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The morphology of the right atrioventricular valve in the adult human heart

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Studies of the morphometry and normal anatomy of the tricuspid valve are in constant demand. Knowledge of the morphology of the normal tricuspid valve may be useful, for example in the context of the transfer of a leaflet of the tricuspid valve for repair or insufficiency of the mitral valve, in repair of the tricuspid valve after blunt chest trauma and in other surgical techniques of this region. In this study, performed in a group of 107 formalin-fixed adult human hearts, we attempted to assess the form and number of the main and accessory cusps in the tricuspid valve. Rare anatomical variants of the tricuspid valve were found. Using a planimeter we evaluated the surface area of the tricuspid valve and particular leaflets. With the help of a Vernier scale we measured the length and height of individual leaflets of the tricuspid valve and the length of the commissures. No differences were found between the length of the anterior and septal leaflets. The posterior leaflet was the shortest, while the anterior leaflet was the widest and had the largest surface area. The posterior leaflet was wider than the septal leaflet and had the smallest surface area. No differences were found between the main and accessory leaflets in the length of the commissures.

Key words: tricuspid valve, human heart, morphology, right ventricle, leaflet

INTRODUCTION

The tricuspid valve has become a subject of continual interest owing to the progress in cardiosurgical techniques and electrophysiology [16]. Surgical repair of the mitral valve using tissue of the tricuspid valve is becoming ever more frequent as a result of the reduced rate of complications in comparison with repair using synthetic materials. Plastic repair of the tricuspid valve is increasingly being performed in children with complicated defects of the heart [9]. Frequent infectious complications of the tricuspid valve are sometimes indications for surgical treatment, including severing the infected part of leaflet or replacement with a biological prosthesis. This demands great anatomical knowledge [4, 18, 34]. The high degree of thrombogenicity of artificial valves implanted into the tricuspid ostium argues a superiority of repair techniques over the supply of artificial valves [5].

Surgical repair of the mitral and tricuspid valves are performed simultaneously using the Vega method (by decreasing the circuit of the right atrioventricular ostium with a ring) or, in the event of stenosis, with the balloon-plastic method [20]. Post-traumatic damage of the tricuspid valve is more frequent than damage of the mitral valve because the tricuspid valve is located anteriorly to the mitral valve and closer to the chest wall [6, 7, 25].

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The increasing number of heart transplantations demonstrates the problem of damage to the tricuspid valve as a complication of myocardial biopsy [24]. An extraordinary ability to compensate for the tricuspid valve has been shown by means of novel imaging techniques of the heart. Many cases of insufficiency of the tricuspid valve are subclinical [11, 13].

On the evidence of existing studies and textbooks the tricuspid valve is a heterogeneous structure with a great range of variants and features which may be treated as evolutionary atavisms [10, 22, 27, 32]. Accessory leaflets and their incidence and configuration are still controversial, although many studies have treated this question since the early 20th century [12, 17, 24, 26]. Despite the great interest in cardioanatomy, the issue of the morphology of the tricuspid valve is still unresolved.

MATERIAL AND METHODS

The study material consisted of 107 formalin-fixed adult human hearts of both sexes (30 female and 77 male) which were without macroscopic developmental failures or pathological changes. The hearts were aged between 18 and 90 and were divided into 5 age-dependent groups: from 18 to 28 years (21 male and 4 female), from 29 to 40 years (21 male and 5 female), from 41 to 55 years (22 male and 13 female), from 56 to 73 years (13 male and 5 female) and from 74 to 90 years (9 male and 4 female). The hearts were taken from the collection of the Department of Anatomy of the Medical University of Gdańsk, Poland.

The hearts were opened by dissection of the wall of right atrium from the ostium of the superior cardinal vein and then along the right margin of the right ventricle. The tricuspid valves were cut usually between the anterior and posterior leaflets. In order to measure the length and height of particular leaflets we used the Vernier scale. The shapes of the excised valves were copied into graph paper with the points of attachment of the tendinous chords marked (Fig. 1). The surface area of particular leaflets was measured with a planimeter. The number of leaflets, their location, morphology and size were studied. Using as the criterion of division the number of cusps of the tricuspid valve, we established six types and these were divided into subtypes on the basis of the location of accessory leaflets. Our earlier classification [14, 21] was extended with type 0 and the subtypes referred to. Types 3 and 4 were divided into subtypes.

The height of a leaflet was defined according to Szostakiewicz-Sawicka [26, 27] as the greatest distance between the basic and free margin of a leaflet. The length of a commissure was defined as the shortest distance between the basic and free margin of a leaflet in an intercuspidal incisura. The height of a leaflet was defined according to Szostakiewicz-Sawicka [26, 27] as the greatest distance between the intercuspidal incisurae. Figure 2 shows the height and length of leaflets.

Accessory leaflets were divided according to the earlier classification [26] into two groups: true and spurious accessory leaflets. A "true" accessory leaflet was understood to be one which received tendinous chords from two or more groups of papillary

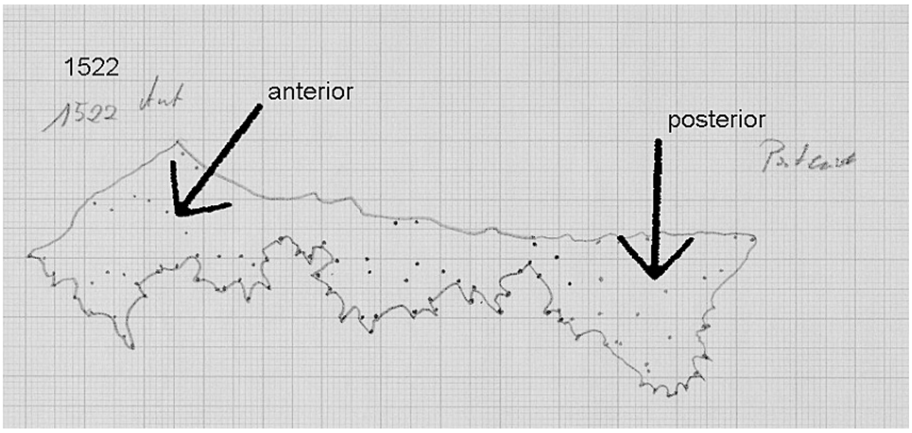

Figure 1. Copied into graph tricuspid valve with points of attachment of tendinous chords. Example of a tricuspid valve (no. 1522) copied onto graph paper with points of attachment of the tendinous chords. The arrow labelled "anterior" shows the anterior leaflet of the tricuspid valve, while the arrow labelled "posterior" shows the posterior leaflet of the tricuspid valve. Points in the illustration show the points of attachment of the tendinous chords.

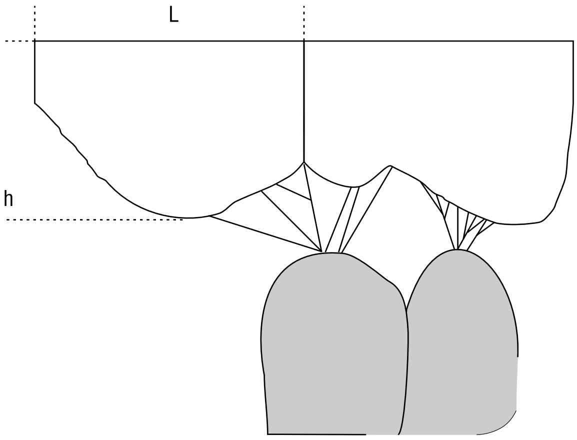

Figure 2. Scheme of the length and height of a leaflet. The letter "L" marks the length of the leaflet and "h" the height.

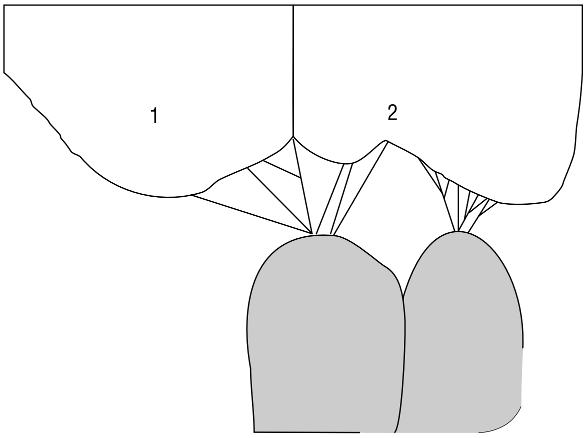

Figure 3. Scheme of true and spurious accessory leaflets. Scheme of spurious (1) and true (2) accessory leaflets of the tricuspid valve.

muscles, and a "spurious" leaflet as one receiving them from one group of papillary muscles (Figs. 3–5).

RESULTS

The analysis started with the classification of valves. The frequencies with which particular types and subtypes occurred are presented in Table 1.

We distinguished type 0 of the tricuspid valve as a form consisting of two main leaflets, anterior and septoposterior. This type was further divided into two subtypes: 0x, which consisted of only two main leaflets, and 0y, with two main leaflets and one spurious accessory cusp. One heart in the group belonged to the latter subtype and the length of the

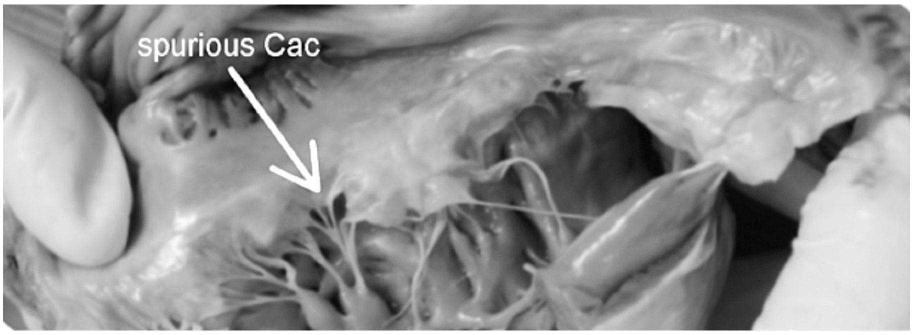

Figure 4. Spurious accessory leaflet. The arrow indicates a spurious accessory leaflet.

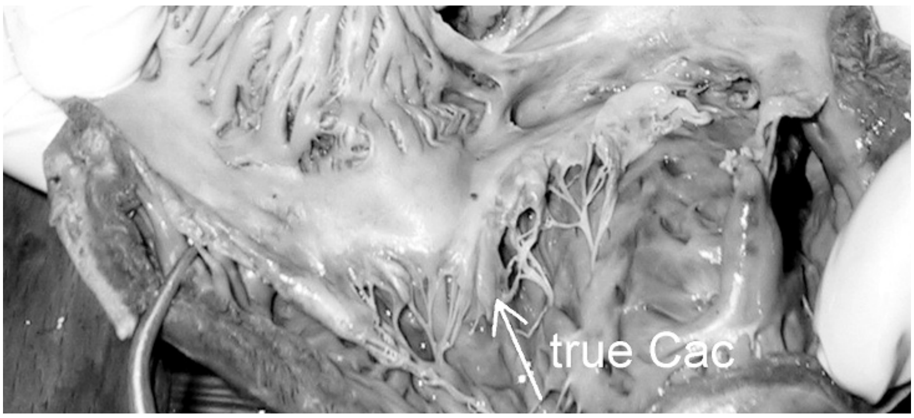

Figure 5. True accessory leaflet. The arrow indicates a true accessory leaflet.

Table 1. Frequency of occurrence of particular types of tricuspid valve in the group studied

Type	Number of leaflets	Frequency of occurrence in the group studied (%)
0X	2	1.83
0Y	3	0.92
1	3	10.09
2	4	41.28
Subtype A		22.02
Subtype B		9.17
Subtype C		10.09
3	5	34.86
Subtype A		3.67
Subtype B		10.09
Subtype C		6.42
Subtype D		2.75
Subtype E		9.17
Subtype F		2.75
4	6	8.26
Subtype A		4.59
Subtype B		1.83
Subtype C		0.92
Subtype D		0.92
5	7	2.75
Subtype A		0.92
Subtype B		1.83

accessory leaflet in this heart was 9.5 mm as compared to the 41 mm length of the anterior part of the attachment of the valve. This fact determined the classification of this cusp as "accessory" according to the criteria established by Szostakiewicz-Sawicka [26, 27].

Type 0 of the tricuspid valve occurred in 2.75% of the group studied, with subtype 0x in 1.83% (Fig. 6) and subtype 0y in 0.92% (Fig. 7). The "typical" form of the tricuspid valve, type 1, was present in 10.09%. The four-cuspidal form, type 2, was present in 41.28% of the hearts studied, subtype 2A in 20.02%, subtype 2B in 9.17% and 2C in 10.09% of the group examined. The five-cuspidal variant, type 3, was observed in 34.86% of the group studied. This variant was divided into six subtypes. Classification of subtypes 3A and 3B was made according to our previous paper. Subtype 3A occurred in 3.67% of the group studied. Two accessory cusps in this subtype were located between the anterior cusp (CA) and the posterior cusp (CS). Accessory cusps were numbered counting from the side of CA. Subtype 3B appeared in 10.09% and took a form in which the first accessory leaflet was located between the anterior and septal leaflets (CS) and the second between CP and CS. Subtypes 3C–3F, which were not observed in previous studies, were found. Subtype 3C has valves made up of accessory leaflets localised as follows: the first between CA and CS and the second between CS and CP. This subtype was observed in 6.42%. Subtype 3D appeared in 2.75% and contained valves with two accessory leaflets between CA and CP. Accessory cusps were numbered counting from the side of CP. Subtype E contained valves with two accessory leaflets between CS and CP and was found it in 9.17% of the hearts studied. Subtype 3F appeared in 2.75% and contained valves with the first of the accessory leaflets between CS and CP and the second between CA and CP.

A six-cuspidal form (type 4), in which three accessory cusps were present, was quite rare, this

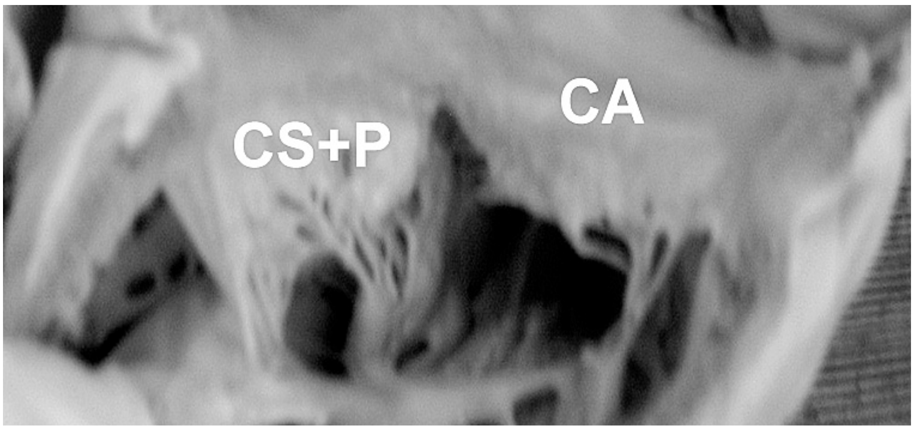

Figure 6. Photograph of a tricuspid valve of type 0x. CA — anterior leaflet, CS+P — septoposterior leaflet.

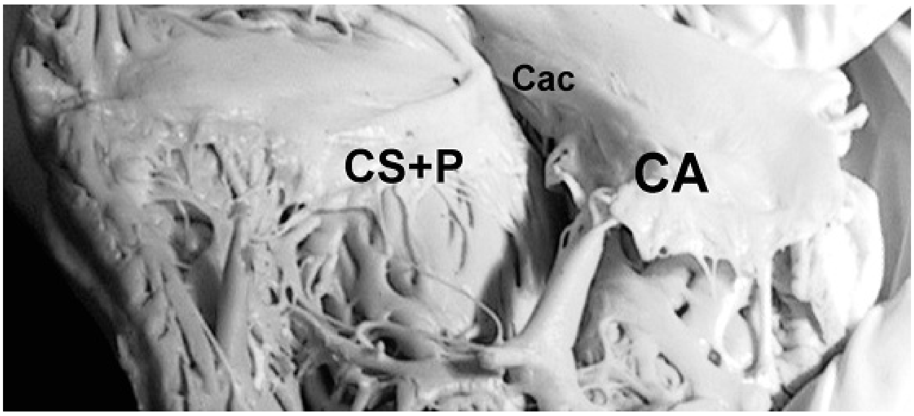

Figure 7. Photograph of a tricuspid valve of type 0y. This subtype also includes an accessory leaflet (Cac).

variant being observed in 8.26% of the group studied. On the basis of the location of the accessory cusps we distinguished four subtypes. Under subtype 4A we classified valves with one accessory leaflet between CA and CS, described as Cac1, and two accessory leaflets between CS and CP numbered, counting from CS, as Cac2 and Cac3. As subtype 4B we distinguished valves with two accessory cusps between CA and CS numbered, counting from CA, as Cac 1 and Cac2 and one accessory leaflet (Cac3) between CS and CP. In subtype 4C, as in 4B, two accessory cusps were present between CA and CS (Cac 1 and Cac2) and an accessory leaflet (Cac3) between CA and CP. Subtype 4D contained three accessory leaflets located between the main leaflets. The accessory leaflet lying between CA and CS was designated Cac1, that between CS and CP as Cac 2 and that located between CA and CP as Cac3. The incidence of subtypes in type 4 was: subtype 4A — 4.59%, 4B — 1.83%, 4C and 4D — 0.92%.

The rarest form of right atrioventricular valve was the seven-cuspidal variant classified as type 5. This form was present in 2.75% of the group studied. Valves classified as this type were observed in two configurations: subtype 5A, with one accessory cusp between CA and CS (Cac 1), and three accessory leaflets between CS and CP numbered, counting from the side of CS, as Cac 2, Cac 3, and Cac 4, and subtype 5B — Cac 1, situated between CA and CS and two accessory leaflets between CS and CP counting from the side of CS, with the last (Cac 4) accessory cusp between CA and CP. Subtype 5A was present in 0.92%, and subtype 5B in 1.83% of the hearts examined.

We also measured the length, height and surface area of the main and accessory leaflets. The average length of the anterior leaflet was 31.98 ± 8.74 mm. The average length of the posterior leaflet was 24.1 ± ± 9.08 mm and the average length of the septal leaflet was 32.16 ± 8.79 mm. Values for the height of the main leaflets were as follows: for the anterior leaflet — 20.71 ± 5. 23 mm, for the posterior leaflet — 18.88 ± 4.66 mm and for the septal leaflet — 17.22 ± ± 4.71 mm. The value of the average surface area of the anterior leaflet was 452.66 ± 172.46 mm^2, for the posterior cusp it was 310.66 ± 173.03 mm^2 and for the septal leaflet 404.44 ± 174.01 mm^2.

Next we compared the length, height and surface areas of the main and accessory leaflets. The average length of the main leaflet was 29.41 ± ± 9.61 mm (27.26% of the circuit of attachment of the tricuspid valve) and for the accessory leaflet it was 15.14 ± 6.84 mm (15.39% of the circuit of attachment of the tricuspid valve). The average height of the main leaflet was 18.94 ± 5.06 mm and of the accessory leaflet it was 13.69 ± 4.59. The surface area of the main leaflet was 389.24 ± ± 182.45 mm^2 and of the accessory it was 142.02 ± ± 100.51 mm^2.

The Shapiro-Wilk test was used to ensure that all the groups of valves and leaflets studied were in conformation with the Gaussian curve. Student's t test was used to calculate statistics to confirm hypotheses about differences in the values of length, height and surface area ($p < 0.05$).

All the values for the main cusps were greater than for the accessory leaflets. Using Student's t test we found no differences in the lengths of the anterior and septal leaflets. The posterior leaflet was the shortest, while the anterior leaflet was the highest and had the largest surface area. The posterior leaflet was higher than the septal leaflet and had the smallest surface area. The surface areas of whole valves within particular types are presented in Table 2. Student's t test ($p < 0.05$) did not confirm any differences in surface area in particular types of valves.

Accessory leaflets were present in 93 of the hearts studied. These were divided into two groups: true and spurious accessory cusps. True accessory leaflets made up 39% of the accessory cusps and spurious accessory leaflets were observed in 61% of this group. The proportion of true to spurious accessory leaflets in particular types of tricuspid valve is shown in Table 3. The highest proportion of true accessory leaflets was in type 2. In types 3 and 4 the proportion of true to spurious accessory cusps was similar and lower than in type 2. The proportion of spurious accessory cusps was highest in type 5. The difference between type 5 and the others may be explained by the arrangement of the tendinous chords.

Commissures were observed in the majority of intercuspidal incisurae. These were 6.33 ± 2.59 mm in length and Table 4 shows the values in particular types of valve. The statistics for testing hypotheses about differences in length of the commissures in particular types of tricuspid valve did not confirm the differences.

Table 2. Surface area in particular types of tricuspid valve

Type of valve	Surface area [mm^2]	SD
0	1549.64	339.84
1	1347.93	217.83
2	1418.41	479.03
3	1436.06	407.15
4	1365.18	205.82
5	1350.28	46.99

Table 3. Proportions of true to spurious accessory leaflets in particular types of tricuspid valve

Type of valve	True accessory leaflets (%)	Spurious accessory leaflets (%)
2	49.91	50.09
3	41.03	58.97
4	41.67	58.33
5	16.67	83.33

Table 4. Length of commissures in particular types of tricuspid valve

Type of valve	Length of commissures [mm]	SD
0	6.00	3.11
1	6.42	2.23
2	6.76	2.69
3	6.08	2.69
4	5.97	2.02
5	5.75	2.33

DISCUSSION

Using the number of leaflets as the criterion for the division of valves, we distinguished six main types. Subtypes were classified on the basis of the location of accessory cusps, a classification that was performed according to earlier studies [14, 21] but which was extended to include types not previously described. Types 1 to 5 are the same as in the previous paper. Type 0 was established to describe the variant of the tricuspid valve with two main leaflets, and this was divided into 2 subtypes: 0x and 0y. Distinguishing type 0y and classifying the smallest leaflet as an accessory was in accordance with criteria established by Szostakiewicz-Sawicka et al. [26, 27] for the classification of leaflets into "main" and "accessory" in the right atrioventricular valves of vertebrates. We found no significant difference in the incidence of particular types of valve with respect to sex and age.

This relation has also been studied by, Łukaszewska-Otto [17], Wafae et al. [33] and Kosiński et al. [14]. Łukaszewska-Otto et al. [17], in studies performed in a group of 130 hearts, observed the three-cuspidal variant in 8.46%, the four-cuspidal variant in 36.15% (the variant corresponding to subtype 2A in our nomenclature in 23.8%, that corresponding to subtype 2B in 7.8%, and to 2C in 4.5%), the five-cuspidal form in 33.85%, the six-cuspidal form in 17.69%, the seven-cuspidal form in 1.53% and the eight-cuspidal form in 1.53%. The results of the study performed by Kosiński et al. [14] in a group of 50 hearts are as follows: type 1 — 9.1%, type 2 — 38.2% (subtypes 2A — 22.02%, 2B — 9.17%, 2C — 7.8%), type 3 — 32.7%, type 4 — 16.7% and type 5 — 3.6%. Skwarek et al. [21], in a study performed in a group of 75 hearts, found the following incidence: type 1 — 9.3%, type 2 — 36.15% (subtypes 2A — 23.8%, 2B — 7.8%, 2C — 4.5%), type 3 — 33.3%, type 4 — 13.3% and type 5 — 4.1% (subtypes 5A — 2.6%, 5B — 1.3%). The results of a study performed by Wafae et al. [33] in a group of 50 hearts are: the two-cuspidal form in 4%, the three-cuspidal form in 28%, the four-cuspidal form in 52%, the five-cuspidal form in 14% and the six-cuspidal form in 2%. All the above-mentioned studies were performed in groups of adult human hearts. A further important study was performed by Szostakiewicz-Sawicka et al. [26] in groups of primates, while human hearts were represented by only 30 hearts, both adult and children, with a control group to study hearts in the phylogenetic development of tricuspid value. This led to the claim of a dependence on the form of the tricuspid valve in evolution. The incidence of particular forms of tricuspid valve in this study was: the three-cuspidal form — 30%, the four-cuspidal form — 46.6% and the five-cuspidal form — 23.3%. Szostakiewicz-Sawicka et al. [26, 27] established a complete classification of the tricuspid valve which is useful for all vertebrates. However, we used the earlier classification of Kosiński et al. [14], as this is more convenient with respect to the human tricuspid valve.

For the three-seven cuspidal form range our results are convergent with those of Łukaszewska-Otto et al. [17], Skwarek et al. [21] and Kosiński et al. [14]. The authors of the research referred to did not compare the shape, length, height and area of the designated cusps. We did not notice the eight-cuspidal form and this is probably accounted for by its rare occurrence. Our results do not agree with those of Szostakiewicz-Sawicka et al. [27], which may be explained by the small group of human hearts used in that study. Nor do our results agree with those of Wafae et al. [33] except with regard to the bicuspidal form. This lack of convergence may be explained not only by the small size of the group but also by the lack of a clear definition for distinguishing accessory cusps in that study, in which the author established the concept of bipartite leaflets and divided the accessory cusps into two groups (accessory and commissural leaflets) but without describing the principles for this distinction. Because of the use of different criteria by Wafae et al. [33], we cannot compare our results unambiguously.

We observed a bicuspidal form of the tricuspid valve, which has been classified as type 0. This type was, in its pure form, observed in two cases (1.83%), while in one heart one accessory leaflet was observed. We have used the criteria of Szostakiewicz-Sawicka et al. [26] for describing the cusp as an accessory, namely that the length of the leaflet was less than half the part of attachment to the adjacent wall of the ventricle. The bicuspid form of the tricuspid valve did not occur in the studies conducted by the above-mentioned authors [14, 17, 21]. Amongst the first modern researchers to study the tricuspid valve were Jastrzębski et al. [12], who, on the basis of personal experience, established 54 theoretically possible forms of the tricuspid valve. However, the bicuspid form of the tricuspid valve is not referred to in these studies. This may be the result of this being a rare anatomical variant. An author who did describe this form was Testut et al. [28, 29]. According to him, the bicuspid form occurs in 2–3% of population, although the position of the leaflets in this variant was not described. This incidence is in agreement with our results.

The bicuspid form of the tricuspid valve has been described as a frequent variant in other primates [26, 27] such as the Macaque, Cebus and Lemur, in forms corresponding to both type 0x, and type 0y in our classification.

In 1990 Victor and Nayak [31] proposed a simplification of the anatomy of the tricuspid valve by a new division into two leaflets: septal and mural. There has been a poor response to this because of the lack of compatibility with temporospatial relations during phylogenesis and embryogenesis and because Ebstein's anomaly negates this division. Many subsequent studies denied the concept of the tricuspid valve as bicuspid [1, 2, 10, 15, 23, 24]. Our results are not consistent with this, as we have observed anterior and posteroseptal leaflets and not septal and mural. Victor and Nayak [30] have linked their view with the operating technique in tricuspid stenosis.

With regard to classification of the main types our results are in agreement with those of Łukaszewska-Otto et al. [17], Skwarek et al. [21] and Kosiński et al. [14]. The differences between the subtypes of types 2 and 5 may be explained by the small number of hearts of these types. An associated problem is that of describing of the principles by which accessory cusps are differentiated from main leaflets. This is to be the subject of our next study.

Despite the evidence of many studies showing the presence of accessory leaflets in the tricuspid valve, Sutton et al. [24] postulate that the name "tricuspid" should be reserved for the right atrioventricular valve. His study, comparing the number of leaflets in formalin-fixed hearts with echocardiography on these hearts, has shown that in echocardiography valves always have three closing lines without regard to the number of leaflets. It is probable that accessory leaflets may be responsible not only for lack of continuity of the tricuspid valve but also for the accessory jets sometimes seen in echocardiography [3].

The next issue we considered was that of the length, height and surface area of the leaflets of valves. These dimensions were compared firstly for particular main leaflets and next separately for the main and accessory leaflets. Wafae et al. [33] in their study expressed the length of leaflets as a percentage of the circuit of attachment of the tricuspid valve, and in their study of main leaflets this parameter equalled 26.32%, while for accessory leaflets it was 16.90% and for commissural leaflets 7.31%. Our results agree with these with reference to the main leaflets, but we cannot compare the results for accessory cusps because of his division into accessory and commissural leaflets.

The results of Łukaszewska-Otto et al. [17] for the length of leaflets are as follows: for the anterior leaflet 24.09 mm, for the posterior leaflet 20.91 mm and for the septal leaflet 17.91 mm. The average height of the main leaflet was 29.41 mm and of the accessory leaflet 15.41 mm, our results being lower than those of Łukaszewska-Otto et al. [17]. In both studies the highest was the anterior leaflet and the lowest the septal.

The surface areas of the main leaflets decreased progressively from type 1 to type 5, while those of the accessory leaflets were greatest in type 3 and the smallest in type 5. The quotient of surface of main leaflets to accessory leaflet were greatest in type 1 and smallest in type 5. Wafae et al. [33] estimated the surface area of the leaflets as a model consisting of the sum of the areas of a triangle and a rectangle and found the commissures forming the borders of each leaflet to be equal in length. This model treats leaflets as ideal in geometrical shape and neglects irregularities in the shape of the valve. This basis does not agree with our measurement. Wafae et al. [33] expressed the surface areas of particular leaflets as a proportion of the surface of the valve; for the main leaflets this was equal to 27.28%, for the accessory to 18.24% and for the commissural leaflets to 3.78%. The proportions of areas in particular types of the tricuspid were not calculated. The data of Wafae et al. [33] agree most closely with our results for types 2 and 3 and least closely for types 4 and 5. This may be caused by the increased number of accessory leaflets in successive types and in consequence the increasing proportion of these in the total surface of valve. The convergence between our results and those of Wafae et al. [33] may be caused by neglecting the irregularity of the valves in each case. Their method enables the proportion of the surface of the valve to be calculated while ours also allows the surface to be specified in square millimetres. Our method allows the "excess" area of the valve to be evaluated in comparison with the surface area of the right atrioventricular junction, as well as their relations and changes during human life. This will be theme of our next study.

The word "commissure" does not exist in anatomical nomenclature and has been introduced by surgeons [8, 19]. We have studied the length of commissures; our results are consistent with those in a previous study conducted on a group of hearts as a whole [21]. Additionally, we have compared the length of commissures in particular types. No differences were found between valve types.

Our hope has been to close the gap between the surgical and anatomical understanding of the morphology of the tricuspid valve.

REFERENCES

1. Anderson RH, Benson R, Wilcox MD (2000) Reply. Ann Thorac Surg, 69: 1990.
2. Anderson RH, Webb S, Brown NA, Lamers W, Moorman A (2003) Development of the heart: (2) Septation of the atriums and ventricles. Heart, 98: 949–958.
3. Ballinger PW (1995) Merrill's atlas of radiographic positions and radiologic procedures. 8th Ed. Mosby, Year Book Inc. St Louis Missouri.
4. Cardarelli MG, Gammie JS, Brown JM, Poston RS, Pierson RN 3rd, Griffith BP (2005) A novel approach to tricuspid valve replacement: the upside down stentless aortic bioprosthesis. Ann Thorac Surg, 80: 507–510.
5. Carrier M, Hebert Y, Pellerin M, Bouchard D, Perrault LP, Cartier R, Basmajian A, Page P, Poirier NC (2003) Tricuspid valve replacement: an analysis of 25 years experience at asingle center. Ann Thorac Surg, 75: 47–50.
6. Crumbley AJ, Van Bakel AB. Tricuspid valve repair for biopsy-induced regurgitation after cardiac transplantation. Ann Thorac Surg, 1994; 58: 1156--1160.
7. Dimas VV, Grifka RG, Fraser CD Jr (2004) Combined tricuspid valvuloplasty and superior cavopulmonary anastomosis for repair of traumatic tricuspid valve injury. Tex Heart Inst J, 31: 418–420. Comment in: Tex Heart Inst J (2005) 32: 114 (author reply 114).
8. Glover RP, Bailey CP, O'Neill TJE (1950) Surgery of stenotic valvular disease of the heart. JAMA 144: 1049–1052.
9. Hartyanszky I, Prodan Z, Kiraly L, Mihalyi S, Bodor G, Tamas C, Lozsadi K (2005) Challenges in the surgical

management of hearts with functional single ventricle. Orv Hetil, 33: 1721–1726.
10. Hudson REB (1965) Cardiovascular Pathology. Vol. I and II. 1st Ed. LTD, London.
11. Januszewicz W, Kokot F (2001) Interna. Vol. 1. 1st Ed. PZWL, Warsaw.
12. Jastrzębski C (1926) O zmienności kształtu zastawki trójdzielnej serca i o otworach wrodzonych w jej płatkach. Kosmos, Seria A. Biologia, 51: 191–198.
13. Kelley WN (1989) Internal Medicine. 1st Ed. Lippincott Company, Philadelphia.
14. Kosiński A, Kuta W, Grzybiak M, Ciszkowicz M, Kamiński R (2000) Morfologia zastawki trójdzielnej w sercu człowieka dorosłego i innych naczelnych. Przegl Med, 2: 80–83.
15. Lamers W H, Virágh S, Wessels A, Moorman AFM, Anderson RH (1995) Formation of the tricuspid valve in the human heart. Circulation, 91: 111–121.
16. Langberg JJ, Man KC, Vorperian VR, Williamson B, Kalbfleisch SJ, Strickberger SA, Hummel JD, Morady F (1993) Recognition and catheter ablation of subepicardial accessory pathways. J Am Coll Cardiol, 22: 1100–1104.
17. Łukaszewska-Otto H (1970) Zmienność budowy zastawki przedsionkowo-komorowej prawej u człowieka. Rozprawa habilitacyjna. Akademia Medyczna w Warszawie.
18. Miki K, Maekura R, Higara T, Hirotani A, Hashimoto H, Kitada S, Miki M, Yoshimura K, Naka N, Motone M, Fujikawa T, Takashima S, Kitazume R, Kanzaki H, Nakatani S, Watanuki H, Tagusari O, Kobayashi J, Ito M (2005) Infective tricuspid valve endocarditis with pulmonary emboli caused by Campylobacter fetus after tooth extraction. Intern Med, 10: 1055–1059.
19. Rocache M (1967) La commisurotomie tricuspide. Thèse pour le doctorat en medecine. Faculté de médecine de Paris edition, Paris.
20. Sharieff S, Sagir T, Shah-e-Zaman K (2005) Concurrent percutaneous valvuloplasty of mitral and tricuspid valve stenoses. J Invasive Cardiol, 17: 340–342.
21. Skwarek M, Grzybiak M, Kosiński A, Hreczecha J (2004) Notes on the morphology of the tricuspid valve in the adult human heart. Folia Morphol, 63: 319–324.
22. Skwarek M, Hreczecha J, Grzybiak M, Kosiński A (2005) Remarks on the morphology of the papillary muscles of the right ventricle. Folia Morphol, 64: 176–182.
23. Skwarek M, Hreczecha J, Grzybiak M, Kosiński A (2005) Unusual anatomical features of the right atrioventricular valve. Folia Morphol, 64: 183–187.
24. Sutton JP III, Yen Ho S, Vogel M, Anderson RH (1995) Is the morphologically right atrioventricular valve tricuspid? J Heart Valve Dis, 4: 571–575.
25. Stahl RD, Karwande SV, Olsen SL, Taylor DO, Hawkins JA, Renlund DG (1995) Tricuspid valve dysfunction in the transplanted heart. Ann Thorac Surg, 59: 477–480.
26. Szostakiewicz-Sawicka H Grzybiak M (1981) Zgodność rozwoju osobniczego niektórych cech budowy serca z przypuszczalnym kierunkiem ich rozwoju w antropogenezie. Morfologia, podręczniki, skrypty AWF. Seria: Monografie, 199: 9–16.
27. Szostakiewicz-Sawicka H (1967) Zastawka przedsionkowo-komorowa prawa u naczelnych. Rozprawa habilitacyjna. Acta Biol Med Soc Sc Gedan, 11: 545–589.
28. Testut L (1923) Anatomia Umana. Vol. IV. Angiologia, 3rd Ed. Utet, Torino.
29. Testut L, Latarjet A (1948) Traite d'anatomie humaine. Vol. II. 6th Ed. G. Doin Cie, Paris.
30. Victor S, Nayak VM (1994) The tricuspid valve is bicuspid. J. Heart Valve Dis, 3: 27–36.
31. Victor S, Nayak VM (1998) Bicuspidation for tricuspid stenosis. Ann Thorac Surg, 65: 1468–1470.
32. Williams P, Warwick R, Dyson M, Bannister L (eds.) (1989) Gray's anatomy atlas. 37th Ed. Churchill Livingstone, Edinburgh, London, Melbourne, New York.
33. Wafae N, Hayashi H, Gerola LR, Vieira MC (1990) Anatomical study of the human tricuspid valve. Surg Radiol Anat, 12: 37–41.
34. Yamashita S, Noma K, Kuwata G, Miyoshi K, Honaga K (2005) Infective endocarditis at tricuspid valve following central venous catheterization. J Anesth, 19: 84–87.