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Diameters of the cavo-sinus-tricuspid area in relation to type I atrial flutter

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*Cardiac arrhythmias have troubled patients and fascinated physicians for centuries. The twentieth century was an era of progress, when the mechanism of cardiac disorders became more commonly recognised. Arrhythmias may be due to abnormalities of automaticity, to abnormalities of conduction, or to a combination of both. In order for re-entry to occur, an area of slowing conduction combined with unidirectional block must be present. Much investigation has centred on the underlying re-entry mechanisms of atrial flutter. In the light of these facts, it would seem that a close acquaintance with the detailed topography of the vena cava orifice (*cavo*), coronary sinus orifice (*sinus*) and the attachment of the septal leaflet of the tricuspid valve (*tricupid*) area could be of great interest, especially for invasive cardiologists.*

The research was conducted on material consisting of 41 hearts of humans of both sexes from the age of 12 to 80 (6 female, 35 male). Classical macroscopic methods of anatomical evaluation were used. The following measurements were made: the shortest distance between the Eustachian valve and the attachment of the tricuspid valve on the left margin of the coronary sinus orifice (diameter 1)*, the distance between the attachment of the tricuspid valve and the inferior margin of the sinus orifice* (diameter 2)*, the distance between the Eustachian valve and the attachment of the tricuspid valve on the right margin of the coronary sinus orifice* (diameter 3)*, the distance between the inferior margin of the vena cava inferior and the attachment of the tricuspid valve* (diameter 4) *and, finally, the diameter between the attachment of the septal cups of the tricuspid valve and the external border of the vena cava inferior* (diameter 5).

*No correlation was found between the age and sex of the three groups of the material. The dimensions of the structure examined were similar in the three groups of hearts. In young adult hearts all the diameters measured ranged from 4 to 47 mm The average diameters were, respectively: 15.02 mm (*diameter 1*), 8.97 mm* (diameter 2)*, 17.27 mm* (diameter 3)*, 26.87 mm* (diameter 4)*, 36.42 mm* (diameter 5)*. In the mature adult hearts all the diameters measured ranged from 8 to 45 mm: 18.19 mm* (diameter 1)*, 10.54 mm* (diameter 2)*, 19.95 mm* (diameter 3)*, 28.90 mm* (diameter 4)*, 39.63 mm* (diameter 5)*. In the older adults hearts all the diameters measured ranged from 4 to 47 mm. The average diameters were, respectively: 15.65 mm* (diameter 1)*, 8.70 mm* (diameter 2)*, 7.25 mm* (diameter 3)*, 26.80 mm* (diameter 4)*, 35.85 mm* (diameter 5).

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On the basis of our study we were able to conclude that the diameters of the cavo-sinus-tricuspid area were constant and did not differ significantly within the three (young, mature, old) adult groups examined.

key words: cave-sinus-tricuspid area, type I atrial flutter, diameters, isthmus, ablation

INTRODUCTION

Cardiac arrhythmias have troubled patients and fascinated physicians for centuries. The twentieth century was an era of progress when cardiac arrhythmias became more common than ever before. Not only has the incidence of cardiac arrhythmias increased, but recognition of them has also improved remarkably [5]. This is due to the fact that the mechanism of cardiac disorders is more commonly recognised. Arrhythmias may be due to abnormalities of automaticity, to abnormalities of conduction, or to a combination of both. The suppression of one area of automaticity to a subordinate area of greater extent than normal may lead to an arrhythmia based on the loss of an automatic focus. The second primary cause of arrhythmias is re-entry. In order for re-entry to occur, an area of slowing conduction combined with unidirectional block must be present. Much investigation has centred on the underlying mechanisms of atrial flutter. Most authors believed it to be due to the repetitive firing of a single focus (unifocal theory). This theory was championed by Sherf et al. [21]. On the other hand, there is doubt as to whether a flutter has a circulating wave front as its matrix. This theory was put forward by Han [4] and Bigger and Goldreyer [1]. The circus movement theory found credence because of the behaviour of a ring of tissue cut from the umbrella of a jellyfish and of rings of muscle cut from the atria of fish and from ventricles of turtles for reviews see Hurst [5]. The stimulation of any of these tissues produced a circulating wave that continued uninterrupted round and round the ring. This was the first well-known entrainment phenomenon to be described. Type I atrial flutter is the most common supraventricular tachycardia with a re-entrant circuit. On ECG the waves of the flutter are labelled F waves and their rate is usually between 250 and 350 per minute. In most cases this dysrrhythmia occurs in diseased hearts, especially in those of patients with ischaemic heart disease. On the basis of current knowledge the terminology can be simplified, as this tachyarrythmia can be classified on the basis of re-entry around established anatomic landmarks [7, 14]. The anterior boundary is the tricuspid annulus [13], and the posterior barriers are the crista terminalis and eustachian ridge [19]. The tachycardia circuit is broad anteriorly and laterally but it becomes constrained in its course to the right atrium. The area is bordered anteriorly by the tricuspid valve and posteriorly by the inferior vena cava, coronary sinus, and eustachian ridge [3]. This area, the so-called cavo-sinus-tricuspid, has become a target site for ablative therapy [8], which is the treatment of choice in typical atrial flutter. This procedure is performed by linear lesion [17], which enables the macrore-entrant circuit running within the walls of the right atrium to be stopped.

In view of the above-mentioned facts, it would seems that a close acquaintance with the detailed topography of the vena cava orifice (*cavo*-), coronary sinus orifice (*sinus*-) and attachment of the septal leaflet of the tricuspid valve (-*tricupid*) area could be of great interest, especially for invasive cardiologists. We therefore decided to examine the diameters of the above-mentioned area.

MATERIAL AND METHODS

The research was conducted on material consisting of 41 hearts of humans of both sexes from the age of 12 to 80 (6 female, 35 male). The hearts were fixed in a 10% formalin with 98% ethanol solution. Only hearts showing no pathological changes or congenital disorders were considered. The material was divided into the appropriate age groups (Table 1).

Classical macroscopic methods of anatomical evaluation were used. The topography of the cavo-sinus-tricuspid area was examined in relation to the coronary sinus orifice, vena cava inferior orifice and

Table 1. Breakdown of the material

Material (groups of hearts)	Age	Number of hearts
Young adult group	12–38 years	20
Mature adult group	42–59 years	12
Older adult group	62–80 years	9
Total	12–80 years	41

the attachment of the posterior leaflet of the tricuspid valve. All measurements were made using scientific compasses and a slider with an accuracy of up to 0.5 mm. The following measurements were made: the shortest distance between the tendon of Todaro/Eustachian valve and the attachment of tricuspid valve on the left margin of the coronary sinus orifice *(diameter 1)*, the distance between the attachment of the tricuspid valve and the inferior margin of the sinus orifice *(diameter 2)*, the distance between the Eustachian valve (e.g. valve of the vena cava inferior) and the attachment of the tricuspid valve on the right margin of the coronary sinus orifice *(diameter 3),* the distance between the inferior margin of the vena cava inferior and the attachment of the tricuspid valve *(diameter 4)* and, finally the diameter between the attachment of the septal cups of the tricuspid valve and the external border of the vena cava inferior *(diameter 5)*. All these diameters are demonstrated in Figure 1.

The averages for the diameters are calculated with standard deviations for each group. The statistical analysis was supported by the F-Snedecor and t-Student tests for odd-number data. In the event of abnormal distribution, the differential significance between the two groups was tested using the Mann--Whitney-Wilcoxon test. A result of $p < 0.05$ was considered to be the level of statistical significance.

RESULTS

On the basis of our study we found that the average diameters within the area studied in all the hearts examined were as follows: 16.02 ± 3.29 mm for the distance between the tendon of the Todaro/Eustachian valve and the attachment of the tricuspid valve on the left margin of the coronary sinus orifice *(diameter 1)*, 9.32 ± 2.70 mm for the distance between the attachment of the tricuspid valve and the inferior margin of the sinus orifice *(diameter 2)*, 17.98 ± 4.68 mm for the distance between the valve of the vena cava inferior and the attachment of the tricuspid valve on the right margin of the coronary sinus orifice *(diameter 3),* 27.04 ± 4.81 mm for the distance between the inferior margin of the vena cava inferior and the attachment of the tricuspid valve *(diameter 4)* and 37.14 ± 5.27 mm for the diameter measured between the attachment of the septal cups of the tricuspid valve and the ex-

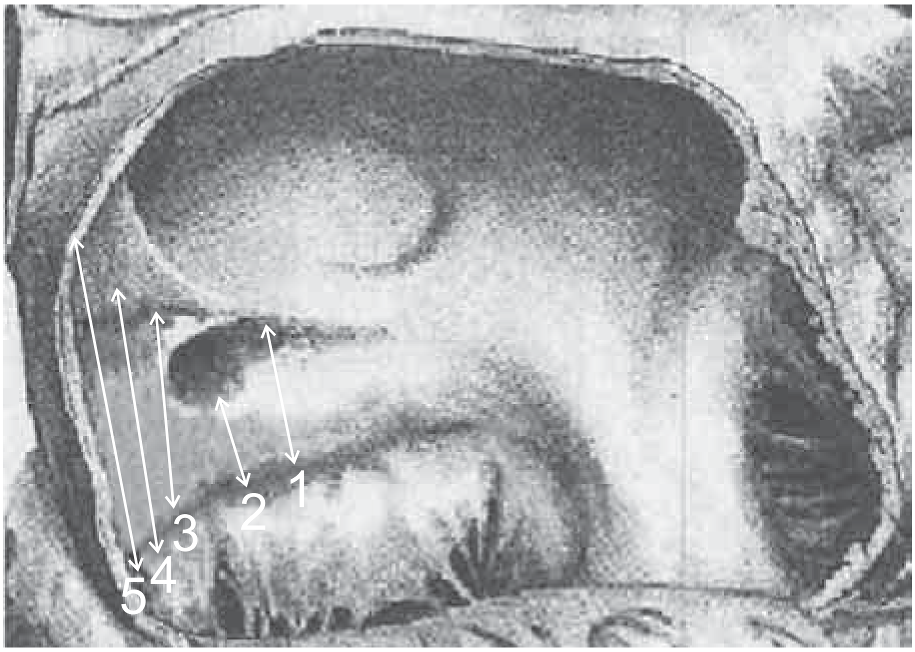

Figure 1. The measurements were performed on the specimen; distance between the tendon of the Todaro/Eustachian valve and the attachment of the tricuspid valve on the left margin of the coronary sinus orifice *(diameter 1)*, the distance between and the attachment of the tricuspid valve and the inferior margin of the sinus orifice *(diameter 2)*, the distance between the Eustachian valve (e.g. valve of the vena cava inferior) and the attachment of the tricuspid valve on the right margin of the coronary sinus orifice *(diameter 3)*, the distance between the inferior margin of the vena cava inferior and the attachment of the tricuspid valve *(diameter 4)* and the diameter measured between the attachment of the septal cups of the tricuspid valve and the external border of the vena cava inferior *(diameter 5)*.

ternal border of the vena cava inferior *(diameter 5)* (Table 2).

No correlation was found between the age and sex of the three groups of the material The dimensions of the structure examined were similar in the three groups of hearts (Table 3). In young adults hearts all the diameters measured ranged from 4 to 47 mm (fig. 2). The average diameters were, respectively: *diameter 1* — 10–20 mm; 15.02 mm, *diameter 2* — 4–16 mm; 8.97 mm, *diameter 3* — 11–26.5 mm; 17.27 mm*, diameter 4* — 20–36 mm; 26.87 mm, *diameter 5* — 27–47 mm; 36.42 mm. In mature adults hearts all the diameters measured ranged from 8 to 45 mm (fig. 3). The longest average diameter was between the attachment of the septal cups of the tricuspid valve and the external border of the vena cava inferior *(diameter 5* — 39.63 mm), the shortest was the distance between the attachment of the tricuspid valve and the inferior margin of the sinus orifice *(diameter 2* — 10.54 mm). Other average diameters were 18.19 mm *(diameter 1)*, 19.95 mm (*diameter 3)* and 28.90 mm *(diameter 4)*. In older adults hearts all the diameters measured ranged from 4 to 47 mm (fig. 4). The respective average diameters were as follows: 16.02 ± 3.29 mm for the distance between the vena cava valve and the attachment of tricuspid valve on the left margin of the coronary sinus orifice *(diameter 1)*, 9.32 ± 2.70 mm for the distance between the attachment of the tricuspid valve and the inferior margin of the sinus orifice *(diameter 2)*, 17.98 ± 4.68 mm for the distance between the valve of the vena cava inferior and the attachment of the tricuspid valve on the right margin of the coronary sinus orifice *(diameter 3),* 27.04 ± 4.81 mm for the distance between the inferior margin of the vena cava inferior and the attachment of the tricuspid valve *(diameter 4)* and 37.14 ± 5.27 mm for the diameter measured between the attachment of the septal cups of the tricuspid valve and the external border of the vena cava inferior *(diameter 5).* All these parameters are presented in Table 3.

DISCUSSION

Radiofrequency ablation procedures are currently the most popular method of treatment of type I

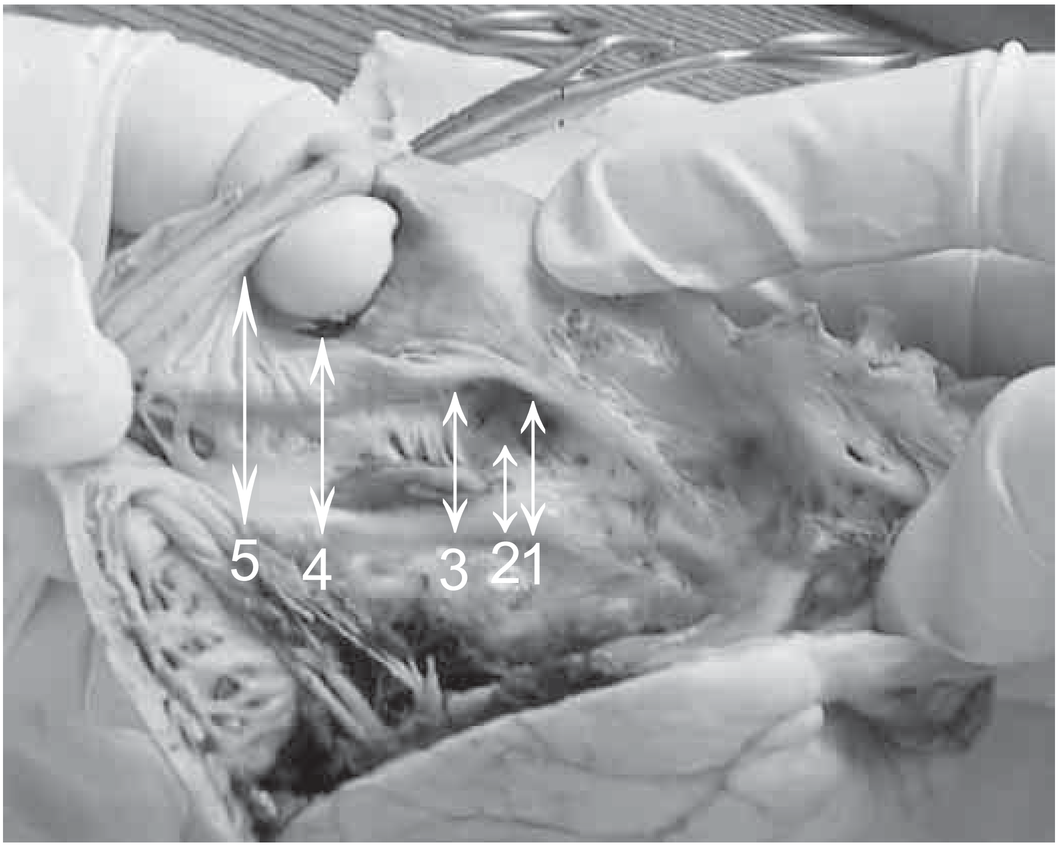

Figure 2. The relevant diameters in a heart from the young group (male, 21 year-old); all diameters as Figure 1.

Table 2. The relevant measured parameters in the hearts examined; all diameters as Figure 1

Study	Specimen	Age	Sex	Weight	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Diameter 5
1	1001	21	K	260	12	5	12	23.5	36.5
2	1023	21	M	380	18	10	19	21	32
3	1040	35	K	390	15	10	15	30	38
4	375	32	M	300	14	11	15	30	47
5	1028	36	M	260	14	12	21	21	35
6	1026	62	K	250	17	12	21	33	44
7	1006	30	M	320	19	16	26.5	31	35
8	1033	19	M	300	18.5	9	22	32	45
9	1032	44	M	300	17	11	22	26	45
10	1030	50	M	340	18.5	11	19.5	33	41
11	1021	38	M	350	16	7.5	15	20	32
12	1009	23	M	180	12	5	19	27	34
14	827	64	M	285	11	6	11	16	25
16	1007	62	M	340	19	9	17	27.5	31
17	1005	32	M	250	13	7	11	29	42
18	1010	33	M	220	10	4	11	36	45
19	1022	50	M	350	12	9	13	26	42
20	1017	46	K	210	16	8	17	26	37
22	1004	27	M	240	16	10	18	32	39
23	1038	26	M	240	14	8	14	23	35
24	1008	12	M	130	16	8	13	24	27
25	677	10	M	250	13	9	13	22	33
26	1029	28	M	250	13	7	15	24	37
27	1039	80	K	270	11	4	11	30	38
28	1040	62	M	300	11.5	6	14	28	40
29	1054	45	K	320	18	15	21	33	43
30	1055	59	M	420	16	10	17	27	38
31	1056	46	M	350	21	14	20	34	42
32	617	67	M	420	18	11	13.5	22	35.5
33	545	57	M	330	21	12	20	25	42
34	682	80	M	470	20	9	18	24.5	34
35	315	36	M	450	20	13	26	31	41
36	826	20	M	585	13	9	19	27	35
37	672	80	M	300	16	9	20	30	35
38	687	37	M	300	16	9	21	32	34
39	673	70	M	370	12	9	18	23	35
40	825	48	M	260	19	9	29	35	39
42	582	65	M	300	21	12	29	34	41
44	679	42	M	300	22	9	20	22	30
45	905	36	M	270	18	10	20	22	26
46	44804	47	K	300	20	8	21	31	37
AVG		43.3		310	**16.02**	**9.32**	**17.98**	**27.4**	**37.14**
SD		18.7		82.30	**3.29**	**2.7**	**4.68**	**4.81**	**5.27**

Table 3. The measured parameters in the hearts examined, by individual age group and with statistical analysis between the groups; all diameters as Figure 1

Group	Study	Age	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Diameter 5
Young	25	10	13	9	13	22	33
Young	24	12	16	8	13	24	27
Young	8	19	18.5	9	22	32	45
Young	36	20	13	9	19	27	35
Young	1	21	12	5	12	23.5	36.5
Young	2	21	18	10	19	21	32
Young	12	23	12	5	19	27	34
Young	23	26	14	8	14	23	35
Young	22	27	16	10	18	32	39
Young	26	28	13	7	15	24	37
Young	7	30	19	16	26.5	31	35
Young	4	32	14	11	15	30	47
Young	17	32	13	7	11	29	42
Young	18	33	10	4	11	36	45
Young	3	35	15	10	15	30	38
Young	5	36	14	12	21	21	35
Young	35	36	20	13	26	31	41
Young	45	36	18	10	20	22	26
Young	38	37	16	9	21	32	34
Young	11	38	16	7.5	15	20	32
			15.02	**8.97**	**17.27**	**26.87**	**36.42**
p value Young *v.* Mature			0.74	0.55	0.61	0.83	0.32
p value Young *v.* Old			0.15	0.90	0.52	0.55	0.96
Mature	44	42	22	9	20	22	30
Mature	9	44	17	11	22	26	45
Mature	29	45	18	15	21	33	43
Mature	20	46	16	8	17	26	37
Mature	31	46	21	14	20	34	42
Mature	46	47	20	8	21	31	37
Mature	40	48	19	9	29	35	39
Mature	10	50	18.5	11	19.5	33	41
Mature	19	50	12	9	13	26	42
Mature	33	57	21	12	20	25	42
Mature	30	59	16	10	17	27	38
			18.19	**10.54**	**19.95**	**28.9**	**39.63**
p value Mature *v.* Young			0.74	0.55	0.61	0.83	0.32
p value Mature *v.* Old			0.34	0.68	0.33	0.49	0.40
Old	6	62	17	12	21	33	44
Old	16	62	19	9	17	27.5	31

Table 3. The measured parameters in the hearts examined, by individual age group and with statistical analysis between the groups; all diameters as Figure 1 (continous)

Group	Study	Age	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Diameter 5
Old	28	62	11.5	6	14	28	40
Old	14	64	11	6	11	16	25
Old	42	65	21	12	29	34	41
Old	32	67	18	11	13.5	22	35.5
Old	39	70	12	9	18	23	35
Old	27	80	11	4	11	30	38
Old	34	80	20	9	18	24.5	34
Old	37	80	16	9	20	30	35
			15.65	**8.7**	**17.25**	**26.8**	**5.85**
p value Old *v.* Young			0.15	0.90	0.52	0.55	0.96
p value Old *v.* Mature			0.34	0.68	0.33	0.49	0.40

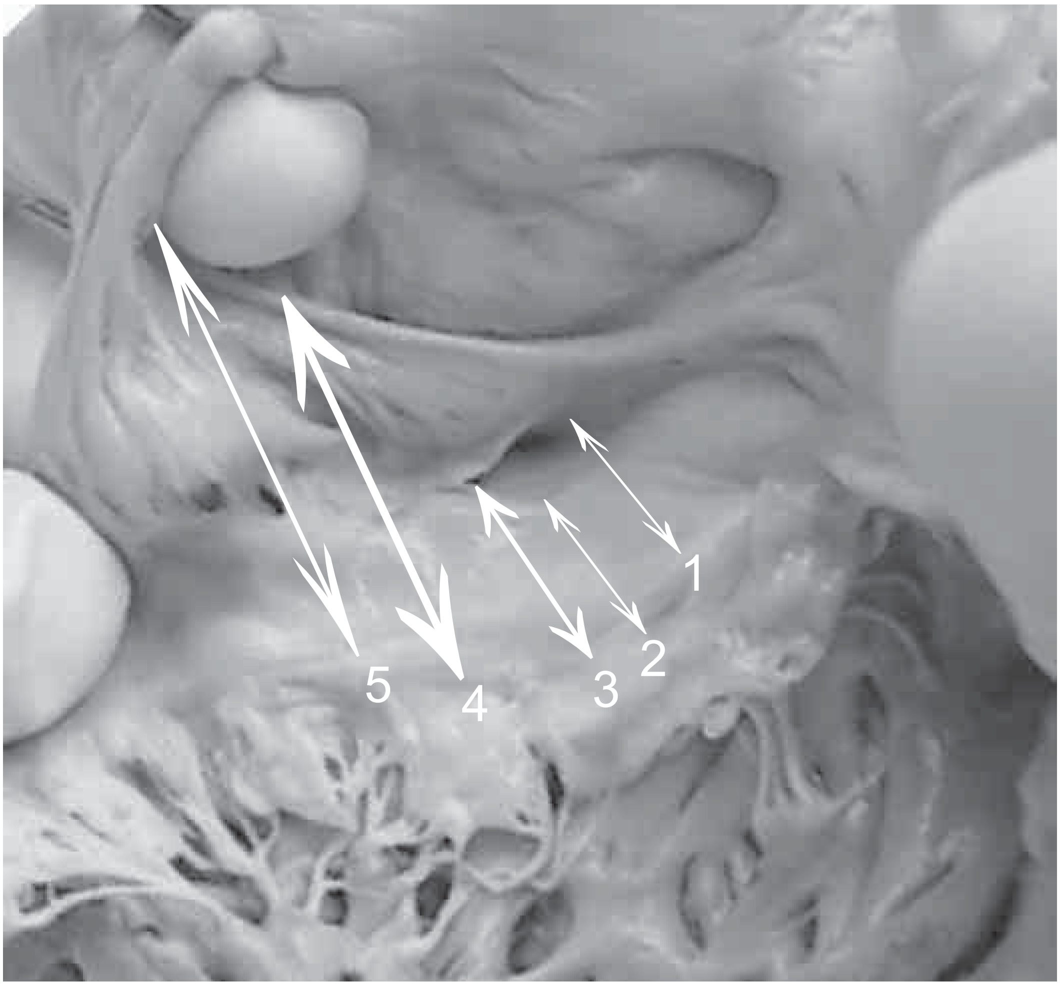

Figure 3. The relevant diameters in a heart from the mature group (female, 45 year-old); all diameters as Figure 1.

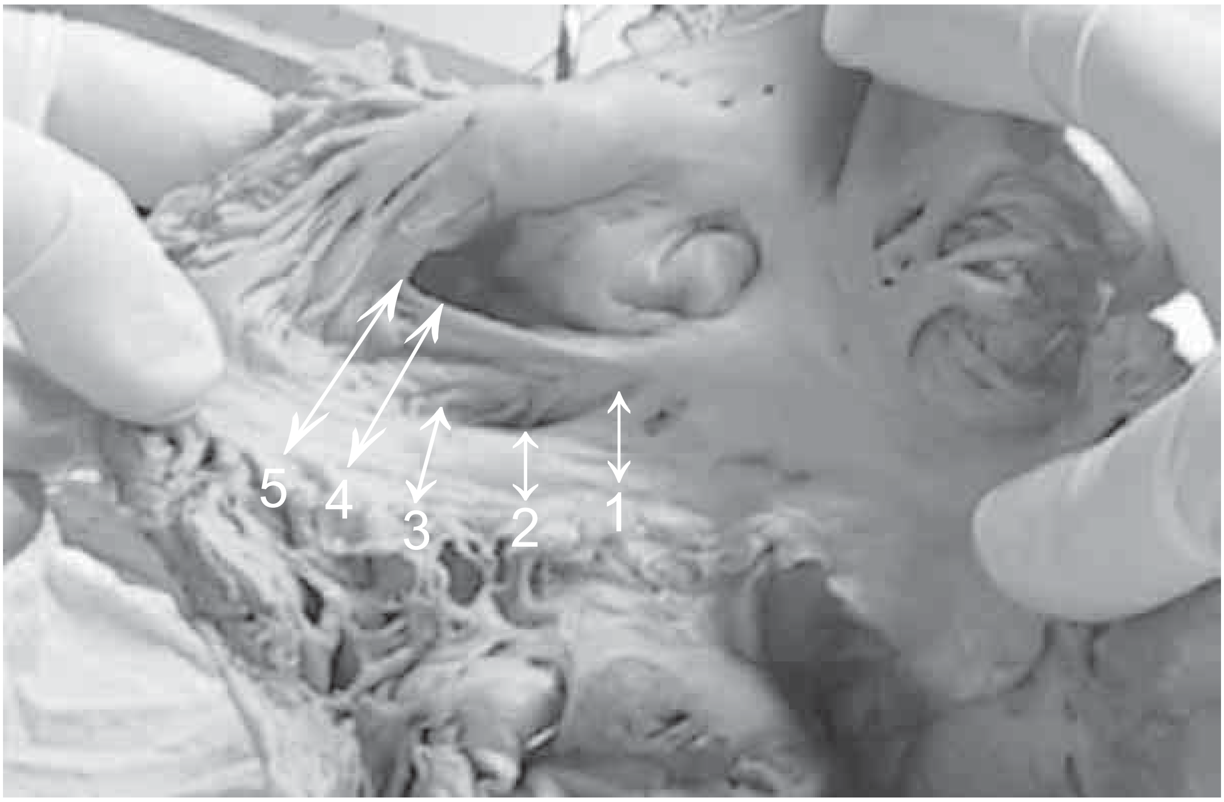

Figure 4. The relevant diameters in a heart from the older group (male, 80 year-old); all diameters as Figure 1.

atrial flutter [24]. A detailed anatomical knowledge of the cavo-sinus-tricuspid area is extremely important in the electrophysiology of common atrial flutter. Murgatroyd's question, *What goes around, comes around — but where?* is still relevant [11]. The main authorities for the basis for ablation of type I atrial flutter, Cosio et al. [2], stated that the cavo-tricuspid area is the site of decremental conduction. On the basis of this phenomenon a re-entry wave could exist. Olsson et al. [15] and Shah et al. [20] confirmed, with respect to the entrainment phenomenon, that this particular area is characterised by so-called "concealed entrainment". This means that a slowing of conduction may be present in this area, thus marking it out as the best point for the ablation site. Early ablation procedures (1980–1990) failed on numerous occasions after 70–100 applications. This was connected with placing the line of ablation on *diameter 2* as measured by us. However, this was the minimum diameter of those measured in our cohort of hearts, although a gap of conduction over the coronary orifice does still exist in this situation. At the beginning of the nineties Poty et al. [16] and Nagawa et al. [12] placed the ablation line in the area between the vena cava inferior and the tricuspid ring (*diameters 4* and *5* in our study). Successful ablation rates in type I atrial flutter significantly increased. Iesaka et al. [6], postulated in their electrophysiological research that in some patients dual isthmus phenomenon may occur in this area, which could be directed to dual septal exits. According to our measurements, this possibility could not be confirmed from the anatomical point of view. In a situation in which two isthmuses could be present, the diameters would be larger in size (*diameters 1* and *2*) in some of the hearts examined. However, this does not exclude such electrophysiological properties. Olgin et al. [13, 14] confirmed, on the basis of echocardiographic intracardiac recordings, that human flutter barriers exist within the right atrium. They termed these important structures *crista terminalis, valva venae cavae inferioris,* and *annulus tricuspidalis*. They called the important cavo-tricuspid region the *isthmus*. This structure is the main point for a successful target site during ablation procedure. We did not find any measurements related to this structure in the literature. On the basis of our study we hope to provide exact parameters of this particular area to improve the effectiveness of the invasive procedures.

Tritto et al. [23], during electrophysiological examination of a patient with atrial flutter, described conduction abnormalities in the region of the vena cava inferior ostium (superiorly and inferiorly). They pointed out that the differences from patient to patient could be connected with anatomical variations in the morphology of this region. This hypothesis was not confirmed by our study. All the diameters, especially those measured between the vena cava inferior and the tricuspid valve (*diameters 4* and *5*) were similar in each group. It is possible that the sample of hearts examined to represent the three groups were too small to have any statistical significance.

Ren et al. [18] examined the right atrial wall thickness by means of high-resolution intracardiac echocardiographic imaging during radiofrequency catheter ablation procedures. The examinations were performed in five anaesthetised closed chest swine. They found that transmural lesion size after ablation correlates with the time of application and the thickness of the wall before the procedure. They stated that the ablation procedure in such a thin area could be hazardous, because of the possibility of atrial wall perforation by the ablative catheter. Unfortunately, they did not measure the diameters in the frontal axis. In our specimens this area was calculated as having a range of 20 to 36 mm (average 27.40 ± 4.81 mm). Our previous studies regarding the subthebesian fossa [9, 10] also confirm the importance of this area. The diameters measured within the fossa differ slightly from those found in this study. This may, we think, be linked to the larger surface of the subthebesian fossa with respect to the diameter measured between the tricuspid annulus and the vena cava inferior orifice. The measurements were, moreover, performed on different groups of hearts.

On the basis of our study we were able to conclude that the diameters of the cavo-sinus-tricuspid area were constant and did not differ significantly within the three (young, mature, older) adult groups examined. We hope that confirmation of similar parameters for this anatomical structure will be of help in the ablation procedure of type I atrial flutter.

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