Coll. Antropol. **30** (2006) 1: 43–47
Original scientific paper

Morphometric Analysis of the Sternum

Robert Selthofer[1], Vasilije Nikolić[1], Tomislav Mrčela[2], Radivoje Radić[1], Igor Lekšan[1], Igor Rudež[3] and Kristina Selthofer[4]

[1] Department of Anatomy, School of Medicine, University »J. J. Strossmayer«, Osijek, Croatia
[2] Faculty of Electrical Engineering, University »J. J. Strossmayer«, Osijek, Croatia
[3] Department of Cardiac Surgery, University Hospital Dubrava, Zagreb, Croatia
[4] Department of Cardiology, University Hospital Osijek, Osijek, Croatia

A B S T R A C T

Sternum has a great clinical significance, considering that median sternotomy is the most common surgical approach used in cardiac surgery. The aim of this study is to standardize the sternum according to size, shape and sex and to obtain ranges of the »standard sternum«. The study was done on 55 male and 35 female sterna of the average age of 65. Complex morphometric analysis of breadth, length and thickness of the sterna were performed on sternal segments which were defined by costal notches. Morphometric analysis shows that the general sternum structure in the females and in the males is equal. The standard dimensions of female and male sternum were determined. Standardization according to shape suggests that there is one standard sternum shape present in more than 2/3 of analysed samples of both sexes.

***Key words**: sternum, morphometric analyse, median sternotomy*

Introduction

Sternum (the breastbone) is a flat bone situated vertically in the median and anterior part of the thoracic skeleton. It has a great clinical significance, considering that median sternotomy is the most common surgical approach used in cardiac surgery. When applying this surgical intervention, the sternum is cut through in midline from the jugular notch to the xiphoid process and thus access to the anterior mediastinal organs, especially to the heart and major blood vessels is gained[1,2].

Dehiscence of the sternotomy closure and consequential separation of the sternum halves as well as development of deep mediastinitis is a relatively rare but a serious complication. Incidence rate is between 0.5–2.5%[3], but some studies show that it can be higher, even up to 8%[4]. Suture dehiscences may be influenced by various factors, such as suture technique, osteoporosis level, sex, comorbidity, various perioperative and postoperative factors and many others[5,6].

Clinical significance of the sternum is also manifested during procedures of cardiopulmonary resuscitation. Sternum fracture is common consequence of active compressive-decompressive cardiopulmonary resuscitation (ACD–CPR), in other words of artificial respiration and heart massage. Fractures sustained during this procedure may cause severe heart injuries which often lead to patient's death[7,8]. Studies conducted on cadavers show that sternum fractures are more common in the females over 50[9]. The important factor causing fractures, besides osteoporosis, is considered to be the fact that female sternum is considerably thinner than the male and therefore more prone to fractures[10]. With regard to exceptional variability of sternum dimensions and shape, it is very probable that divergence from »standard sternum« may also influence occurrence of sternal dehiscence and cause proneness to fractures. Despite that, morphometry of different organs and parts of the skeleton is well known[11], data of the sternum morphology and morphometry are still insuficient[12]. Those findings are of great importance in anthropological researches[13,14].

The aim of this study is to standardize the sternum according to size, shape and sex by applying complex morphometric analysis, and to obtain ranges of the »standard sternum« according to the sex and to the individual dimensions.

Received for publication November 17, 2005

Materials and Methods

Material for the present study consisted of 90 human sterna: 35 female and 55 male, of the average age of 65. The specimens were taken from osteological collection of Faculty of Medicine, Department of Anatomy at the University »J. J. Strossmayer« in Osijek, Croatia. Specimens were fixated in formalin solution over three month. Complex morphometric analysis was performed[15,16].

Total sternum length, sternal angle, breadth, length and thickness of the manubrium and the body of the sternum were measured.

Total sternum length is the distance measured from the jugular notch to the xiphoid process end[17]. While measuring the sternal angle, the sternum was set down and fixed in the lateral position at the right angle. On the underground below the sternum, next to the sternum posterior surface, the points were marked immediately below the sternal synchondrosis, next to the lower end of clavicular notch and below the lower end of the fourth costal notch. The sternal angle was determined by drawing lines to join the points marked on the underground. Sternal angle was measured with a protractor with precision of 0.5@.

The breadth, length and thickness of the manubrium and the body of the sternum were also determined (Figure 1). The manubrium breadth was measured in the area below the first costal notch and in the superior end of the second costal notch, in other words immediately above the sternal synchondrosis. These were the points on the samples representing the least and the greatest manubrium breadth. The body breadth was measured on several points: in the middle of the distance between the second and third, the third and fourth, the fourth and fifth, the fifth and sixth and between the sixth and seventh costal notches. The manubrium thickness was measured on two points which represent extreme values of manubrium thickness. The greatest thickness was measured at the intersection of the central longitudinal line and the line joining central points of clavicular notches. The least thickness was determined at the point where the central longitudinal line intersected manubrium at the middle of its length. The samples were measured for manubrium length, the length between the second and fourth costal notches, the length from the fourth costal notch to the xiphoid process and the length of the xiphoid process. The manubrium length was determined by measuring the distance between the centre of the jugular notch and the centre of the sternal synchondrosis. The breadth, length and thickness of the sternum were measured with micrometer with precision of 0.1 mm.

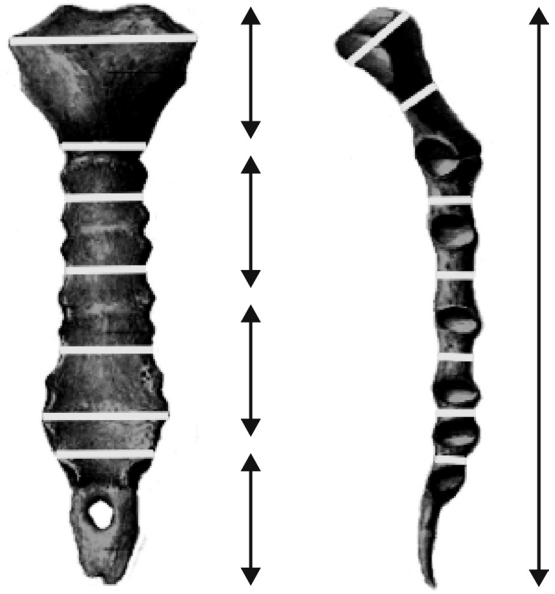

Fig. 1. Breadth, length, thickness of the sternum segments and total length of the sternum.

Results

Morphometric analyse shows that the proportional sternum structure in the females and in the males is equal. Indexes of manubrium breadth and length proportion as well as of body of the sternum breadth and length proportion are almost identical in sterni of both sexes (Table 1). The greatest manubrium breadth is approximately equal or greater than its length, while the average body of the sternum breadth equals approximately 1/3 of its length. There is no statistical significance in sternal angle values.

Knowledge of general sternum structure and of the results of comprehensive morphometric analysis leads to conclusion that there is »standard or typical sternum«. Although general sternum structure in males and in females is almost identical, there are significant sex differ-

TABLE 1
MANUBRIUM INDEX, BODY OF THE STERNUM INDEX AND STERNUM ANGLE

	Female (X±SD, cm)	Male (X±SD, cm)	t	p
IM	1.18±0.16	1.24±0.17	1.21	0.23
IC	0.29±0.07	0.29±0.06	–0.28	0.78
Sternum angle	165.30±7.19	166.35±7.38	0.37	0.71

IM – manubrium index (manubrium width / manubrium length), IC – body of the sternum index (sternum body width / sternum body length)

ences in absolute values of the most of measured parameters. Standard sternum dimensions are determined as mean value of measured parameters with divergence of one standard deviation (Table 2). Analysis of these dimensions shows that more than 2/3 of sternum specimens regardless of sex belong to the »standard sternum« group according to their dimensions.

TABLE 2
STANDARD FEMALE AND MALE STERNUM

Manubrium	Female (X±SD)	Male (X±SD)	p
Max. Breadth (cm)	6.06±0.81	6.82±0.80	<0.05
Min. Breadth (cm)	3.13±0.33	3.68±0.55	<0.05
Average breadth (cm)	4.59±0.50	5.25±0.68	<0.05
Length (cm)	5.24±0.45	5.52±0.36	<0.05
Average thickness (cm)	1.12±0.09	1.26±0.19	<0.05
Area (cm^2)	24.13±3.71	28.98±3.48	<0.05
Volume (cm^3)	27.49±5.53	37.33±6.30	<0.05
Body			
Average breadth (cm)	2.71±0.31	3.07±0.43	<0.05
Length (cm)	9.42±1.40	10.97±1.44	<0.05
Average thickness (cm)	0.92±0.12	1.00±0.11	<0.05
Area (cm^2)	26.14±4.79	34.80±5.50	<0.05
Volume (cm^3)	24.35±5.94	35.08±6.81	<0.05
Sternum			
Total length (cm)	18.29±1.74	20.86±1.46	<0.05
Area (cm^2)	50.26±7.45	63.86±7.68	<0.05
Volume (cm^3)	51.84±10.57	72.42±11.54	<0.05

After measuring sternum breadth section by section, where each section is determined by costal cartilage attachments to the breastbone, the obtained data suggest that there are different shapes of manubrium and body of the sternum.

Typical or standard shape was determined as mean value of measured parameters with divergence of one standard deviation. When morphometric measures diverge more than one standard deviation, the sternum has atypical or non-standard shape.

Manubrium shape was determined according to proportions of the least and the greatest breadth, that is the proportion between the breadths measured immediately above the second costal notch and the breadth between clavicular notches.

Body of the sternum shape was determined according to the proportion of basic and the greatest sternum breadth. In male samples it is measured between the fifth and sixth costal notches and in female samples between the fourth and fifth costal notches.

Basic corpus sterni breadth is average breadth measured between the second and third and between sixth and seventh costal notches, because it was noticed that the upper and the lower part of the body of the sternum have constant breadth. The middle part varies most in single sections breadth and therefore this part is responsible for shape variations. Results show that there is one standard, typical shape that more than 2/3 of analysed specimens have. Identical shapes and almost identical incidence of shapes are found in both sexes. Standard manubrium has *trapezoid* shape, which is deter- mined by breadth proportion of 0.50 in females and 0.53 in males. The remaining third of specimens is divided into extreme groups that diverge from standard shape (Table 3). The values of manubrium breadth proportions lower than one standard deviation determine *triangular* manubrium shape, while the values higher than one standard deviation determine *quadrangular* shape. Standard shape of the body of the sternum, named *longitudinal oval shape,* is determined by proportion that is 0.64 in females and 0.76 in males. *O-shape* of the body of the sternum is noticed in sterni where the breadth proportions are more than one standard deviation lower, while the body where the proportion is more than one standard deviation higher has *flat shape* (Figure 2).

Discussion

Complications in heart surgeries are frequently connected with suture dehiscence of the sternum and development of deep mediastinitis which is followed by high mortality rate[6,18,19].

Results show that there is general sternum structure equal for both sexes. However, the absolute values of measured parameters are significantly different. Female sternum is on average shorter, narrower and thinner than male sternum. Previous studies indicate that female sex is additional risk factor for suture dehiscence of the sternum[20].

TABLE 3
INCIDENCE OF STERNUM SHAPES ACCORDING TO SEX

Mandibularium		Shape	Triangular	Trapezoid	Quadrangular
	%	Female	14.8	74.1	11.1
		Male	9.1	79.5	11.4
		Shape	O-shape	Longitudinal oval	Flat
Body	%	Female	12.5	75	12.5
		Male	7	79	14

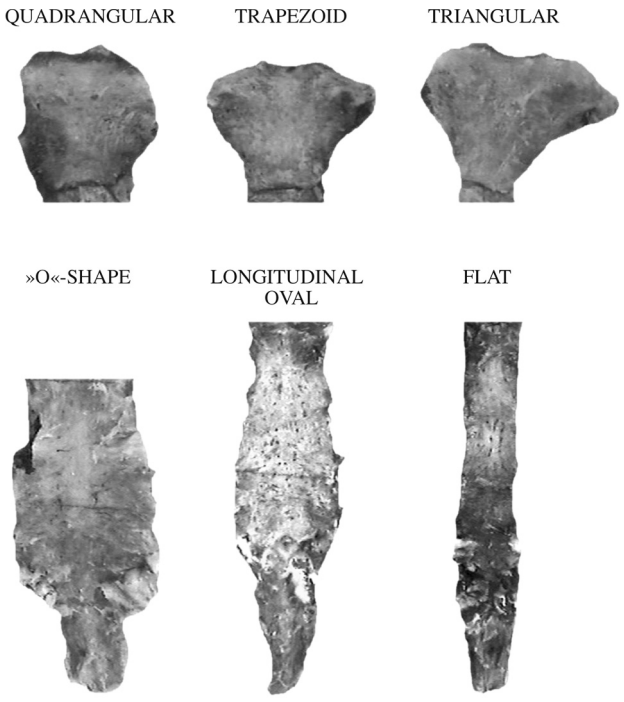

Fig. 2. Types of sternum shapes.

Standardization according to shape suggests that there is one standard sternum shape present in more than 2/3 of analysed samples of both sexes. The remaining third of samples represent extreme variants of the standard shape, diverging from the standard shape values for more than one standard deviation. However, their incidence is relatively rare. This result is expected considering biomechanical movements and anatomical location of the sternum that is exposed to constant movements in the process of respiration[17,21]. The thorax shape of a truncated cone and continuous inspiration/ expiration movements set conditions for the longitudinal oval sternum shape, which is named »standard sternum«. All the analysed parameters lead to conclusion that there is one standard sternum shape with relatively rare variations that form a group of atypical sternum shapes, which represent modifications of the standard shape.

Determining the standard dimensions of female and male sternum and distinguishing typical from atypical sternum shape may help in standardization of studies investigating qualities of various kinds of sutures and materials used in median sternotomy performed on biological material. Results of morphometric analysis present foundation for further research of biomechanical features of the sternum. The obtained data may also help in efficient planning of operative interventions and serve as additional information in assessment of sternum suture dehiscence risk[22].

Acknowledgements

This work was supported by the Ministry of Science of the Republic of Croatia (Grant No. 0219011).

REFERENCES

1. CHENG, W., D. E. CAMERON, K. E. WARDEN, J. D. FOUGER, V. L. GOTT, Ann. Thorac. Surg., 55 (1993) 737. — 2. LOSANOFF, J. E., J. W. JONES, B. W. RICHMAN, Cardiovasc. Surg., 10 (2002) 102. — 3. SATTA, J., J. LAHTINEN, L. RAISANEN, E. SALMELA, T. JUVONEN, Scand. Cardiovasc. J., 32 (1998) 29. — 4. CULLIFORD, A. T., J. N. CUNNINGHAM, R. H. ZEFF, J. Thorac. Cardiovasc. Surg., 72 (1976) 714. — 5. JUTLEY, R. S., D. E. T. SHEPERD, D. W. L HUKINS, R. R. JEFFREY, Cardiovasc. Surg., 11 (2003) 85. — 6. STAHLE, E., A. TAMMELIN, R. BERGSTROM, Eur. J. Cardio-thorac. Surg., 11 (1997) 1146. — 7. BAUBIN, M., W. RABL, K. P. PFEIFFER, A. BENZER, H.GILLY, Resuscitation, 43 (1999) 9. — 8. RABL, W., M. BAUBIN, C. HAID, K. P. PFEIFFER, R. SCHEITHAUER, Forensic Sci. Int., 89 (1997) 175. — 9. DE WAELE, J. J., P. A. A. CALLE, L. BLONDEEL, F. E. G. VERMASSEN, Eur. J. Trauma, 28 (2002) 178. — 10. STINI, W. A., Coll Antropol., 27 (2003) 23. — 11. SAVKOVIĆ, A., V. NIKOLIĆ, J. DELIĆ, E. ISAKOVIĆ, Coll Antropol., 28 (2004) 701. — 12. SELTHOFER, R: Problem of structure and strength of the sternum after cardiac surgery median sternotomy and suture. Ph. D. Thesis. In Croat. (School of Medicine, University »J. J. Strossmayer«, Osijek, 2005). — 13. BOOKSTEIN, F. L., D. E. SLICE, P. H. GUNZ, P. H. MITTEROECKER, Coll. Antropol., 28 (2004) 121. — 14. RUDAN, I., T. ŠKARIĆ-JURIĆ, N. SMOLEJ-NARANČIĆ, B. JANIĆIJEVIĆ, D. RUDAN, I. MARTINOVIĆ KLARIĆ, L. BARAĆ, M. PERIČIĆ, R. GALIĆ, M. LETHBRIDGE-ČEJKU, P. RUDAN, Coll. Antropol., 28 (2004) 585. — 15. KLARIĆ, I. M., F. LOVAŠIĆ, B. BUDISELIĆ, T. ŠKARIĆ-JURIĆ, L. SZIROVICZA, A. CHAVENTRE, Coll. Antropol., 23 (1999) 91. — 16. LEKŠAN, I., M. MARCIKIĆ, V. NIKOLIĆ, R. RADIĆ, R. SELTHOFER, Coll. Antropol., 29 (2005) 237. — 17. KRMPOTIĆ-NEMANIĆ, J.: Anatomija čovjeka. In Croat. (Medicinska naklada, Zagreb, 1993). — 18. ZACHARIAS, A., R. H. HABIB, Chest, 110 (1996) 1173. — 19. BASKETT, R. J., C. E. MACDOUGALL, D. B. ROSS, Ann. Thorac. Surg., 67 (1999) 462. — 20. BREYER, R., S. MILLS, A. HUDSPETH, F. JONSTON, A. CORDELL, Ann. Thorac. Surg., 37 (1984) 412. — 21. NIKOLIĆ, V., M. HUDEC: Principi i elementi biomehanike. In Croat. (Školska knjiga, Zagreb, 1988). — 22. RUDEŽ, I.: Clinical and biomechanic properties of new method for sternum closure after median sternotomy. Ph. D. Thesis. In Croat. (School of Medicine, University »J. J. Strossmayer«, Osijek, 2005).

R. Selthofer

Department of Anatomy, Faculty of Medicine, University »J. J. Strossmayer«, Huttlerova 4, 31000 Osijek, Croatia
e-mail: selthofer.robert@kbo.hr

MORFOMETRIJSKA ANALIZA PRSNE KOSTI

S A Ž E T A K

Sternum ima veliko kliničko značenje s obzirom da medijana sternotomija predstavlja najčešći kirurški pristup u kardijalnoj kirurgiji. Cilj rada je bio kompleksnom morfometrijskom analizom tipizirati prsnu kost po veličini, obliku i spolu te na osnovi takve analize dobiti dimenzije standardnog sternuma. Istraživanje je provedeno na 55 muških i 35 ženskih sternuma prosječne dobi 65 godina. Provedena je kompleksna morfometrijska analiza širina, duljina i debljina prsne kosti po definiranim segmentima koji su određeni prema rebrenim urezima. Rezultati pokazuju da postoji jedinstven opći plan građe prsne kosti neovisan o spolu. Dobivene su vrijednosti standardnog ženskog i muškog sternuma. Tipizacijom sternuma po obliku utvrđeno je da neovisno o spolu dvije trećine uzoraka ima standardan oblik.