https://doi.org/10.25130/tjds.7.2.5

Tikrit Journal for Dental Sciences 7(2) (2019)74-82

Tikrit Journal for Dental Sciences

https://tjds.tu.edu.iq

Sex Determination and Foramen Magnum Measurement (CT Study Case in Sulaimani Population)

Shara Mustafa haji Karem(1)
Salah Qadir Mahmood(2)
Ranjdar Mahmood Talabani(3)
Layla A. Abas(4)
Shoxan H. Azeez(5)
Aram Mohammed Sha(6)

(1,2,4,5) Dental Nursing Department, Sulaimani Polytechnic University, Iraq.
(3,6) College of Dentistry, University of Sulaimani, Iraq.

Article Info:
-Article History:
-Received: 1/12/2019
-Accepted: 23/12/2019
-Available Online: */12/2019

Keywords:
Foramen Magnum, Sex Determination, Computed Tomography Images

Corresponding Author:
Name: Shara Mustafa Karem(1)
Salah Qadir Mahmood(2)
Ranjdar Mahmood Talabani(3)
Layla A. Abas(4)
Shoxan H. Azeez(5)
Aram Mohammed Sha(6)
E-mail:
Shara_mustafa@yahoo.com(1)
Tel: 00964-0770 145 2600(1)
Affiliation:
(1) Asst. Lec. Oral and Maxillofacial Radiology.
(2)Asst. Lec. Public Health (Radiation Protection) Department of Radiology.
(3)Lec. Conservative Dentistry.
(4)Asst. Prof. Community Health.
(5,6) Asst. Lec. Periodontics .

Abstract

Foramen magnum that is positioned under the sagittal suture and surrounded by the lateral, squamous, and basilar parts of the occipital bone is one of the most important structures in the base of the skull. Genetic, socioeconomic, and environmental factors have a significant impact on sexual dimorphism in FM dimensions which is population-specific. The present retrospective study was carried out in Sulaimani teaching hospital, Sulaimani, Iraq. The study sample consisted of 100 adult patients including 50 females and 50 males aged 20-70 years. All of the patients had CT scanned for their necks and heads over the period June 2017 to March 2019. In order to examine the foramen magnum, its sagittal diameter, transverse diameter, area, index, and circumference were measured. Student's t-test and histogram were used to analyze the data, and Receiver Operating Characteristic (ROC) curve and Binary Logistic Regression model were employed to obtain a model for sex determination. We found that women had a lower average value than men in our study. According to the independent t-test results; the genders were significantly different in terms of all measured parameters ($p<0.05$). As demonstrated by the ROC curve, the predictability of the dimensions in sexing the crania for sagittal diameter, transverse diameter, and area of foramen was respectively 76.0%, 66.0%, and 74.0%. The current study indicated a high percentage of sex predictability regarding the dimensions, areas, and circumference, which is because of the highly significant difference between the genders.

Introduction:

One of most significant structures in the skull base is foramen magnum [1]. It is located below the sagittal suture and surrounded by the lateral, basilar, and squamous parts of the occipital bone [2]. It has been referred to as an ideal gender determination structure because it is covered by a large volume of soft tissue and located in the deepest section of the posterior cranial fossa [3]. Sexual dimorphism in FM dimensions is population-specific and highly affected by genetic, socioeconomic, and environmental factors. In addition to being a medico-legal requirement, identifying an individual's sex is a highly significant issue for the family from an emotional viewpoint [4]. In a study carried out by Rogers (2005), 17 morphological characteristics of the skull were examined in order to specify the individuals' sex. According to the results, supraorbital ridge, malar size/rugosity, zygomatic extension, and nasal aperture had primary importance in identifying the individuals' sex, followed by chin form and nuchal crest with secondary significance; mastoid size with tertiary significance, followed by palate size/shape, forehead shape, mandibular symphysis/ramus size, nasal size, and other characteristics [6]. Sex identification in living individuals has s significant role in issues like insurance claims, property disputes, and other different licenses; however, its importance after death lies in identifying the deceased in cases like murder or missing for a long period of time in order to facilitate the body disposition ceremonies after death and remarriage permission. It should also be mentioned that identity determines the society's responsibility to preserve human dignity and rights beyond life [4]. Therefore, there humanitarian and legal reasons behind positive identification of sex [5]. Over the past years, computed tomography (CT) has helped forensic medicine obtain forensic databases from skeleton remnants [8]. Post-mortem examinations can be performed with the help of particularly multi-detector CT and magnetic resonance imaging (MRI) [7]. Previously conducted studies focusing on morphometric measurements have used dry bones for this purpose [9]. In the present study, the foramen magnum obtained from three-dimensional (3D)-CT images of the Sulaimania population were assessed with to determine whether these measurements were helpful for determination of sex.

Aim of study:

This study aims to evaluate sexual dimorphism in dimensions of foramen magnum in the Sulaimania population.

Materials and methods

The current retrospective study was carried out in Sulaimani teaching hospital, Iraq. The studied sample consisted of 100 patients including 50 females and 50 males with an age range of 20-70 years. Using a CT scan machine (1.0 mm slice thickness, 257 mA, 100 kv), CT scan images were taken from the head and neck of all patients from June 2017 to March 2019. The patients' demographic data were obtained from their recorded clinical files. Patients with syringomyelia associated with chiari malformations, congenital anomaly of the cranio vertebral junction, hindbrain (chiari malformation), dizziness, and headache [10,11]or any diseases that have been confirmed to cause deviations from normal ranges in foramen measurements [12,13] were excluded from the study.

Measurement

RadiAnt DICOM viewer software was used for morphometry through the following technique.

Figure 1 presents the landmarks on the foramen.

1- FMSD: The sagittal diameter (s) refers to the distance between Basion (B) and Opisthion (O) that are
2- respectively anterior posterior direction of the FM.
3- FMTD: The transverse diameter (t) refers the distance between maximum lateral curvature of lateral
4- margins of FM.

The measurements were repeated two times, and comparison of the average results was performed. As recommended by Krag et al. (1988) for spinal morphometry measurement [14], when 0.1 mm or more difference was recorded, a third measurement was performed. FM area (FMA) was calculated from FMTD and FMSD utilizing different formulae given by Routal and Teixeira:

Teixaria Area = π ([FMSD + FMTD)/4] [16]

Radinsky Area =FMSD×FMTD×π/4
FMI =FMTD×100/FMSD

The FMI (foramen magnum index) was evaluated using Martin and Saller classification : [15]

a. Narrow: X–≤81.9
b. Medium: 82.0–85.9
c. Large: ≥86.0–X.

FMC (foramen magnum circumference) (C) to estimate the radius (r) of the foramen magnum, so assuming FM as a circular. This radius is then applied to the formula for the area of a circle. [17]

C=2*π*r Area=π*r²

Statistical analysis

After the data were collected collection, and before they were entered to computer and analyzed, the questions of study were encoded. An excel spreadsheet for data entry. Afterwards, IBM SPSS Statistical Package for the Social Sciences (SPSS version 21) was used for statistical analysis of the data. Kolmogorov-Simonov test was used to check the compliance of quantitative random variables with Gaussian curve (normal distribution). Mean and SD (standard deviation) were used to describe the quantitative continuous variables which were normally distributed. Independent sample t-test was employed to assess the statistical significance of difference between the two groups. Median, mean rank, arithmetic mean, and standard deviation were used to describe the non-normally distributed variables. Mann-Whitney, which is a non-parametric test, was used to assess between the two groups regarding their mean rank difference. The cut-off point for gender with regard to certain variables such as sagittal and transverse diameters was identified using ROC (Receiver Operating Characteristics). Accordingly, specificity and sensitivity with negative and positive predictive values were calculated. Frequency and relative frequency distribution of different variables were presented in tabular forms. Some variables of the study were described using different types of diagrams. P-values of 0.05 were used as a cut-off point for significance of statistical tests.

Results:

It was observed that on average the sagittal diameters (s) were shorter than the transverse diameter (t) (p< 0.001) and this difference was highly significant. The means of sagittal diameter for the males and females in this study were respectively 35.84 and 32.50) mm, and transverse diameter was 29.67 mm for the males and 26.67 mm for the females. Independent t-test and Mann-Whitney test were used to examine whether diameters and area of foramen were significant detectors of sex, and the results showed a statistically highly significant p-value for all the dimensions, See Tables (1, 2). Analyzing both sexes in terms of the sagittal and transverse diameters indicated p-values of respectively 0.001 and 0.01. Radinsky's formula was used to measure the foramen magnum area (R) which revealed a p-value of 0.001. Measuring the foramen magnum area through Teixeira's formula, i.e. Area (T), indicated a p-value of 0.001. Moreover, measuring the circumference showed a p-value of 0.001. All the above values were <0.05, which are highly statistically significant. According to Martin and Saller classification, the results indicated large type of FMI. The results obtained from independent t-test showed no significant difference between males and females in terms of their mean FMI (P=0.30). In both diameters interindividual variation is observed and is seen in Figures 2 , 3 and 4.

The next analysis phase was obtaining an equation to determine the sex of the individuals on applying the value of the variable. Table (3) presents the BLR model for each variable. Based the model, any detected value of <0.5 is regarded to be female and equal to or more than 0.5 as male. Afterwards, to test strength of each model, the area under the Receiver Operating Characteristic (ROC) curve was used. Figures 5, 6, 7, and 8 present the ROC curve of each variable. The area under the curve is used to predict the variable in sexing the crania. Both methods were used to measure the variables, leading to an area of 0.832 for area of foramen, 0.809 for transverse diameter, and 0.759 for sagittal diameter. Moreover, all values of the area under the curve are more than 0.6, which suggests that the variables are significant discriminants for the two groups, i.e. males and females. Accuracy, specificity and sensitivity are shown in Table (4).

Discussion:

One of the important ways to form a comprehensive base on sex determination in medico legal cases is skull morphometry. The skull, femora, and pelvis are the most appropriate for radiological determination of sex. When the skeleton exists wholly, gender can be detected with 100% precision in contrast to cases of explosions, warfare, and other mass disasters. Analytical methodologies developed on skeletal data achieved from European documented skeletal collections have increased with the increasing expertise of forensic anthropology in Europe, which is evident by the setup of academic association bodies like the Forensic Anthropology Society of Europe or FASE [25]. Previously, no studies have evaluated sexual dimorphism of the foramen magnum region in a population in the Kurdistan Region-Iraq. Sex determination in the human cranium is generally depend on size differences and strong city [26]. These differences are individual to each population and thought to be affected by genetic, environmental and socio-economic factors [27]. Sexual dimorphism is people specific [27].

Gender determination can be carried out using either morphological or morphometric methodologies. In their study, Kanodia et al. examined 100 dry adult skulls without any bony abnormality and 100 normal CT scans of posterior cranial fossa [21]. Shepur et al. studied 30 CT scan images and 150 dry skulls [23], and Patel and Mehta studied 100 skulls [24]. The results of all of these studies showed that the sagittal diameter was significantly bigger that the transverse diameter, and this is consistent with the foramen shape. The results of almost all of these studies revealed that males had higher mean foramen dimensions females. This finding has also been observed by other researchers such as Olivier [18], Routal et al. [19], Sayee et al. [20], Gruber et al. [21], Gargi et al. [22], and Raghavendra Babu et al. [3]. In their study, Uthman et al. [1] used CT images to measure the foramen magnum and indicated that the foramen magnum area and circumference measurements were the best discriminant parameters respectively with 69.3% and 67% accuracy rates. Almost in line with that study, the results of the present study indicated that accuracy of area and sagittal diameter was 80.0% and for transverse diameter 71.0%. The anatomic and radiographic methods are may be the causes of these differs. In our study we find no significant difference in mean FMI between males and females (P=0.30) same result as Gargi V. et al., [22] (p=0.941by using cone beam computed tomography imaging. On the subject of FMC, Vidisha et al. [22] reported the measurement as 108.1±7.1 for males and 102.2±6.8 for females, which were higher than the ones obtained in the current study. These differences can be contributed to the differences between radiographic and anatomic methods. The mean value of FMC was found to be 102.8±6.2 for males and 92.2±9.4 for females. These results are in line with those of the current study. It is noteworthy that the applied statistical analysis, the sample study size, and the ethnic group involved have a significant effect on the observations of sex detection. In the current study, the mean sagittal diameter was 35.85 mm in males and 32.50 mm in females, and the mean transverse diameter was 26.23 mm in females and 29.67 mm in males. Comparing the results of the present study with those of the studies mentioned above revealed that the mean values are 3 to 5 millimeters lower, which is likely to as a result of the ethnic variation. The area in this study was estimated through two formulas: Radinsky's and Teixeria's. Despite the fact that the area values achieved through Teixeria's formula, Area (*T*), were more than those obtained through Radinsky's formula, Area (*R*), the statistical analysis performed by ROC and BLR showed the area under the curve to be 0.832 for both areas. In their study, Kanchan et al. (2013) examined 118 dry skulls in south Indian ethnic group and observed that the foramen areas calculated using Teixeria's and Radinsky's formulas are better predictors of sex than the transverse and sagittal dimensions as indicated in the present study. The current study indicated the capacity of each dimension to predict sex. It was observed that sex predictability was highest for the area of 0.832 for area of foramen, 0.809 for transverse diameter, and 0.759 for sagittal diameter. Similar to this observation are those reported by Uthman et al. (69.3% for area) [(1)], and Raghavendra Babu et al. who showed a greater predictability for sagittal diameter (86.5%) and area (81.6%, 82.2%) in comparison with transverse diameter (65.4%) (3).

Clinical relevance

The present study was aimed at determining sex dimorphism of foramen magnum dimensions. However, because of enormous overlapping of female and male values, depending solely on the foramen measurements is not recommended. However, given the high capacity of foramen magnum dimensions in determining sex, as shown in the present study and previously conducted ones, the foramen measurements can be employed as a supplement to other sexing evidence available in order to exactly ascertain the sex of the skeleton.

Acknowledgement:

Our special thanks and respect to Hassan Baba Rasul for his help and support. Our special thanks and respect to the current and previous staff of x-ray department in Sulaimani Teaching Hospital, for their help and support.

Conflict of interest and source of funding

Nil

.

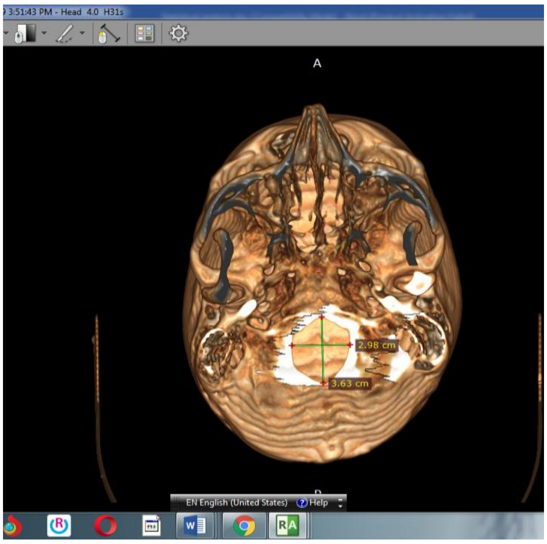

Fig.(1): The skull base showing foramen magnum transverse and sagittal diameters measuring by RadiAnt DICOM viewer

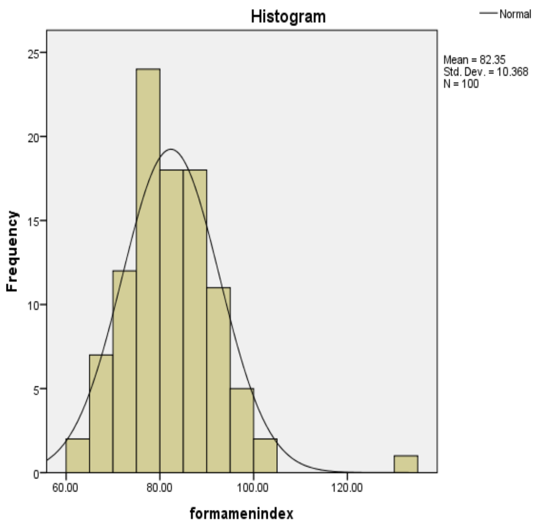

Fig.(2): The values of foreman index shown a high interindividual variability

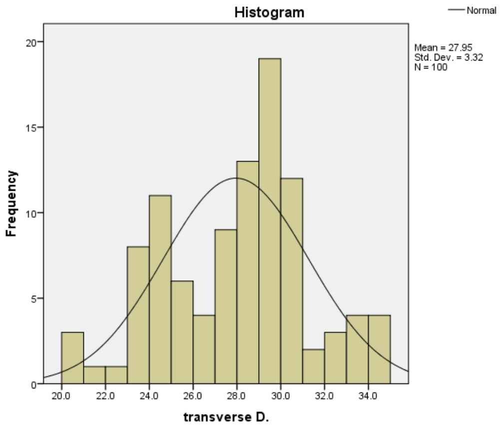

Fig.(3): A high interindividual variability was observed in the values of transverse diameter (mm)

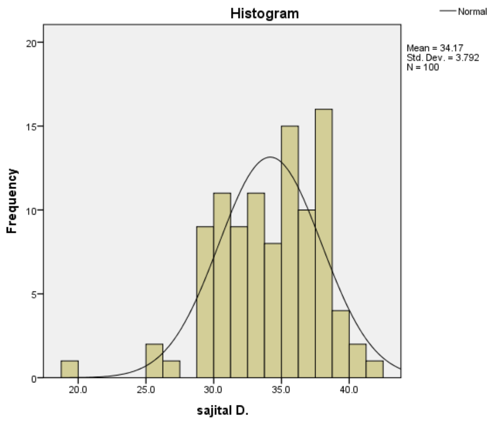

Fig.(4): A high interindividual variability was observed in the values of sagittal diameter (mm)

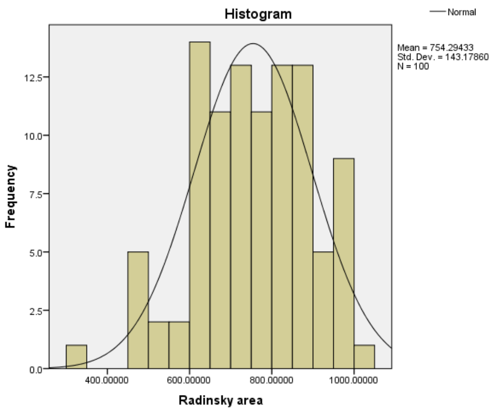

Fig.(5): A high interindividual variability was observed in the values of Radinsky area

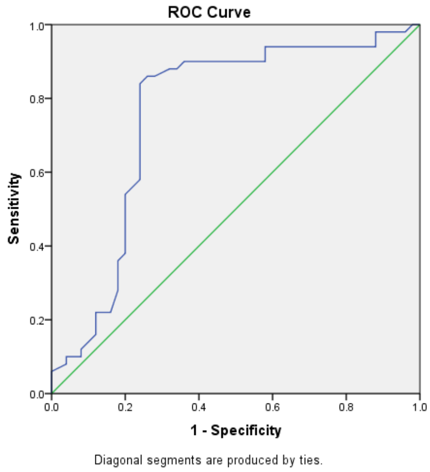

Fig.(6): ROC curve for the predicted chance of sagittal diameter

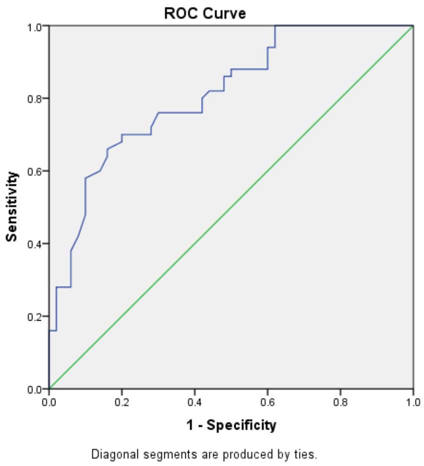

Fig.(7): ROC curve for the predicted chance of transverse diameter

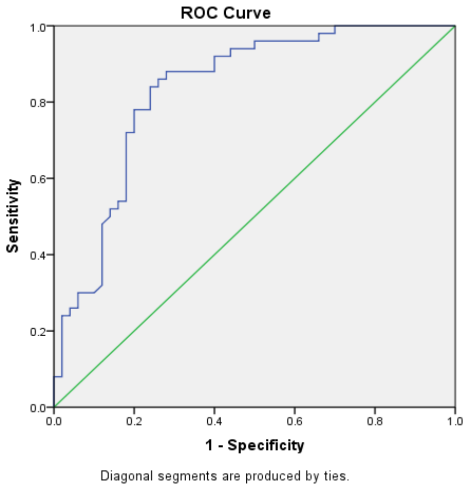

Fig.(8): ROC curve for the predicted chance of areas

Table (1):- Descriptive analysis, means and ranges for all the dimensions in both sexes using independent t-test

	Male		**Female**		P value*
	Range	Mean (SD)	Range	Mean (SD)	
Sajital D.	26 - 42	35.84 (2.95)	19.8 – 39.9	32.50 (3.83)	< 0.001
Transverse D.	24.6 – 34.9	29.67 (2.69)	20.2 – 32.7	26.23(3.00)	< 0.001
Radinsky area	612.2 – 1010.6	834.45 (100.79)	318.6 – 983.1	674.14 (134.72)	< 0.001
Teixeria area	619.8 - 1017.4	845.09 (100.22)	321.8 – 998.7	690.56 (137.97)	< 0.001
Foramen magnum index	64.7 – 132.3	83.42 (11.35)	61.6 – 103.5	81.28 (9.28)	0.30
Circumference	88.2 – 113.0	102.8 (6.2)	63.3 – 111.5	92.2 (9.4)	< 0.001

Table (2):- Descriptive analysis, means and ranges for all the dimensions in both sexes using Mann Whitney- test

	Male		**Female**		**P value***
	Median	**Mean rank**	**Median**	**Mean rank**	
Sajital D.	36.15	64.04	32.25	37.57	< 0.001
Transverse D.	29.80	66.29	26.70	35.04	< 0.001
Radinsky area	842.30	67.61	658.67	33.90	< 0.001
Teixeria area	853.57	66.94	672.27	34.74	< 0.001
Foramen magnum index	82.73	52.76	80.02	48.24	0.44
Circumference	103.5	67.02	91.5	33.98	< 0.001

* Mann Whitney- test

Table(3):-The Binary Logistic Regression model for the determination of sex based on the dimensions of the foramen

		B	**S.E.**	**Wald**	**Sig.**	**Exp(B)**
Step 1a	**SagitalD**	16.66	3.96	17.68	0.00	17169350.99
	TransverseD	16.87	3.99	17.90	0.00	21169141.47
	Teixeriaarea	-0.65	0.15	17.59	0.00	0.52
	Radiniskyarea	-2.36	1.40	2.84	0.09	0.09
	Constant	-543.09	128.03	17.99	0.00	0.00

(The cut-off value is 0.5.)

Table(4):-Sensitivity, accuracy, and specificity for the three foramen dimensions

	Sensitivity	**Specificity**	**Accuracy**	**Area under curve**
Sagittal dimension	76.0%	84.0%	80.0%	0.759
Transverse dimension	66.0%	76.0%	71.0%	0.809
Areas	74.0%	86.0%	80.0%	0.832

References

1-Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. Dentomaxillofac Radiol. 2012; 41:197–202.

2-. Kanchan T, Gupta A, Krishan K. Craniometric analysis of foramen magnum for estimation of sex. Int J Med Health Pharma Biomed Engg. 2013;7:166–8.

3-Raghavendra Babu YP, Kanchan T, Attiku Y, Dixit PN, Kotian MS. Sex estimation from foramen magnum dimensions in an Indian population. J Forensic Leg Med. 2012;19:162–7.

4-Rai B, Kaur J. Evidence Based Forensic Dentistry. 1st ed. Berlin Heidelberg: Springer-Verlag:2013.

5- Rajendran R, Sivapathasundharam B. Shafer's Textbook of Pathology. 5th ed. New Delhi: Elsevier: 2007.

6- Rogers T. L. "Determining the sex of human remains through cranial morphology, "Journal of Forensic Sciences.2005; 50(3): 493–500.

7-Petju M., Suteerayongprasert A., Thongpud R., et al. Importance of dental records for victim identification following the Indian Ocean tsunami disaster in Thailand. Public Health. 2007; 121(4): 251–257.

8-Torimitsu S., Makino Y., Saitoh H., sakuma a., ishi n., yajima d., et al. Morphometric analysis of sex differences in contemporary Japanese pelves using multidetector computed tomography. Forensic Sci Int. 2015:257: 530.e1-530.e7

9-Cirpan S., Yonguc GN., Mas NG., et al. Morphological and Morphometric Analysis of Foramen Magnum: An Anatomical Aspect. J Craniofac Surg. 2016; 27(6): 1576–1578.

10-Cesmebasi A., Loukas M., Hogan E., et al. The Chiari malformations: a review with emphasis on anatomical traits. Clin Anat. 2015; 28(2): 184–194.

11- Isik N. Chiary Malformation and Syringomyelia. Türk Nöroşirürji Dergisi. 2013; 23(2): 185–194.

12- Ulutabanca H., Acer N., Küçük A., et al. Chiari type I malformation with high foramen magnum anomaly. Folia Morphol. 2015; 74(3): 402–406.

13 -Aydin S, Hanimoglu H, Tanriverdi T, et al. Chiari type I malformations in adults: a morphometric analysis of the posterior cranial fossa. Surg Neurol. 2005; 64(3): 237–41; discussion 241, doi: 10.1016/j.surneu.2005.02.021, in-dexed in Pubmed: 16099255.

14-M. H.Krag,D.L.Weaver, B. D. Beynnon, andL.D.Haugh,"Morphometry of the thoracic and lumbar spine related to transpedicular screw placement for surgical spinal fixation,"Spine, 1988;13(1) : 27–32.

15- Di Vella G, Campobasso CP, Dragone M, Introna F Jr. Skeletal sex determination by scapular measurements. Boll Soc Ital Biol Sper 1994;70:299-305

16-Soames RW. Grays Textbook of Anatomy. International Edition. New York: ChurchillLivingstone; 1995

17-René G., Sue B., Jason L.: Sex determination from the foramen magnum: discriminant function analysis in an eighteenth and nineteenth century British sample . Int J Legal Med. 2009;123(1):25-33.

18- Olivier G :Biometry of the human occipital bone,"Journal of Anatomy.1975; 120(3): 507–518.

19-Tanuj K.,Anadi G.,Kewal K."Metrical studies with sexual dimorphism in foramen magnum of human crania".Journal of the Anatomical Society of India.1984: 33(2): 85–89.

20- Sayee R., Janakiram S., Thomas I.M. :"Foramen magnum measurements of Crania from Karnataka, "Journal of the Anatomical Society of India. 1987: 36(2):87–89,

21- Kanodia G, Parihar V, Yadav YR, Bhatele PR, Sharma D. "Morphometric analysis of posterior fossa and foramen magnum,"Journal of Neurosciences in Rural Practice2012; 3(3):261–266,

22- vidisha G., ravi P.S., Sangeeta M., Nagaraju K., Sumit G. Sexual Dimorphism of Foramen Magnum between Two Different Groups of Indian Population:
A Cross‑Sectional Cone‑Beam Computed Tomography Study.Journal of Forensic Science and Medicine. 2018 ;4 (3) :150-155

23- M. P. Shepur, M. Magi, B. Nanjundappa, P. P. Havaldar, P. Gogi, and S. H. Saheb, "Morphometric analysis of foramenmagnum,"International Journal of Anatomy and Research,2014;.2:249–255.

24- R. Patel and C. D. Mehta, "Morphometric study of Foramen Magnum at the base of human skull in South Gujarat,"IOSR Journal of Dental and Medical Sciences,2014; 13,(.6),:23–25.

25-Brinkmann B . Forensic anthropology. Int J Legal Med .2007;121:431–432

26-Hermann B, Grupe G, Hummel S, Piepenbrink H, Schutkowski H . Prähistorische Anthropologie—Leitfaden der Feld- und Labormethoden. Springer, Berlin;1990.

27- Hamilton ME Sexual dimorphism in skeletal samples. In: Hall RL (ed) Sexual dimorphism in homo sapiens—a question of size. Praeger Publishers, New York, 1982; 107–163.