error.

*Significant (P<0.05).

In this study, we concluded that if the result of measured parameters was equal to or greater than the cut-off level, it indicated that the sex was male, and if it was less than the cut-off level, it indicated that the sex was female. The cut-off level for the mastoid triangle area in adult cases was 647.22 mm^2, with an accuracy of 81.67%; the cut-off level of equation a was 0.499 with an accuracy of 85%; and equation b showed the highest accuracy in sex determination with an accuracy of 87% and a cut-off level of 0.471.

Close to this study, the study of Helmy et al. in an Egyptian population reported that the cut-off level of the mastoid triangle area in adult cases was 641 mm^2, with an accuracy of 67.4% [25]. Bhayya et al. concluded that, the mastoid process was a good indicator for sex determination in adults with an accuracy of 82% [37].

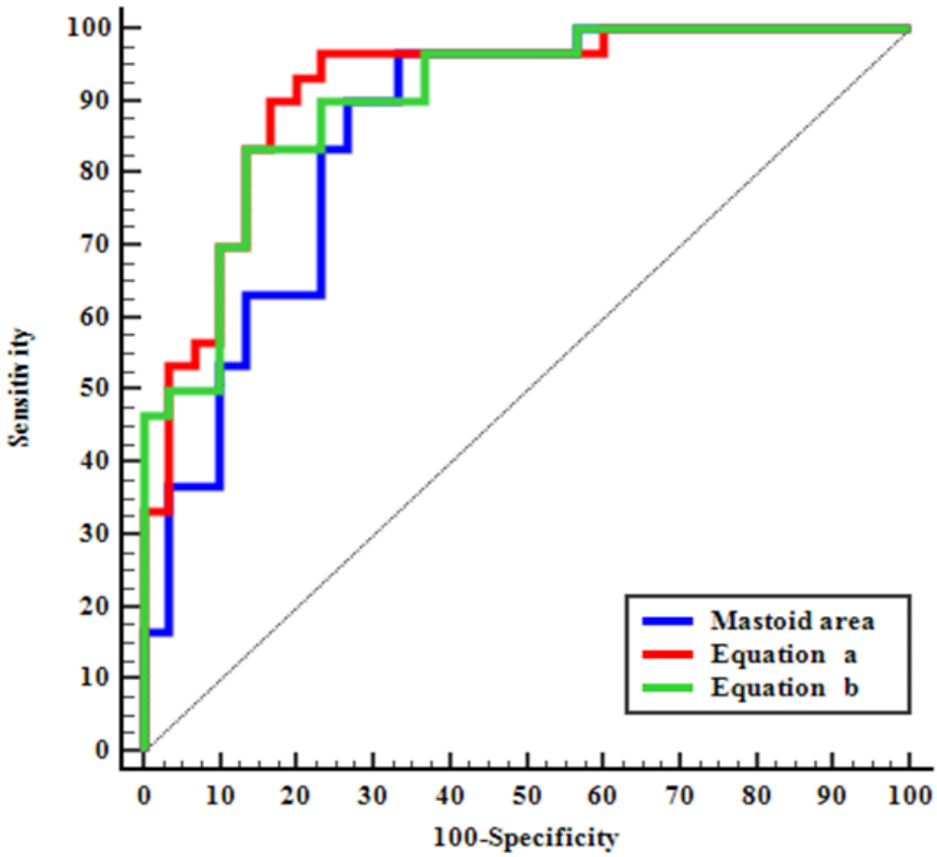
Table 3. Multivariate logistic regression equation predicting sex from the studied cranial measurements

Equations	Predictive Formula	P	Cut-off Level
a	X=((0.057×Sella turcica A-P diameter)+(0.233×FMW)–(0.001×FMA)+(0.467×LLOC)–(0.016×LROC)+(0.02×Mastoid triangle area)–30.385))	<0.001*	0.499
b	X=((0.1×A-P diameter)+(0.483 × LLOC)+(0.022×Mastoid triangle area)–26.117))	<0.001*	0.471

International Journal of
Medical Toxicology & Forensic Medicine

Abbreviations: A-P: Anterior-posterior; FMW: Foramen magnum width; FMA: Foramen magnum area; LROC: Length of the right occipital condyle; LLOC: Length of the left occipital condyle.

*Significant (P<0.05); If X ≥ cut off value, sex is male; If X < cut off value, sex is female.



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Medical Toxicology & Forensic Medicine

Figure 4. ROC curve of the mastoid triangle area, equation a, and equation b for predicting men from women in adult cases

ROC curve: Receiver operating characteristic curve.

However, Ominde and Igbigbi reported that FMW was the best sex-discriminating variable, with an accuracy of 64.3% compared to other FM parameters in an adult Nigerian sample [13].

The accuracy of sex determination is directly proportional to the number of variables [38]. The main strength of this study is that we investigated the most reliable sexually dimorphic parameters of the sella turcica, FM, and mastoid processes. In addition, we applied logistic

Table 4. ROC curve comparing between the best single parameter and the significant logistic regression equations in determining the sex

Parameter	Cut-off	%				
		Sensitivity	Specificity	PPV	NPV	Accuracy
The mastoid triangle area (mm^2)	647.22	96.67	66.67	74.4	95.2	81.67
Equation a	0.499	86.67	83.33	71.9	85.1	85
Equation b	0.471	83.33	86.37	86.21	83.87	87

International Journal of
Medical Toxicology & Forensic Medicine

Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value; ROC curve: Receiver operating characteristic curve.

regression analysis since it is an objective technique to select the least number of traits and the maximum discriminatory effectiveness for estimating sexual dimorphism from skull morphometric measurements [39]. We identified the cut-off level of the most efficient parameter when used alone and the significant logistic regression equations that were obtained for predicting sex. Further research is needed to define more accurate equations based on detected significant cranial measurements.

Conclusion

This study determined that the sella turcica A-P diameter, mastoid area, FMW, FMA, LROC, and LLOC were significantly higher in Egyptian men. The mastoid area is the most significant parameter for differentiation between men and women, with a cut-off level of 647.22 mm^2. The A-p diameter of the sella turcica, LLOC, and mastoid area represented the best combination of all measured parameters for determining the adult sex. We detected two equations where men are predicted if the "X" value of the equation is equal to or greater than the cut-off level and women if it is less than the cut-off level.

Limitations

The study was conducted on a relatively small sample of 60 adult Egyptians, which may restrict the findings' applicability to a larger population, including different ethnic groups and age ranges. A larger and more diverse sample may yield more complete results.

This study focused only on measuring the relationship between the measured parameters and sex determination without addressing the relationship between age and stature. Further research considering these aspects is recommended.

Ethical Considerations

Compliance with ethical guidelines

The Research Ethics Committee of Ain Shams University, Cairo, Egypt approved the study (Code: FWA 000017585, FMASU M D 127/2021). After the importance of the study was explained to patients or their caregivers, informed written consent was obtained from all patients or their caregivers.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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References

[1] Raikar NA, Meundi MA, David CM, Rao MD, Jogigowda SC. Sexual dimorphism in foramen magnum dimensions in the South Indian population: A digital submentovertex radiographic study. Journal of Forensic Dental Sciences. 2016; 8(3):180. [DOI:10.4103/0975-1475.195104] [PMID]

[2] Abo El-Atta HM, Abdel-Rahman RH, El-Hawary G, Abo El-Al-Atta HM. Sexual dimorphism of foramen magnum: An Egyptian study. Egyptian Journal of Forensic Sciences. 2020; 10(1):1-12. [DOI:10.1186/s41935-019-0167-x]

[3] Zheng J, Ni S, Wang Y, Zhang B, Teng Y, Jiang S. Sex determination of Han adults in Northeast China using cone beam computer tomography. Forensic Science International. 2018; 289:450.e1-450.e7. [DOI:10.1016/j.forsciint.2018.05.036] [PMID]

[4] Yasa Y, Bayrakdar IS, Ocak A, Duman SB, Dedeoglu N. Evaluation of sella turcica shape and dimensions in cleft subjects using cone-beam computed tomography. Medical Principles and Practice. 2017; 26(3):280-5. [DOI:10.1159/000453526] [PMID]

[5] Moodley M, Rennie C, Lazarus L, Satyapal K. The morphometry and morphology of the foramen magnum in age and sex determination within the South African Black population utilizing Computer Tomography (CT) Scans. International Journal of Morphology. 2019; 37(1):251-7. [DOI:10.4067/S0717-95022019000100251]

[6] Chaudhary RK, Mahajan A, Piplani M, Khurana BS. Determination of sex from mastoid dimensions among North Indians. Medico-legal Update. 2019; 19(1):65-9. [DOI:10.5958/0974-1283.2019.00014.8]

[7] Radinsky L. Relative brain size: A new measure. Science. 1967; 155(3764):836-8. [DOI:10.1126/science.155.3764.836] [PMID]

[8] Kendig K. Is a 2000-Year-Old Formula Still Keeping Some Secrets? The American Mathematical Monthly. 2000; 107(5):402-15. [DOI:10.1080/00029890.2000.12005213]

[9] Kumar NP, Priyanka EN, Ganesh R, Sushmitha R. Morphometric analysis of foramen magnum using helical computed tomogrophy for gender determination. World Journal of Ad-

vanced Research and Reviews. 2020; 8(3):1-6. [DOI:10.30574/wjarr.2020.8.3.0439]

[10] Abd El Rahman HA, Hussein MM, Khedr DKM. Metric analysis of sella turcica for sex identification using multidetector computed tomography in a sample of adult Egyptians. Mansoura Journal of Forensic Medicine and Clinical Toxicology. 2023; 31(1):75-93. [DOI:10.21608/mjfmct.2023.176705.1057]

[11] Chou ST, Chen CM, Chen PH, Chen YK, Chen SC, Tseng YC. Morphology of sella turcica and bridging prevalence correlated with sex and craniofacial skeletal pattern in Eastern Asia population: CBCT study. BioMed Research International. 2021; 2021:6646406. [DOI:10.1155/2021/6646406] [PMID]

[12] Turamanlar O, Öztürk K, Horata E, Acay MB. Morphometric assessment of sella turcica using CT scan. Anatomy: International Journal of Experimental & Clinical Anatomy. 2017; 11(1):6-11. [Link]

[13] Ominde BS, Ikubor JE, Iju WJ, Ebeye A, Igbigbi PS. Morphometry of the maxillary sinus and its role in sex determination in Delta State Nigeria: Retrospective CT study. Journal of Indian Academy of Forensic Medicine. 2023; 45(1):52-7. [DOI:10.48165/jiafm.2023.45.1.15]

[14] Verma P, Gupta N, Sameera Y, Faraz SA, Sharma P, Sharma B. Foramen magnum as determinant of sexual dimorphism in Sri Ganganagar population: A radiographic study. Journal of Indian Academy of Oral Medicine and Radiology. 2021; 33(1):71-6. [DOI:10.4103/jiaomr.jiaomr_205_20]

[15] Aghakhani K, Kazemzadeh N, Ghafurian F, Soltani B, Soltani S. Gender determination using diagnostic values of foramen magnum. International Journal of Medical Toxicology and Forensic Medicine. 2016; 6(1):29-35. [Link]

[16] Meral O, Belkıs Toklu B, Meydan R, Kaya A, Karadayı B, Acar T. Sex estimation from foramen magnum parameters in adult Turkish population: A computed tomography study. Legal Medicine. 2020; 47:101775. [DOI:10.1016/j.legalmed.2020.101775] [PMID]

[17] Madadin M, Menezes RG, Al Saif HS, Abu Alola H, Al Muhanna A, Gullenpet AH, et al. Morphometric evaluation of the foramen magnum for sex determination: A study from Saudi Arabia. Journal of Forensic and Legal Medicine. 2017; 46:66-71. [DOI:10.1016/j.jflm.2017.01.001] [PMID]

[18] Gapert R, Black S, Last J. Sex determination from the foramen magnum: discriminant function analysis in an eighteenth and nineteenth century British sample. International Journal of Legal Medicine. 2008; 123(1):25-33. [DOI:10.1007/s00414-008-0256-0] [PMID]

[19] Darwish R, Salama N, Elsirafy M, Kholeif W. Identification of sex from foramen magnum of Egyptian skulls using three dimensional computed tomography. Ain Shams Journal of Forensic Medicine and Clinical Toxicology. 2014; 22(1):74-86. [DOI:10.21608/ajfm.2014.19158]

[20] Aljarrah K, Packirisamy V, Al Anazi N, Nayak SB. Morphometric analysis of foramen magnum and occipital condyle using CT images for sex determination in a Saudi Arabian population. Morphologie. 2022; 106(355):260-70. [DOI:10.1016/j.morpho.2021.07.006] [PMID]

[21] Chovalopoulou ME, Bertsatos A. Estimating sex of modern Greeks based on the foramen magnum region. Journal of Anthropology. 2017; 2017:1-7. [DOI:10.1155/2017/9129801]

[22] Rai H, Keluskar V, Patil S, Bagewadi A. Accuracy of measurements of foramen magnum and occipital condyle as an indicator for sex determination using computed tomography. Indian Journal of Health Sciences and Biomedical Research KLEU. 2017; 10(1):80-3. [DOI:10.4103/2349-5006.198595]

[23] Gruber P, Henneberg M, Böni T, Rühli FJ. Variability of human foramen magnum size.Anatomical record. 2009; 292(11):1713-9. [DOI:10.1002/ar.21005] [PMID]

[24] Loyal P, Ongeti K, Pulei A, Mandela P, Ogeng'o J. Gender related patterns in the shape and dimensions of the foramen magnum in an adult Kenyan population. Anatomy Journal of Africa. 2013; 2(2):138-41. [Link]

[25] Helmy M, Elbeshbeshi M, Gadelhak B. Sex determination by metric assessment of mastoid triangle using multidetector computed tomography: Egyptian study. Mansoura Journal of Forensic Medicine and Clinical Toxicology. 2021; 29(1):51-62. [DOI:10.21608/mjfmct.2020.40708.1023]

[26] Ibrahim A, Alias A, Shafie MS, Das S, Nor FM. Osteometric estimation of sex from mastoid triangle in Malaysian population. Asian Journal of Pharmaceutical and Clinical Research. 2018; 11(7):303-7. [DOI:10.22159/ajpcr.2018.v11i7.25986]

[27] Jaja BN, Ajua CO, Didia BC. Mastoid triangle for sex determination in adult n igerian population: A validation study. Journal of Forensic Sciences. 2013; 58(6):1575-8. [DOI:10.1111/1556-4029.12299] [PMID]

[28] Kiran M, Shetty M, Shetty SS, Shetty V. Morphometric sex estimation using mastoid triangle: A prospective study. Journal of Indian Academy of Forensic Medicine. 2021; 43(2):108-13. [DOI:10.5958/0974-0848.2021.00029.4]

[29] Toneva DH, Nikolova SY, Zlatareva DK, Hadjidekov VG, Lazarov NE. Sex estimation by Mastoid Triangle using 3D models. Homo. 2019; 70(1):63-73. [DOI:10.1127/homo/2019/1010] [PMID]

[30] Galdames ICS, Matamala DAZ, Smith RL. Sex determination using mastoid process measurements in Brazilian skulls. International Journal of Morphology. 2008; 26(4):941-4. [DOI:10.4067/S0717-95022008000400025]

[31] Rogers TL. Determining the sex of human remains through cranial morphology. Journal of Forensic Sciences. 2005; 50(3):493-500. [DOI:10.1520/JFS2003385] [PMID]

[32] Petaros A, Sholts SB, Slaus M, Bosnar A, Wärmländer SK. Evaluating sexual dimorphism in the human mastoid process: A viewpoint on the methodology. Clinical Anatomy. 2015; 28(5):593-601. [DOI:10.1002/ca.22545] [PMID]

[33] Burdan F, Dworzanska A, Dworzanski W, Klepacz R, Cendrowska-Pinkosz M, Halasa J, et al. Foramen magnum-new and old anthropological data. Global Journal of Anthropology Research. 2014; 1(1):25-34. [DOI:10.15379/2410-2806.2014.01.01.05]

[34] Uysal S, Gokharman D, Kacar M, Tuncbilek I, Kosar U. Estimation of sex by 3D CT measurements of the foramen magnum. Journal of Forensic Sciences. 2005; 50(6):1310-4. [DOI:10.1520/JFS2005058] [PMID]

[35] Wescott DJ, Moore-Jansen PH. Metric variation in the human occipital bone: Forensic anthropological applications. Journal of Forensic Sciences. 2001; 46(5):1159-63. [DOI:10.1520/JFS15115J] [PMID]

[36] Amores-Ampuero A, Alemán I. Comparison of cranial sex determination by discriminant analysis and logistic regression. Anthropologischer Anzeiger; Bericht uber die biologisch-anthropologische Literatur. 2016; 73(3):207-14. [DOI:10.1127/anthranz/2016/0604] [PMID]

[37] Bhayya H, Tejasvi A, Jayalakshmi B, Reddy MM. Craniometric assessment of gender using mastoid process. Journal of Indian Academy of Oral Medicine and Radiology. 2018; 30(1):52-7. [DOI:10.4103/jiaomr.jiaomr_127_17]

[38] Ramamoorthy B, Pai MM, Prabhu LV, Muralimanju BV, Rai R. Assessment of craniometric traits in South Indian dry skulls for sex determination. Journal of Forensic and Legal Medicine. 2016; 37:8-14. [DOI:10.1016/j.jflm.2015.10.001] [PMID]

[39] Ekizoglu O, Hocaoglu E, Inci E, Can IO, Solmaz D, Aksoy S, et al. Assessment of sex in a modern Turkish population using cranial anthropometric parameters. Legal Medicine. 2016; 21:45-52. [DOI:10.1016/j.legalmed.2016.06.001] [PMID]