Original article

Sex Identification Using Frontal Sinus Dimensions among Egyptians Attending Suez Canal University Hospital

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ABSTRACT

Background: Sex identification is an important step in the identification of unknown human remains; the frontal sinuses are significant in forensic identification due to its irregular shape. Study **aim***:* Getting accurate method for sex identification among Egyptian population through frontal sinus dimensions using CT. **Subjects and Methods***:* cross-sectional descriptive study, using 172 unidentified Para nasal CT images from diagnostic radiology department of Suez Canal University Hospital in Ismailia. CT images from patients aged from 21 to 50 years were divided into two groups. Group I included86 Para-nasal CT images of known sex in which males and females were equally included. Group II included86 Para-nasal CT images in not known to which sex is the researcher. Comparison and correlation tests were done to detect the variables with high statistical significance in sexual dimorphism between two sexes; these highly statistically significant variables were used to develop binary logistic regression formula for sex identification.**Results:**4 variables showed highest significance and correlation, which were Right sinus width (RW), Maximum total width (MW), Maximum total height (MH) and Right anterior posterior length (RL). Binary logistical regression formula showed overall accuracy of 73.2 %. **Conclusion:** CT analysis of frontal sinuses measurements provides a valid and reasonable method for sex identification.

KEYWORD: Frontal sinuses measurements, Computed tomography, Sex determination, Logistic regression analysis.

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I. INTRODUCTION

Identification of human remains is considered one of the most essential aspects of forensic medicine. Not only for its humanitarian value but also for the completion and certification of official documents such as death certificates. In mass disaster management, identification of human remains is often a crucial issue(Wiersema, 2016).

Sex identification is more reliable if the complete skeleton is available for analysis but in most forensic cases human skeletal remains are often incomplete or damaged. That's why forensic anthropologists are concerned with means to determine sex from isolated fragmentary remains especially when criminals mutilate their victims in attempt to make their identification difficult and also in mass disasters(Benghiac et al., 2017).

Numerous techniques of sex identification have been proposed, based either on visual assessment or recording of linear metric variables(Kahana and Hiss, 1997).

The skull has long been recognized as the second most sexually dimorphic bone after the pelvis. When only skull remains are available and other ways of identification fails, radiographs of frontal sinuses may be useful (Avelar et al., 2017).

Skull is composed of hard tissue and is the best-preserved part of skeleton after death; hence in many cases it is the only available part for forensic examination(Nuzolese, 2018).

Frontal sinuses morphology is unique to everyone and can be used in person identification. The frontal sinuses is one of the most significant tool in forensic identification due to its irregular shape and because of the individual characteristics which makes the frontal bone unique for every individual, just as fingerprints (Belaldavaret al.,2014).

The CT images-based method offers highly accurate anatomical models, which make examinations less time-consuming, virtual manipulation of the bone easier and without previous preparation or alteration to material studied(Krishan et al.,2016).

Computerized tomography scans of the sinuses have replaced X-ray radiographs in routineradiological diagnosis. In

French medical guidelines, there is no more indication for using X-ray radiographs for the diagnosis of sinus pathology (Michel et al., 2015).

The present study aims to determine the accuracy of using of the frontal sinuses' measurements by 2d CT in sex determination using Logistic regression analysis.

II. MATERIALS AND METHODS

It's a descriptive cross-sectional study which was carried out to measure the accuracy of sex identification using computerized tomography (CT) on frontal sinus among volunteered patients using unidentified Para-nasal CT images from the diagnostic radiology department of Suez Canal University Hospital in Ismailia.

II.1. Sample size:

Sample size was calculated according to the following equation (3):

$$n = 1+2C \quad \frac{s^2}{d^2}$$

Where:C=7.85 when power is 80% and α error = 0.05. S:The standard deviation of the antero-posterior length of left frontal sinus, one of the measured parameters; which equals 5.23.d:Is the expected difference between means of antero-posterior length of left frontal sinus between males and females; which equals 2.35.So, the calculated sample size according to the equation (n)was 78 persons per group and the expected drop out of 10% was added. Therefore, (n) was 86 persons per group. The total sample size was 172 para-nasal CT images from patients aged from 21 to 50 years. The collection of the study individuals started in January 2018 till the completion of the calculated sample size.

II.2. Studied groups:

Group I (Original group): included 86 Para-nasal CT images of the original group (known sex); divided into group 1a (males) and group 1b (females).Regression formula was derived from this group to estimate the participants' sex.Males and females were equally included in the original sample.

Group II (Test group): included 86 Para-nasal CT images of the test group; in which the sex was not known to the researcher (single-blind method).The

pre-derived regression formula was applied on this group to test its accuracy in sex prediction.

Individuals who accepted to participate in the study and signed a written informed consent where included in the study. All individuals with any signs of sinus pathology, surgery, congenital anomalies, fractures or head trauma were excluded from the study. Also, patients who refused to participate were excluded from the study.

Regarding the original group, (9) variables were measured as shown in figure (1),figure (2) and figure (3) which were: Right sinus width (RW), left sinus width (LW), maximum total width (MW), right sinus height (RH), left sinus height (LH), maximum total height (MH), right anterior posterior length (RL), left anterior posterior length (LL) and frontal sinus index (FSI).

Right sinus width, left sinus width and maximum total width, were performed on a coronal plane. Right sinus height, left sinus height and maximum total height were performed on a coronal plane.

The highest (H) and the lowest point (L) of the frontal sinus were marked and the maximum total height (MH) was obtained by uniting them. Right sinus depth and left sinus depth were performed on axial plane. The most right point (R) and the most left point (L) of the frontal sinus were marked and the maximum total width (MW) was obtained by uniting them.

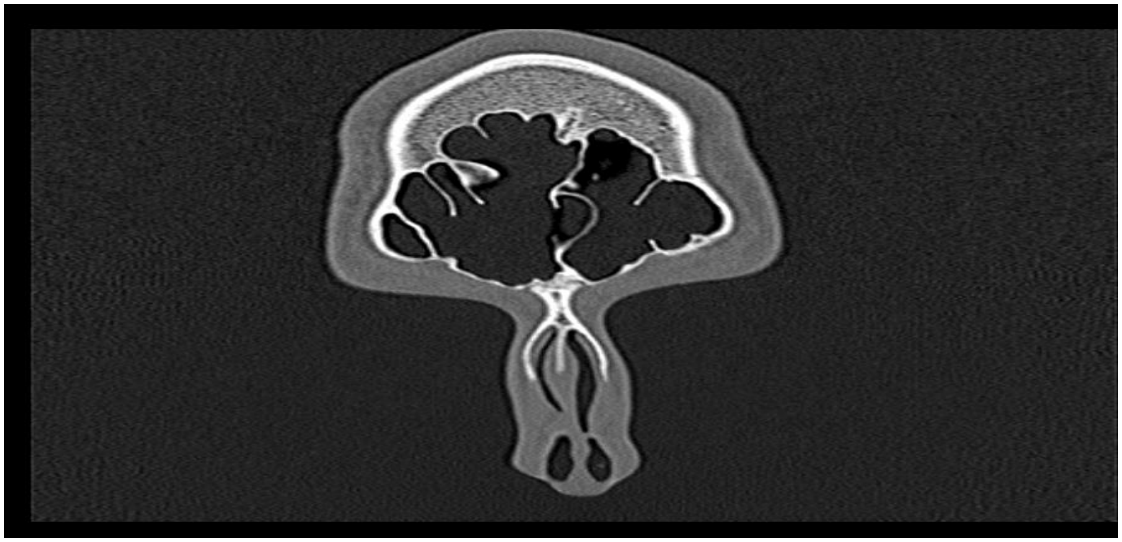
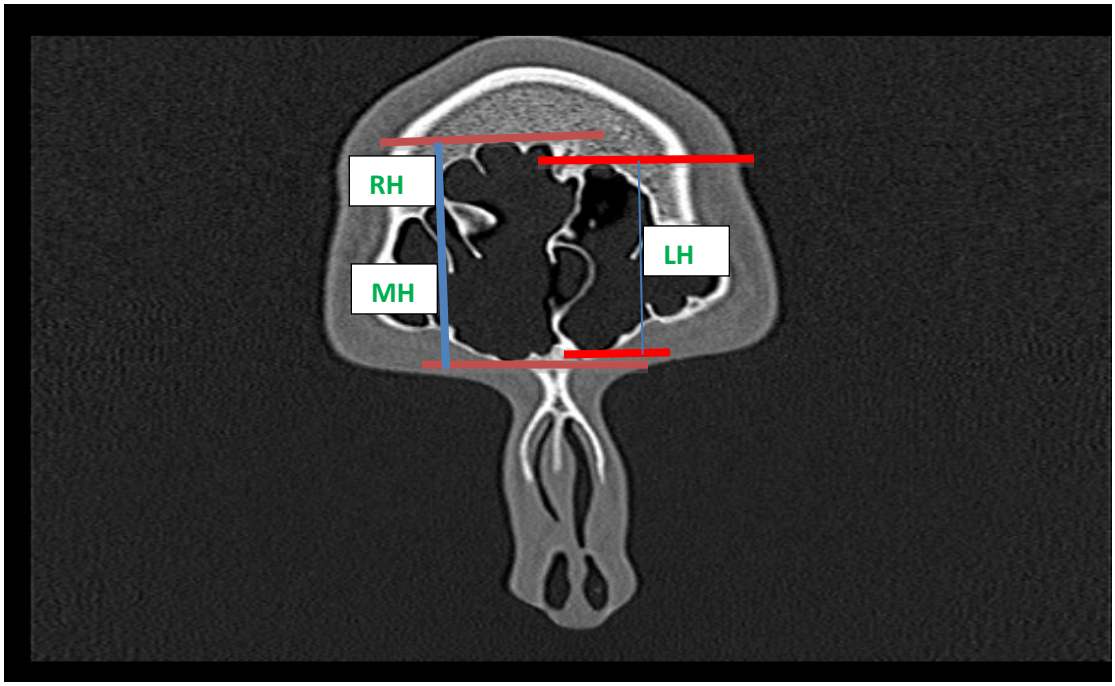


Figure (1): CT of male frontal sinuses (coronal view) showing right sinus width (RW), left sinus width (LW) and maximum total width (MW) "Quoted from work station"



Figure(2):CT of female frontal sinuses (coronal view) showing right sinus height (RH), left sinus height (LH) and maximum total height (MH) "Quoted from work station"

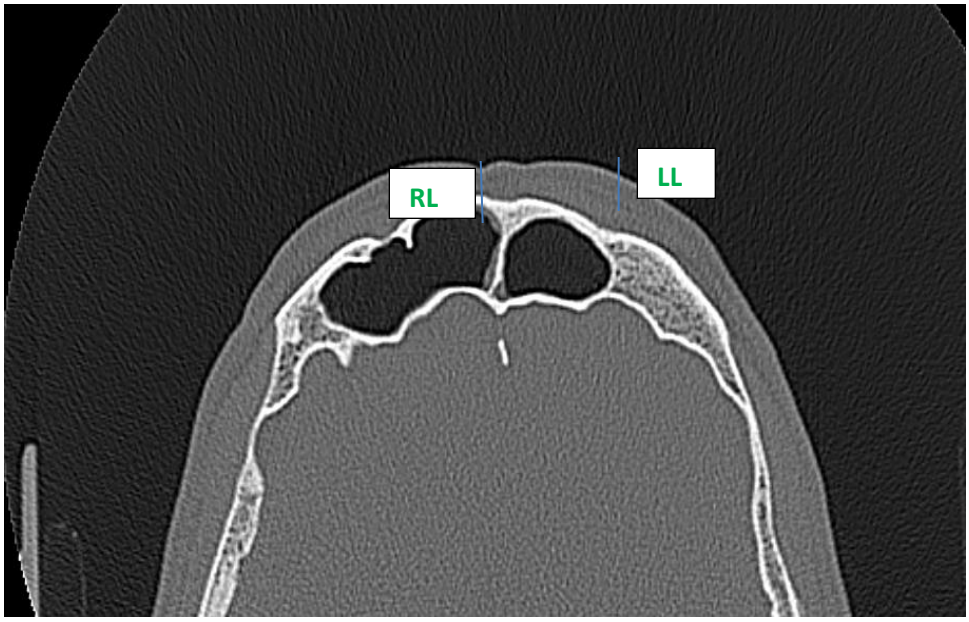


Figure (3): CT of male frontal sinuses (axial view) showing right sinus anteroposterior length (RL) and left sinus anteroposterior length (LL) "Quoted from work station"

II.3. Statistical analysis

Statistical analysis was done by the software package; SPSS (software package used for statistical analysis) version 22.0.Standard parameters (including mean and standard deviation) were calculated for each variable for both males & females. Unpaired Student's t test (for normally distributed variables) and Mann Whitney U test (for not normally distributed variables) were used for comparison between the groups (I) and (II) (males & females).Spearman correlation was used for not normally distributed variables to determine which of these variables highly correlated with sex.

Logistical regression formula for sex identification:

Abinary logistic regression analysis is performed using the four radiometric variables which had the greatest difference and correlation: Right sinus width (mm), Total width (mm), Total height (mm) and Right anteroposterior length(mm) to develop the logistical regression formula for sex identification. Variables with the greatest association and highest significance according to comparison and correlation tests were narrowed to 4 variables. These variables

were entered in a binary logistic regression model to develop a logistical regression formula for sex prediction. Binary logistic regression model was developed based on the logistic function and the sex. Parameters of the model were determined allowing the prediction of probability of the male and female gender. The enter method was used to select the variables and composition of the mathematical model.

$P(sex) = 1/(1+e^{-(b0+b1x1+b2x2+b3x3+b4x4)}) =$

$[1/(1+e^{-(93.153+55.798*\text{Rt sinus width}+-.013*\text{total width}+-55.899*\text{total height}+0.213*\text{Rtant.post length})})]$

II.3.2. Assessment of goodness of fit of the resultant model is done by:

Overall fit of the model (omnibus test), The regression coefficient (β).

The p-value based on Wald statistic used to test the significance of individual logistic regression coefficients for each independent variable and combination of variables.

Odds Ratio for each variable.The resultant logistical regression formula was applied to identify the sex of the reconstructed para-nasal CT images of the test group (unknown sex).

II.4. Ethical consideration: Ethical approval was obtained from the Research Ethics Committee, Faculty of Medicine; Suez Canal University. Consent from the head of the diagnostic radiology department of Suez Canal University Hospital was taken. Written informed consent was obtained from the participants before the procedure starts.

III. RESULTS

Tables (1 &2) included data regarding all measured frontal sinuses variables showing that frontal sinuses variables were larger in males than females. Only 4 variables showed highest significance and correlation(Right sinus width (RW), maximum total width (MW), maximum total height (MH) and right anterior posterior length (RL)).While left sinus width (LW), right sinus height (RH), left sinus height (LH), left anterior posterior length (LL) and frontal sinus index (FSI) showed no significance and low correlation.

Table (1): Description and comparison of radiometric variables of the original group for both sexes (n=86)

Measurements (mm)	Gender	Mean	Std. Deviation	p-value
Rt sinus width (RW)	Male	32.77	4.18355	0.000[1] **
	Female	27.18	4.94610	
Lt sinus width (LW)	Male	30.99	4.58389	0.188[2]
	Female	29.49	5.82078	
Maximum total width (MW)	Male	64.71	7.46153	0.000[1] **
	Female	55.19	8.19150	
Rt sinus height (RH)	Male	22.60	5.82086	0.139[2]
	Female	21.05	4.96563	.
Lt sinus height (LH)	Male	26.66	2.23198	0.287[2]
	Female	26.13	1.95816	
Maximum total height (MH)	Male	34.91	4.18014	0.000[1] **
	Female	28.45	4.94610	
Frontal sinus index (FSI)	Male	.551	.062909	0.227[1]
	Female	.531	.092239	
Rtanteroposterior length (RL)	Male Female	14.27 12.48	4.67787 6.21191	0.019[1] *
Lt anteroposterior length (LL)	Male Female	15.33 13.93	4.85401 4.15190	0.147[2]

n: number of subjects; Rt: right; Lt: left; 1. Student's t-test; 2: Mann Whitney U test
* Statistically significant at $p < 0.05$; ** Highly statistically significant at $p < 0.01$.

Table (2):Correlation between sex and different significant frontal sinus measurements in both sexes (n=86)

Measurements (mm)	R	R^2	p-value
Right sinus width (RW)	0.526	0.277	0.00[1**]
Left sinus width (LW)	0.171	0.29	0.118[2]
Maximum total width (MW)	0.524	0.275	0.000[1**]
Right sinus height (RH)	0.161	0.025	0.140[2]
Left sinus height (LH)	0.116	0.135	0.290[2]
Maximum total height (MH)	0.581	0.338	0.000[1**]
Frontal sinus index (FSI)	0.132	0.0174	0.227[1]
Right anteroposterior length (RL)	0.562	0.315	0.000[1**]
Left anteroposterior length (LL)	0.158	0.025	0.148[2]

n: number of subjects; **Highly statistically significant at $p < 0.001$
1: Pearson correlation (normally distributed data) is correlation coefficient indicates only two variables (R); 2: Spearman correlation (not normally distributed data) is the coefficient of multiple determinations (R^2).

Table (3) demonstrated the data of the binary logistic regression analysis, which was done using the above mentioned highly significant and correlated variables. The data showed highly statistically significance. The binary logistical regression formula was applied on the test group (unknown sex).

Table (3): logistic regression analysis of the variables in the binary logistical regression formula (n=86)

Measurements	B	p-value	OR
Right sinus width	1.223	0.997	1.64
Maximum total width	1.726	1.000	0.45
Maximum total height	0.783	0.66	0.25
Right anteroposterior length	0.563	1.000	1.237
Constant	93.153	0.000	0.998

n: number of subjects
β: Regression Beta coefficient p-value based on Wald statistic
OR: Odds Ratio

Tables (4&5) showed the validity of the logistic regression formula in sex identification applied on the test group. By calculating the percentage of each value; study results showed that the sensitivity of the logistic regression formula (the proportion of correctly classified as male) was equal 72.9%, and the specificity the proportion of correctly classified as female) was equal 73.4%. While the accuracy of the logistic regression formula (proportion of those individuals correctly categorized by formula) was equal 73.2 %.The predictive value positive (percentage of being male by formula and actually were male) was 67.5% and predictive value negative (percentage of being female by formula and actually were female) was equal 78.3%.

Table (4): Validity of the binary logistical regression formula in sex identification for the test group (n=86)

		Gender		Total
		Male	Female	
Statistically calculated formula	Male	27 (a) True positive	13(b)	40
	Female	10(c)	36(d) True negative	46
Total		37	49	86

n: number of subjects

(a): TP (true positive): those in whom the formula correctly detected them as males.

(b): those who were males for the formula in question but they were not.

(c): those who were females for the formula in question but they were not.

(d): TN:(true negative) those in whom the formula correctly detected them as female.

Table (5): Percentage of sensitivity, specificity and predictive value.

Male	Female
Sensitivity 72.9%	Specificity 73.4%
Predictive value 67.5%	Predictive value78.3%

IV. DISCUSSION:

The present study that computed tomography (CT) provided a method for imaging frontal sinuses region to be used for sex identification in forensic purposes.The frontal sinuses' measurements in the current study; right sinus width, maximum total width, maximum total height and right anterior posterior length were significantly larger in males. Abate et al., (2022) findings were also slightly larger in males, but the differences were not statistically significant, which is partly in agreement with the results of which revealed that all measurements were significantly higher in males than in females.

The frontal sinuses attain full maturity by 20 years and the sinuses remain

generally stable throughout life until 50 years and above where gradual pneumatization can occur from atrophic changes (Parabhat et al., 2016). Frontal sinuses measurements were done on 98 Brazilian subjects from Bahia on frontal sinus height and width were; maximum total heights of the frontal sinus were (31.72 mm) for males and (28.57 mm) for females and maximum total frontal sinus width were (56.6 mm) for males and (51.05) for females (Pondé et al.,2003). In Germany, a similar study had reported definitive sizes of maximum total frontal sinus width as 27.1 mm for males and 26.3 mm for females and maximum total height 17.3 mm for males and 16.1 mm for females (Spaeth et al; 1997).These variable differences between studies can be attributed to the influence of environmental and genetic factors on the frontal sinuses. Three systemic factors, which are the craniofacial configuration, the thickness of the frontal bone and the growth hormone levels influence the frontal sinuses morphology within each population (Aydınlıoğlu et al., 2003).

Sheikh et al., (2018) found that the frontal sinus measurements width and height in males were higher than females but were statistically insignificant. These sexual morphological differences can be determined by genetic factors, hormonal, muscular and nutritional factors that explain why frontal sinus is larger in males when compared to females. However; limitations in the use of the frontal sinus in personal identification were due to their affection by craniofacial abnormalities, pathological disorders.

Also, it could be affected via the genetic and environmental factors on the size of the frontal sinus (GurjarandGurjar, 2022).The current study revealed a large positive correlation between sex and some frontal sinus measurements namely right sinus width, maximum total width, maximum total height and right anterior posterior length which means that a high value in one variable is associated with a high tendency to be male. This correlation is highly statistically significant.

Binary logistic regression analysis was used for better sex prediction. The model based on binary logistic regression was highly significant to predict the sex in both original samples. Using the previously significant

parameters namely (RW, MW, MH, RL) included in binary logistic formula and applying it on test group II (unknown s ex), we found correct sex discrimination prediction was 73.2% and the correct discrimination rate for females (73.4%) was more than males (72.9%).

So, the validity of this logistic regression formula in sex prediction for the test group II shows that sensitivity was 72.9%, specificity was 73.4%, overall accuracy was 73.2 %, positive predictive value was 67.5% and negative predictive value was 78.3%.Many researchers generally use the frontal sinus to achieve sex determination.

Camarago et al., (2007), used 100 skull radiographs and used mathematical model based on logistic regression analysis which gave a concordance index (accuracy) for sex of 79.7%. Uthman et al., (2010) measured frontal sinus size on 90 paranasal CT scans (45 females and 45 males) and found a model for sex prediction based on left sinus height, with an overall accuracy of 76.9% then they improved their prediction model by combining left sinus height with maximum skull length, which gave an overall sex classification accuracy of 85.9%.

Belaldavaret al.,(2014) reported a 64.6% correct sex discrimination rate accuracy by using 300 digital poster-anterior radiographs obtained from 150 males and 150 females aged 18–30 years, by measuring the right and left areas, maximum height and width of the frontal sinus and implementing the logistic regression analysis for discriminating between sexes. As a result, they encouraged the use of the frontal sinus for sex discrimination.

Krishan et al., (2016) used the frontal sinus index to establish the discriminant function equation for the correlation between sex and frontal sinus index. In this study, the correct sex discrimination percentage of 67.6% was obtained. In general, the difference in the accuracy of previous equations used in the abovementioned studies might be attributed to using different variables in each equation, different measuring techniques, different sample sizes and different statistical tests.

This analysis was limited by age of the individuals, because we were considering age group from 20 years to 50 years due to the varying size of the

sinuses in childhood because of their development and in elderly due to atrophic changes (Soman et al., 2016).

V.CONCLUSION

The present study concluded that computed tomography (CT) provides an excellent and reasonable method for imaging frontal sinuses region to be used for sex identification in forensic purposes.

VI. RECOMENDATIONS

Further studies with larger sample size are recommended to ensure the external validity of the findings and also the possibility to be applied as evidence based practice in the forensic field.

VII. LIMITATIONS:

The frontal sinus region has extreme variations of its size and shape among individual regarding frontal sinus outline shapes among individuals, so the principal limitation to this study was this extensive difference. These variations in shape proved difficult to measure consistently due to irregular populations and asymmetric interlines septa. It was challenging to localize the frontal sinus septum and differentiate its outline pattern from associated bifurcations. Also, these results cannot be generalized on all Egyptian population due to the small number of the sample size. We recommend further studies to be done using the parameters mentioned in this study on greater sector of the Egyptian population to get a radiometric standard specific for the Egyptian population.

VIII. CONFLICT OF INTEREST

The authors declared that there were no conflict of interests.

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الاستعراف على نوع الجنس للبالغين باستخدام أبعاد الجيوب الأنفية الأمامية للمصريين المترددين على مستشفى جامعة قناة السويس

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المقدمة: يعد تحديد الجنس من أهم خطوات التعرف على الرفات البشرية مجهولة الهوية ؛هذا وتعدالجيوبالأنفية الأمامية من العلامات المهمة فيالطب الشرعي بسبب خصائصها الفردية التي تجعل العظم الجبهي فريدًا لكل فرد.**هدف الدراسة:** الحصول على طريقة دقيقة لتحديد الجنس بين السكان المصريين من خلال قياس أبعاد الجيوب الأنفية الأمامية باستخدام التصويرالمقطعي ثنائي الأبعاد. **طريقة الدراسة:** دراسة وصفية مقطعية باستخدام 172 صورة مقطعية ثنائية الأبعادللجيوب الأنفية الأمامية من قسم الأشعة التشخيصية بمستشفى جامعة قناة السويس بالإسماعيلية. تم تقسيم الصور المقطعية للمرضى الذين تتراوح أعمارهم بين 21 إلى 50 سنة إلى مجموعتين.

مجموعة(١): "مجموعة الدراسة"(معلومة الجنس) و تشمل ٨٦ أشعة مقطعية لكلا الجنسين مقسمة بالتساوي بين الذكور والإناث؛ والتي أستخرج منها معادلة الانحدار اللازمة لتحديد الجنس. مجموعة (٢): "مجموعة الاختبار"(مجهولة الجنس) و تشمل ٨٦ أشعة مقطعية لكلا الجنسين؛ والتي طبق عليها معادلة الانحدار التي تم استخلاصها من مجموعة (١)، لاختبار دقتها في الاستعراف عن الجنس.أجريت اختبارات المقارنة والارتباط لكشف المتغيرات ذات الدلالة الإحصائية العالية في ازدواج الشكل الجنسي بين الجنسين. تم استخدام المتغيرات ذات الدلالة الإحصائية العالية لتطوير صيغة الانحدار اللوجستي الثنائي لتحديد الجنس. **النتائج:** تم استخراج معادلة من أفضل القياسات المستخدمة و هم 4 قياسات (عرض الجيب الأنفي الأيمن- العرض الكلي للجيبين الانفيين معا- الطول الكلي للجيبين الأنفيين معا- الطول الأمامي الخلفي للجيب الأنفي الأيمن),ثم تمتطبيق تلك المعادلة على العينة الاختبارية وأظهرت معدل دقة73%.**الخلاصة**: ومن هذا يتضح امكانية استخدام الأشعة المقطعية لأبعاد الجيوب الأنفية في الاستعراف على الجنس باستخدام القياسات .