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Morphological Classification and Sexual Dimorphism of Hyoid Bone: New Approach

Igor Lekšan[1], Mladen Marcikić[2], Vasilije Nikolić[1], Radivoje Radić[1] and Robert Selthofer[1]

[1] Department of Anatomy, School of Medicine, J. J. Strossmayer University Osijek, Osijek, Croatia
[2] Department of Forensic Medicine, School of Medicine, J. J. Strossmayer University Osijek, Osijek, Croatia

A B S T R A C T

Hyoid bone is a part of viscerocranium placed between the tongue root and thyroid cartilage to which it is connected by thyrohyoid membrane. Widely accepted morphological classification does not exist. Sexual dimorphism was analysed in this study and new guidelines for anatomical classification of hyoid bones based on anthropometric parameters were given. Total number of analysed bones was 70. The bones were classified into three groups: symmetrical U-type, symmetrical V-type and asymmetrical type according to the angle between greater horns and the proportion of greater horns length. In the females incidence of asymmetrical type is considerably higher than in the males, while the incidence of symmetrical V-type is lower. The angle value that is on average higher in males may be the parameter indicating that in puberty hyoid bone, still not completely ossified, to some extent follows development of thyroid cartilage because of their close anatomical relation.

***Key words**: hyoid, morphology, dimorphism*

Introduction

Hyoid bone is a part of viscerocranium placed between the tongue root and thyroid cartilage to which it is connected by thyroid membrane. It is a part of both digestive and respiratory tracts. It is placed at the level of the fourth cervical vertebra and articulates with surrounding structures via muscles (suprahyoid and infrahyoid muscle groups) and ligaments (stylohyoid ligaments). It consists of three parts: body, two greater and two lesser horns (Figure 1). Widely accepted morphological classification does not exist. It is commonly classified into two types[1], hyperbolic (U-type) and parabolic (V-type), but there is also alternative classification model that recognizes five bone types: D-, B-, H-, U- and V-type[2]. Existance of large number of asymmetrical bones as well as the assumptions of sexual dimorphism make universal morphological classification even more difficult[3,4]. And besides, several retrospective epidemiological studies indicate that hyoid bone shape may also have forensic significance, especially because of the fact that hanging by the neck is the most common way of commiting suicide in our region[5]. It is considered that the incidence of fractures sustained in hanging and strangulation directly depends on the shape and bone calcification of the hyoid. This assumption is the consequence of significantly larger number of fractures in aged people due to ossification of joints[7] and calcification on increase responsible for losing elasticity and ability of shape adaptation to force impact on one hand, and on the other hand of specific morphological characteristics of fractured bones. The weak place where the fracture most frequently occurs is determined in this way. It is noticed that the fractured bones are longer in anterio-posterior direction and the fracture most frequently occurs in the mean or in the posterior third of the greater horn, mostly in places where curvature grade is between 30° and 60°[8]. However, except for general assumptions of sexual dimorphism and the attempts to classify hyoid bones into several types, a unanimous approach does not exist. Therefore the aim of this study is to analyse sexual dimorphism and set new guidelines in anatomical classification based on anthropometric parameters.

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Material and Methods

The hyoid bones from people of known age and sex used in this study were chosen randomly from the osteological collection of the Faculty of Medicine Department of Anatomy at the University J. J. Strossmayer in Osijek. Study of hyoid bones was conducted on 70 adults, out of which 35 (50%) were male and 35 (50%) were female, varying in age from 15–90 years, but the group was relatively homogenous in distribution according to age and sex, which was confirmed by χ^2 test (p=0.220). The test indicates there is significantly no difference between the sexes (Table 1), so the possible age influence on data reliability was eliminated. As the χ^2 test age limit the average age in the sample group, 60, was taken. Soft tissue was removed from the bones and the bones were fixated in 10% formaldehyde solution over 48 hours. After that the measurements were taken. Anthropometric measurements (Figure 2) were taken directly on cadaveric material with precision of one milimeter. Six standard dimensional parameters for characteristic hyoid bone parts were determined which gave us enough morphometric data to calculate other variables. First the spatial position of greater horns was determined by measuring the distance between the distal parts of greater horns (A) and the distance from anterior middle of the body to the line that connects greater horns (B) and then the position of lesser horns was determined by measuring the distance from anterior middle of the body to the line that connects lesser horns (C), and the distance between lesser horns (D). After that the length of greater horns was determined. First the distance between small and distal part of the greater horn at the right side (E) and between small and distal part of the greater horn at the left side (F) was measured. On the basis of variables obtained by measurings, the proportion (E/F) of the distance between small and distal part of the greater horn at the right side (E) and the distance between small and distal part of the greater horn at the left side (F) as well as the angle the greater horns make (α) was calculated (Figure 3). The angle α was calculated on the basis of four anthropometric variables (Figure 2). These were: the distance between distal parts of greater horns (A), the distance between lesser horns (D), the distance between small and distal part of the greater horn at the right side (E) and the distance between small and distal part of the greater horn at the left side (F). The angle was calculated using the following formula:

TABLE 1
AGE AND SEX RELATED SAMPLE DISTRIBUTION

Age	Male	Female	Total
≥ 60	16	11	27
< 60	19	24	43
Total	35	35	70

χ^2 = 1.507, p = 0.220

$$\alpha = \{[E^2 + F^2 - (A - D)^2] / [2EF]\} \times \cos^{-1}$$

Results

Average hyoid bone dimensions as well as possible dimensional proportions are presented in Table 2.

The table presents average, maximal and minimal dimensional values in general population. Except for dimensional characteristics in general population, sex dimensional differences are also presented (Table 3). Statistically significant dimensional differences between male and female hyoid bones were noticed, which was confirmed by Student t test. Female hyoid bones are on average smaller than male hyoid bones. Dimensional differences are mainly proportional, except for significant deviation in the distance from anterior body middle to the line connecting lesser horns where the average values in males and females are approximately equal. Also, sex distribution of hyoid bones according to shape needs to be determined. In addition to already known hyperbolic (U-type) and parabolic (V-type) hyoid bones as variants of symmetrically shaped hyoid bone[1], we decided to introduce a new type – asymmetrically shaped hyoid bone, as significant difference in the length of greater horns at the right and left side was noticed in certain number of analysed samples. In addition to visual approach, we decided to objectify the classification of hyoid bones. Thus the angle between the greater horns (α) became decisive criterion for classifying hyoid bones into symmetrical U-type or symmetrical V-type. On the other hand, disproportion of greater horns was a

Fig. 1. Hyoid bone parts.

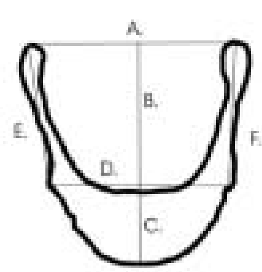

Fig. 2. Anthropometric variables.

Fig. 3. The angle between greater horns.

TABLE 2
DIMENSIONAL CHARACTERISTICS OF HYOID BONES

Parameter	N	Mean ± SD (cm)	Range (cm)
Distance between the distal parts of greater horns (A)	70	4.32 ± 0.70	3.00 ± 6.20
Distance from anterior middle of the body to the line that connects greater horns (B)	70	3.88 ± 0.49	2.30 ± 4.90
Distance from anterior middle of the body to the line that connects lesser horns (C)	70	1.58 ± 0.39	1.00 ± 3.20
Distance between lesser horns (D)	70	3.09 ± 0.45	1.70 ± 4.20
Distance between small and distal part of the greater horn at the right side (E)	70	2.68 ± 0.52	1.50 ± 3.90
Distance between small and distal part of the greater horn at the left side (F)	70	2.66 ± 0.49	1.60 ± 4.00

TABLE 3
COMPARISON OF DIMENSIONAL CHARACTERISTICS IN THE MALES AND IN THE FEMALES

Parameter	Sex	N	Mean ± SD	Range	Student t-test (p)
Distance A	male	35	4.58 ± 0.67	3.50–6.20	<0.01
	female	35	4.05 ± 0.64	3.00–5.70	
Distance B	male	35	4.14 ± 0.41	3.30–4.90	<0.01
	female	35	3.58 ± 0.39	2.30–4.10	
Distance C	male	35	1.55 ± 0.36	1.00–2.70	0.403
	female	35	1.59 ± 0.41	1.00.–3.20	
Distance D	male	35	3.31 ± 0.43	2.20–4.20	<0.01
	female	35	2.90 ± 0.39	1.70–3.60	
Distance E	male	35	2.94 ± 0.36	1.90–3.90	<0.01
	female	35	2.36 ± 0.50	1.50–3.60	
Distance F	male	35	2.93 ± 0.38	1.60–4.00	<0.01
	female	35	2.37 ± 0.42	1.50–3.30	
Angle between the grater horns	male	33	25.27 ± 13.57	1.98–60.0	0.307
	female	27	24.20 ± 14.68	0.10–55.4	

criterion for classifying hyoid bones into asymmetrical type. When classifying hyoid bones into morphological groups, asymmetrical bones, that is the bones with significant difference in the length of the greater horns at the right and left side, were set aside. When comparing the horns the proportion of their length was calculated and when the difference in greater horns length was higher than 10% the bones were classified as asymmetrical. Analysis of obtained data showed there were 10 asymmetrical bones in the sample group. In the group of asymmetrical bones indications of hyperbolic or parabolic morphology were disregarded and therefore excluded from further shape statistics and classified into a separate morphological group (Figure 4).

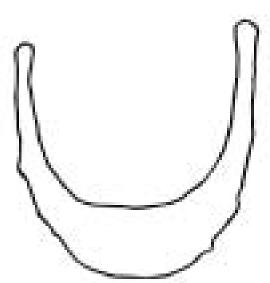

Fig. 4. Asymmetrical hyoid bone.

In further analysis the bones were classified into two symmetrical types: symmetrical U-type and symmetri-

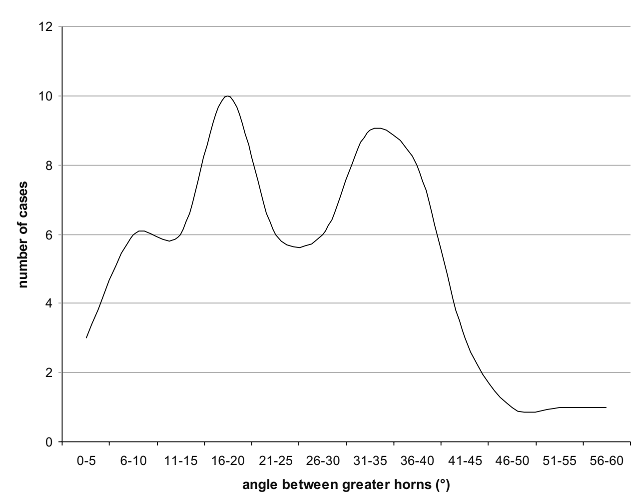

Fig. 5. Numerical distribution of symmetrical hyoid bones according to the angle between greater horns.

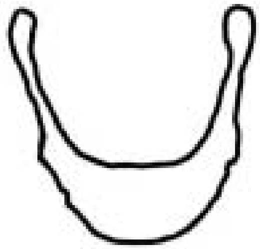

Fig. 6. Symmetrical U-type hyoid bone.

Fig. 7. Symmetrical V-type hyoid bone.

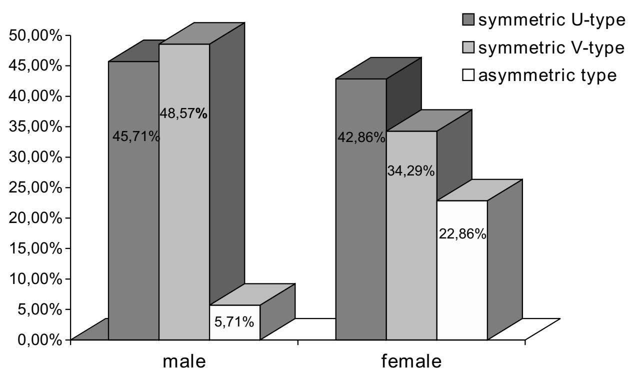

Fig. 8. Statistical incidence of hyoid morphological types in the males and in the females.

cal V-type. The angle α between the greater horns was calculated as it is shown in Figure 3. Distribution of bones according to angle α degree is presented in Figure 5, which points out there exist two groups of hyoid bones. On the basis of the downward-sloping curve the angle value of 25° was determined as borderline value between the two groups. Therefore the bones with the angle between greater horns lesser than 25° belong to symmetrical U-type (Figure 6), while the bones with the angle greater than 25° belong to symmetrical V-type (Figure 7). This approach helped us finally determine morphological types of hyoid bones. Figure 8 presents incidence of symmetrical hyoid bones and sex differences. It also shows that in the females symmetrical U-type is most common, while in the males symmetrical V-type is more common. After classiying the bones the incidence of certain types was determined. Tables 4 and 5 present distribution of single morphological types according to sex as well as statistical significance of these differences tested by χ^2 test. Although there is significant numerical difference in distribution in single bone types, it is not statistically significant, which implies that every type has not only morphological but also statistical validity in general population.

Discussion

The aim of this study was to analyse morphological characteristics of hyoid bones as well as incidence of single morphological types. In this research the emphasis was placed on determining the significance of sexual dimorphism which was mostly confirmed. The sample was homogenous regarding both sex and age distribution and thus the possibility of statistical error was minimized. Research methodology was based on anthropometric analysis of cadaveric samples. Six variables were measured and then the proportion of the greater horns length (E/F) and the angle between greater horns (α) was calculated. In our opinion this method is more precise than the methods used in previous studies[1] due to larger number of dimensional variables. Furthermore, the measurements taken on cadaveric samples and not on radiologic images[4,9] are more reliable. Namely, radiologic imaging allows dimensional deviations depending on radiation angle and bone tissue density, where bone parts of extremely low or high density are not clearly displayed. Anthropometric analysis showed that female hyoid bones are on average smaller in all dimensional proportions, which is confirmed by Student t test that revealed significant statistical difference between sexes. Analysing dimensional characteristics there is only one deviation from general sex pattern, when it comes to the distance from the anterior side of body to the line that connects lesser horns (C). This variable shows that lesser horns have on average equal position in regard to the anterior side of body. In spite of this female hyoid bones are shorter in anterio-posterior direction due to considerably shorter greater horns. Except in anterio-posterior direction, female hyoid bones are considerably narrower, that is smaller in transversal direction, which is also indicated with lesser distances between greater horns (A) and lesser horns (D). Except for significant sex dimensional differences there are also significant morphological differences between male and female hyoid bones. Morphologically, the bones were classified into

TABLE 4
DISTRIBUTION AND STATISTICAL SIGNIFICANCE OF INCIDENCE IN SYMMETRICAL AND ASYMMETRICAL HYOID BONES

Shape of hyoid bone	male	female	total
symmetric	33	27	60
assymmetric	2	8	10
total	35	35	70

χ^2 = 4.20, p = 0.041

TABLE 5
DISTRIBUTON AND STATISTICAL SIGNIFICANCE OF INCIDENCE IN SYMMETRICAL HYOID BONES

Shape of hyoid bone	male	female	total
symmetric U-tip	16	15	31
symmetric V-tip	17	12	29
total	33	27	60

χ^2 = 0.30, p = 0.586

three groups: symmetric U-type, symmetric V-type and asymmetric type.

When classifying symmetrical bones, the idea to determine greater horn detachment from sagittal plane, that is from the line beginning at mid-point of the body was taken into consideration. But, in that case the distance between lesser and greater horns would not be compared, which could have significant influence on obtained results. Then it would be possible that even the bones of symmetrical U-type that are short in anterioposterior direction and wide in the area of lesser horns make more obtuse angle. Therefore this idea was rejected and the angle α accepted as a reliable shape measure because using this angle as variable takes into consideration the influence of bone width in the area of lesser horns. In our opinion the criteria applied in hyoid bone classification in this study are more objective than those used in previous classification attempts[1,2]. By using dimensional parameters such as proportion of greater horns length (E/F) and the angle between greater horns (α) we excluded the possibility of classifying hyoid bones arbitrarily, only on the basis of visual criteria. On one hand, the criterion for classifying the bones into asymmetrical type was 10% difference in greater horns length and on the other hand the criterion for classifying the bones into symmetrical U-type and symmetrical V-type was numerical distribution of bones according to angle α value presented in Figure 5. On the basis of curve shape with two clearly pronounced peaks it is evident that the bones are classified into two groups. Consequently, borderline value of the angle α is clearly noticeable because of downward-sloping curve between two peaks and equals 25°. It may be concluded that on the basis of two above-mentioned variables the hyoid bones are plainly classified and there are no dilemmas about their classification. There is no objective ground for existance of additional groups presented in previous studies[2] because of very similar morphological characteristics between single groups as well as no statistical justification in general population. As it can be seen in Figure 5, along with asymmetrical type only two types are statistically justified: symmetrical U-type and symmetrical V-type. Consequently, previously mentioned U-and H-types (2) can be classified into the symmetrical U-type, and B- and V-types into the symmetrical V-type, while the asymmetrical type corresponds with D-type. Furthermore, we consider terms hyperbolic and parabolic used in previous studies[1] should be avoided because terms symmetrical U- and V-type describe real shape of hyoid bone more precisely. Finally, apart from above-mentioned differences in classification, shape distribution in general population corresponds with results of previous studies[1,2]. Obtained dimensional differences and incidence of single morpholo- gical types lead to conclusion that there are significant differences due to sexual dimorphism, which is manifested in already mentioned significantly smaller dimensions of female hyoid bones, above all dimensions of greater horns. On the other hand, there are significant differences in shape incidence. In the females incidence of asymmetrical type is considerably higher than in the males, while the incidence of symmetrical V-type is lower, which is in direct connection with the angle α value. The angle α value that is on average higher in the males, although statistically not very pronounced ($p= 0.353$), may be the parameter indicating that in puberty hyoid bone, still not completely ossified, to some extent follows development of thyroid cartilage because of their close anatomical relation. Its lamina dextra et sinistra make more acute angle in the males than in the females.

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I. Lekšan

Department of Anatomy, School of Medicine, »J. J. Strossmayer« University Osijek, J. Huttlera 4, 31000 Osijek, Croatia
e-mail: igor_leksan@net.hr

MORFOLOŠKA KLASIFIKACIJA I SPOLNI DIMORFIZAM HIOIDNE KOSTI – NOVI PROSTUP

S A Ž E T A K

Jezična kost dio je viscerokranija smještena između baze jezika i tiroidne hrskavice s kojom je povezana tirohioidnom membranom. Do danas ne postoji opće prihvaćena morfološka klasifikacija. U ovoj studiji smo proučavali spolne morfološke razlike i dali nove smjernice u anatomskoj klasifikaciji jezičnih kostiju na osnovu antropometrijskih pokazatelja. Ukupno je obrađeno 70 jezičnih kostiju. Kosti smo klasificirali u tri skupine: simetrični U-tip, simetrični V-tip i asimetrični tip na osnovu kuta između velikih rogova i omjer dužine velikih rogova. Postoje bitne razlike u zastupljenosti oblika, gdje u žena s jedne strane imamo znatno veći broj asimetričnih kostiju, a s druge strane manji broj kostiju simetričnoga V-tipa. Upravo prosječno veća vrijednost kuta u muškaraca mogla bi ukazivati da jezična kost u pubertetu dok još nije osificirana donekle prati razvoj tiroidne hrskavice s kojom je u uskim anatomskim odnosima.