DETERMINATION OF SEX FROM THE STERNUM AND FOURTH RIB MEASUREMENTS (A CROSS-SECTIONAL STUDY) USING THORACIC COMPUTED TOMOGRAPHY (CT) IMAGES

Ola Abdel- Hady Sweilum [1], Hobab K Alsebaey Galal[2], Rehab Mohammed Habib[3].
[1]-[2]Lecturer of forensic medicine and clinical toxicology, Menofia university, Shebin El Kom, Egypt, [3]Lecturer of radiodiagnosis, Menofia university.

ABSTRACT

Background: Several causes may destroy the skeletal remnants. Environmental causes, blasts, decomposition, and traumatic destruction may impede identification of bones. Furthermore, some forensic science researches showed inconsistency in using skull and pelvis bones in gender identification. In progressive skeletal destruction, the integrity of sternum may be conserved. In the postmortem duration, morphometric investigations of the sternum can be done by using radiological means. **Aim of the work:** This study was done to assess the sensitivity of sternal and 4th rib measurement analysis for sex determination in Egyptian population. **Subjects and methods:** Cross-Sectional study of thoracic Computed Tomography (CT) images of 261 adult Egyptians arrived at Menoufia university hospital. Meso-sternum length (SL), Manubrium length (ML), Sternebra 1 width (MS1), Sternebra 3 width (MS3), 4^{TH} Rib (its width at the level of costochondral junction) were measured. Differences between genders were detected by student *t*-test. **Results:** All sternal and forth rib measurements are significantly higher in males. The highest sensitivity and specificity values for sex discrimination were identified in SL as the sensitivity was 90.6% and specificity was 70.6%.

Sex equation = -13.134+ (SL*0.06) + (ML*0.111) + (MS1*0.045) + (MS3*0.024) + (4^{th} rib*0.092). Conclusion: The sternum represented a reliable bone for sex determination in Egyptian population, based on a CT scan. The data generated from morphometric sternum studies are population specific data. Researchers can use a rapid and easy CT scanning for sternum and fourth rib as an effective method for sex identification. **Recommendation:** -we need to increase the number of conducted studies using radiological methods with proper analyses, as we can add other bones for forensic anthropologic evaluation. - As there are ethnic differences within national populations appeared in previous studies outside Egypt, we recommend other studies on the same bone in other Egyptian areas. - Use the equation of the sternal bone and the fourth rib measurement in determining sex.

Keywords: Sternal measurements, Sex determination, Computed Tomography, sex equation.

INTRODUCTION:

There are characteristic anthropological and biological factors that can be used for identification of an individual. Bone being resistant to putrefaction and damage caused by animals can be used for identification and can help in estimation of age, gender and race **(Mohit Gupta, et al., 2014)**. Significant data for human proof of identity procedures have been provided by anthropometric researches of skeletal structure **(Haglund and Sorg 2002)**.

Sex identification is very important compared with age and race identification as it excludes almost half of the population **(Knight and Saukko 2004)**.

Several causes may destroy the skeletal remnants. Environmental causes, blasts, animals, decomposition, and traumatic destruction may impede identification of pelvis and skull bones. It is not always possible and easy to perform direct measurement analyses on skeletal remains **(Spradley and Jantz 2011)**.

The main anthropological methods used for gender identification are either directly measuring the skeletal remains or by imaging techniques. The major problems to obtaining intact bones are; trauma, decomposition, and disappearance for different causes **(Byers 2002)**.

Furthermore, some researches showed inconsistency in using skull and pelvis bones in gender identification **(Krogman and İşcan 1986, Spradley and Jantz 2011)**.

In progressive skeletal destruction, Mass mortality may be caused specially in terroristic blastic attacks, rapid identification is a crucial procedure and may be only one bone is found intact and all data should be collected from this bone.

Morphometric and radiological investigations of the sternum can be done in the postmortem duration, as sternum has a bony structural advantage having a strong structure and preserved integrity (Torwalt and Hoppa 2005; Ramadan et al. 2010; Osunwoke et al. 2010), it also provides accuracy of 80% or greater in morphometric analyses. Also, Data Bank of Forensic Anthropology was reported that the sternum and manubrium preserve its good state in 59% of forensic cases (Bongiovanni and Spradley 2012).

This study was done to assess the sensitivity of sternal bone and 4th rib morphometric analysis for sex determination in a sample of Egyptian population. Choosing the sternum as the integrity of sternal bone may be conserved better than other bony skeleton and many previous studies were done on other body bones.

SUBJECT & METHODS

This cross-sectional study was done on thoracic Computed Tomography (CT) of 261 adult Egyptians (general population) (159 male and 102 female) live in Menoufia governorate. Their mean age was 54.4 ± 14.3 years for male and 51.7 ± 15.7 years for female. Patients arrived to Menoufia university hospital and referred to radiology department to have CT scan for other reasons.

The study was approved by the ethical committee at Menoufia university and individual consent was waived (not necessary to be taken from each patient). Peoples with any sternal trauma or deformity (congenital or acquired), were excluded from the study.

Computed tomography images were taken by Toshiba 16 channel multi-slice CT scanner in Radiology department, Menoufia university hospital. Images performed with slice collimation 2.5mm, pitch 1 to 1.5.

Method:

Measurements obtained from each patient by CT were:

- Meso-sternum length (MSL) or (SL): the distance from the sternal angle to the sagittal midpoint of the xiphi-sternal joint.

- Manubrium length (ML): the distance from the jugular notch to the sagittal midpoint of the manubrio-sternal joint
- Sternebra 1 width (S1W) or (MS1): the distance between the left and the right first sternebra (depressions between the articulation notches for the second and third costal cartilage).
- Sternebra 3 width (S3W) or (MS3): the distance between the left and right third sternebra (depressions between the articulation notches for the fourth and fifth costal cartilage).
- 4TH Rib: its width at the level of costochondral junction.

All measurements were taken by CT (**Figures 1-4)**.

Figure 1: Male patient 57ys old, CT chest bone window with sagittal reformats showing **sternebral 3** width 18.3 mm.

Figure 2: Male patient 63 ys , CT chest bone window with sagittal reformats showing : **ML** 44.5 mm and **MSL** 68.9 mm.

Figure 3: Female patient 55 ys, CT chest bone window with coronal (A) and sagittal (B) reformats showing: **sternebral 1** width 23.3 mm. **ML** 47.4 mm and **MSL** 82.7 mm.

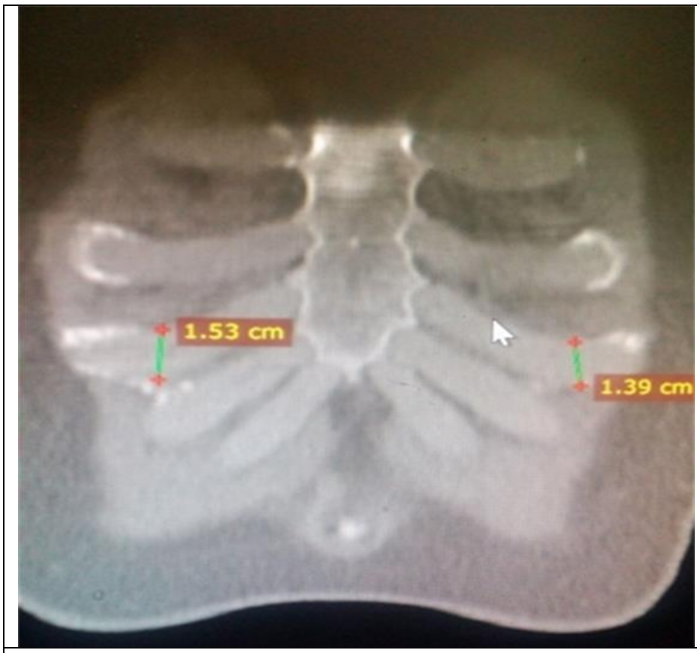

Figure 4: Female patient 32 ys, CT chest bone window with coronal reformats showing **4th rib** width right 15.3 mm left 13.9 mm.

Statistical analysis:

Data were fed to the computer and analyzed using ibm spss software package version 20.0**. (**armonk, ny: ibm corp**) (**kirkpatrick la. And feeney bc. 2013) qualitative data were described using number and percent. The kolmogorov-smirnov test was used to verify the normality of distribution quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level.

The used tests were:

Student t-test

For normally distributed quantitative variables, to compare between two studied groups

receiver operating characteristic curve (roc)

It is generated by plotting sensitivity (tp) on y axis versus 1-specificity (fp) on x axis at different cut off values. The area under the roc curve denotes the diagnostic performance of the test. Area more than 50% gives acceptable performance and area about 100% is the best performance for the test. The roc curve allows also a comparison of performance between two tests.

accuracy

Rate of agreement = (true positives + true negatives) / total tested x 100

odd ratio (or):

Used to calculate the ratio of the odds and 95% confidence interval of an event occurring in one risk group to the odds of it occurring in the non-risk group.

RESULTS:

Table (1): Comparison between male and female as regard sternal and forth rib measurements

	Gender		p
	Male (n= 159)	**Female (n=102)**	
Age (years)			
Range	19 – 80	22 – 72	0.162
Mean ±SD	54.4 ± 14.3	51.7 ± 15.7	
SL	99.3 ± 9.4	89 ± 14.2	<0.001*
ML	51.7 ± 6.6	46.2 ± 5.8	<0.001*
MS1	25.1 ± 3.9	22.2 ± 3.7	<0.001*
MS3	29.2 ± 5.1	26 ± 5.6	<0.001*
4th-rib	9.1 ± 1.4	7.7 ± 2.1	<0.001*

t, p: t and p values for Student t-test for comparing between the two groups
***: Statistically significant at $p \le 0.05$**

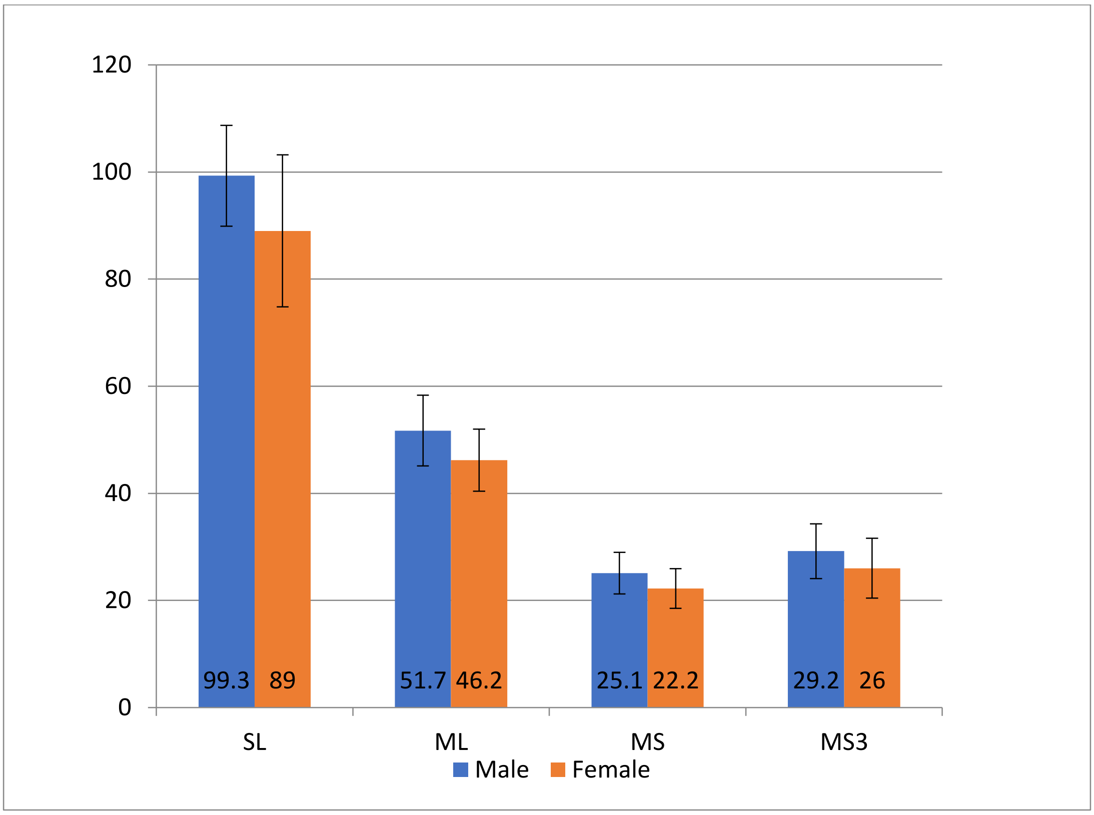

Figure (5): Comparison between male and female as regard sternal measurements

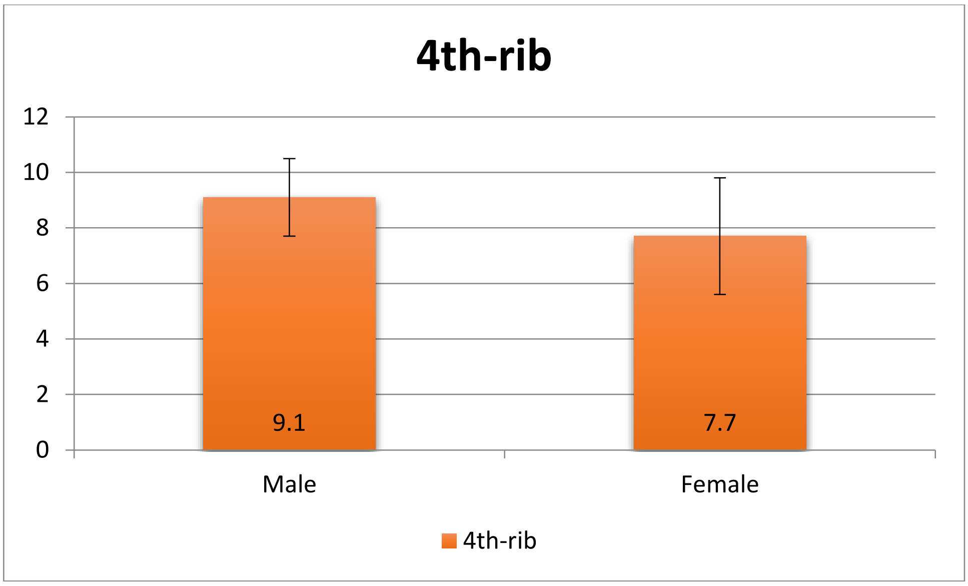

Figure (6): Comparison between male and female as regard forth rib measurement

Table (2): Sex equation with logistic regression

	B	Sig.	OR	95% CI	
				LL	UL
SL	0.060	<0.001*	1.061	1.027	1.097
ML	0.111	<0.001*	1.118	1.058	1.181
MS1	0.045	0.393	1.046	0.943	1.161
MS3	0.024	0.434	1.025	0.964	1.089
4^{th} rib	0.092	0.350	1.097	0.904	1.331
Constant	-13.134	<0.001*			

Sex equation = -13.134+ (SL*0.06) + (ML*0.111) + (MS1*0.045) + (MS3*0.024) + (4^{th} rib*0.092).

Table (3): ROC analysis results

	4th-rib	MS3	MS1	MI	SL	Model
Cutoff point	>7.8	>26.5	>22.5	>48.5	>92.5	>0.146=male
Sensitivity	83%	71.7%	75.5%	79.2%	83.0%	88.7%
Specificity	59.1%	64.7%	64.7%	73.5%	70.6%	82.4%
P .value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
NPV	77.7%	69.5%	72.5%	78%	77.4%	82.4%
PPV	66.9%	67%	68.1%	75%	75.7%	88.7%
AUC	0.72	0.67	0.73	0.78	0.825	0.844

SL accuracy for females = 82.4
SL accuracy for males = 73.5
Model accuracy for females = 84.3
Model accuracy for males = 88.6

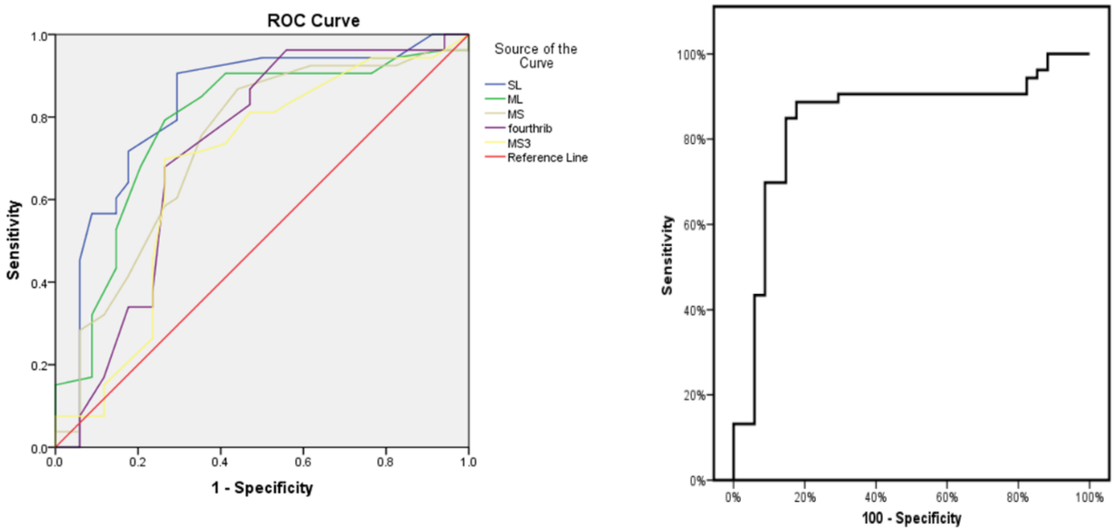

Figure (7): ROC curve of measurement

The present study is a cross-sectional study carried on 261 adult Egyptian population (159 male and 102 female). The mean age ± SD for males was 54.4 ± 14.3 years, while the mean age ± SD for females was 51.7 ± 15.7 years. The mean values of sternal bone (SL, ML, MS1, MS3) and 4^{th} rib measurements (all measured in mm) were higher in male compared with female and this difference was statistically highly significant (P value < 0.001) (Table 1, Figures 5 & 6).

By logistic Regression analysis, we used the result values to generate a formula to determine sex between Egyptian population from sternal (SL, ML, MS1, MS3) and fourth rib measurements (Table 2)

The Equation for sex determination from sternal and fourth rib measurements is:

Sex determination = -13.134+ (SL*0.06) + (ML*0.111) + (MS1*0.045) + (MS3*0.024) + (4th rib*0.092)

ROC analysis was used to determine the optimum values for sex determination. The optimum cut-off value was determined from sensitivity and specificity values. the sensitivity and specificity of each sternal bone measurement and fourth rib measurement used for sex determination.

Sensitivity of SL, ML, MS1, MS3 and fourth rib were 83%, 79.2%, 75.5%, 71.7% and 83% respectively and specificity of SL, ML, MS1, MS3 and fourth rib were 70.6%, 73.5%, 64.7%, 64.7%, and 59.1% respectively. Comparing The sensitivity and specificity for each measurement separately, the optimum sensitivity and specificity values for sex discrimination were identified in the SL measurement (83.0% and 70.6% respectively) (Table 3 & Figure 7).

While the model regression showed that the sensitivity and specificity of the five measurements together (collectively) in sex determination (SL, ML, MS1, MS3, and 4 the rib) were higher than each studied parameter separately (as it was 88.7% and 82.4% respectively) (Table 3 & Figure 7).

The model of highest accuracy (88.6% for males and 84.3% for females) for sex determination used all measurements (Sternal and 4^{th} rib) together. While the model accuracy for SL was 73.5% for males and 82.4% for females. This mean that using of all measurements (sternal and fourth rib) together results in more accurate sex determination.

DISCUSSION

This study included 261 computed tomography (CT) of adult Egyptian population (159 males, 102 female) live in Menoufia governate. The mean ± SD age of male was 54.4 ± 14.3 years while the mean ± SD age of female was 51.7 ± 15.7 years.

A robust structure and preserved integrity of the sternum is the main structural advantages of this single bone. Also, CT scanning for the single bone remnant (as sternum) is considered an effective, easy, and rapid method for identification. **(Sidler et al. 2007)**.

Jit et al. (1980) found that sex determined correctly by sternal bone in 89% male and 82% female. **Dahiphale et al. (2002)** found that 92% male and 87% female, their sex can be determined correctly by sternal bone.

Studying different sternal and forth rib measurements in the present study revealed that the mean values of SL, ML, MS, MS3, 4th rib were higher in males compared with female and the differences were statistically highly significant (P< 0.001). This difference is due to muscular activity and development of male more than female.

The results of the present study are in concordance with **Ekizoglu et al. (2014)**, who found that the mean values of ML, SL, S1W (MS1), and S3W (MS3) were higher in males and the differences were also statistically significant (P<0.001) between both sexes.

Similar to this study, **Gupta et al. (2014)** reported that the mean lengths of the manubrium (ML) were higher in male compared with female (40.639 mm and 37.286 mm respectively), this difference was statistically highly significant (p< 0.000).

Ramadan et al. (2010) studied 340 CT views in a Turkish population and reported that the SL, ML, SW1(MS1), SW3 (MS3) sternal measurements were higher in male compared with females.

In the present study, SL had the highest accuracy between individual measurements (73.5 % in males and 82.4% in females). While accuracy of SL, ML, MS1, MS3, and 4th rib collectively was the highest (88.6% for males and 84.3% for females).

Similar results were revealed by **Ekizoglu et al. (2014)**, as they also observed that SL had the highest accuracy (80.2% in females and 80.9% in males). while SI had the lowest sensitivity and specificity.

In contrast to the present study; **Gupta et al. (2014)** reported that the length of manubrium (ML) is the most reliable parameter for sex detection in central Delhi population. While **Mohit V Changani (2014)**, observed that the combined SL and ML is the most reliable measurement for sex determination from the sternum.

In the present study, ROC analysis was revealed that sensitivity and specificity values for sex determination were higher in SL as a single measurement (as the sensitivity was 83% and specificity was 70.6%), but all measurements together were more sensitive and specific (88.6% and 84.3%).

Similarly, **Ekizoglu et al. (2014)** found that the optimum sensitivity and specificity values for sex discrimination were identified in the SL measurement (sensitivity of SL was 75.9% and specificity was 87.6%).

This is not agreeing with **Torwalt and Hoppa (2005)** and **Ramadan et al. (2010),** who found that only SA and fourth rib together are the best predictor for sex determination when using sternal bone and fourth rib.

However, the present study results including the sex determination equation applied on Egyptian population, as the sternal measurements showed ethnic variations between populations. This was proved by previous studies compared North and West Indian populations and reported larger female sternal measurements in North India and greater male sternal measurements in West India **(Hunnargi et al. 2008, Singh and Pathak 2013, Menezes et al. 2009, Dahiphale et al., 2002).** So, the sternal measurements can be used for population difference determination.

Population specific studies concluded that mean sternum measurements in South African and Indian populations **(Macaluso 2010, Hunnargi et al. 2008)** were lower than those of European **(Marinho et al. 2012, Teige 1983, Ashley 1956, Franklin et al. 2012),** US and Canadian populations **(Spradley and Jantz 2011).**

Macaluso et al. (2014) studied sex determination in a Spanish population and reported that a stepwise analysis of (ML, corpus sterni length, manubrium width, CSWS1, and CSWS3 (corpus sterni width at third sternebra), yielded a sex discrimination accuracy of 89.7%.

CONCLUSION

The present study showed that Sternal Length (SL) is the most reliable parameter in sex determination if we use a single measurement. But the use of multivariate analysis technique (SL, ML, MS1, MS3, and 4th rib) can be more sensitive and specific of sex determination. CT is a useful and accurate tool for sex determination by sternal bone.

RECOMMENDATION

1-we need to increase the number of conducted studies using radiological methods for sex determination, as we can add other bones for forensic anthropologic evaluation.

2- As there are ethnic differences within national population (appeared in previous studies outside Egypt), we recommend other studies on the same bone in other areas in Egypt.

3- Use the result equation of the sternal bone and the fourth rib measurements in determining sex.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest in the research.

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الملخص العربي

تحديد الجنس من قياسات عظمه القص و الضلع الرابع (دراسه مستعرضه) باستخدام الاشعه المقطعيه علي الصدر

د/علا عبد الهادي سويلم1- د/حباب كمال السباعي1 - د/رحاب محمد حبيب2

١-قسم الطب الشرعي والسموم الاكلينيكيه- كليه الطب- جامعه المنوفيه

٢- قسم الاشعه التشخيصيه- كليه الطب- جامعه المنوفيه

المقدمه: يوجد الكثير من العوامل التي تدمر البقايا العظميه وتجعل الاستعراف علي الجنس امر صعب. الا ان عظام القص من اكثر العظام التي تظل متكامله بعد الوفاه ويمكن ان تستخدم في هذا المجال.

المواد و الطرق: قد تمت دراسه مقطع عرضي لعدد ٢٦1 شخص مصري بالغ من محافظه المنوفيه عن طريق الاشعه المقطعيه علي الصدر الخاصه بهم حيث تم قياس الضلع الرابع وبعض القياسات لعظمه القص و قد تم استبعاد اي حالات لديها تشوهات او اصابات في عظمه القص.

النتيجه: اظهرت النتائج انه وجد فروق احصائيه بين الذكور والاناث بالنسبه لجميع قياسات عظمه القص والضلع الرابع. كما انه تبين ان قياس طول القصيه من اكثر القياسات دقه في تحديد الجنس حيث بلغت درجه حساسيتها 83% و نوعيتها حوالي 70.6%. ولكن استخدام قياسات عظمه القص مع الضلغ الرابع مجتمعه اكثر دقه وحساسيه ونوعيه (٨٨,٧% و ٨٢,٤%) في تحديد الجنس من قياس عظمه القصيه او غيرها منفرده.

الاستنتاج : يمكن استخدام قياسات عظمه القص والضلع الرابع مجتمعه في تحديد الجنس بدقه عن طريق الاشعه المقطعيه ويعتبر قياس طول القصيه من اكثر القياسات المنفرده دقه في تحديد الجنس.

التوصيه: نحن بحاجة إلى زيادة عدد الدراسات التي تجري باستخدام الاشعه مع التحليلات المناسبة لها، يمكن تكرار الدراسه علي محافظات اخري حيث انه ثبت من دراسات سابقه وجود فروق بين مواطني نفس البلد. كما يمكننا إضافة عظام أخرى لتساعد في التقييم الأنثروبولوجي الشرعي.

يوصي باستخدام معادله قياسات عظمه القص والضلع الرابع الناتجه في تحديد الجنس.

Sex determination = -13.134+ (SL*0.06) + (ML*0.111) + (MS1*0.045) + (MS3*0.024) + (4th rib*0.092)