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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Macroscopic morphology of right atrial appendage in humans

Rafał Kamiński[1], Marek Grzybiak[1], Ewa Nowicka[1], Adam Kosiński[1], Ewa Lewicka[2], Alicja Dąbrowska-Kugacka[2], Dariusz Kozłowski[2]

[1]Department of Clinical Anatomy, Medical University of Gdansk, Gdansk, Poland
[2]Department of Cardiology and Electrotherapy, Medical University of Gdansk, Gdansk, Poland

Abstract

Background and aim: Atrial fibrillation (AF) is a common arrhythmia in elderly people, and in many cases it is responsible for stroke or pulmonary embolism. One of the factors facilitating atrial thrombus formation is anatomical morphology of the atria, and especially the appendages. The pharmacological treatment of arrhythmia is generally focused on ventricular rate control. Electrical cardioversion is the preferred treatment method in the majority of clinics but it can occasionally produce the potentially dangerous complication of AF.

Methods: A macroscopic study was carried out on 40 (25 male [M], 15 female [F]) human hearts, 18–72 years of age, and a microscopic study in a group of 20 human right atrial appendages (RAA) (M 10, F 10), 18–72 years of age. Only hearts without anomalies were included in the study. Classical anatomical studies and statistic analyses were applied.

Results and conclusions: RAA is triangle shaped with a mean area of 2.73 cm^2. Muscle fascicules build the wall of RAA and compose a dense net inside a chamber. Sagittal bundle connecting terminal crest with an apex of RAA was observed in all examined hearts. In microscopic specimens longitudinal and perpendicular fascicles were described.

Key words: right atrial appendage, atrial fibrillation, right atrium

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INTRODUCTION

Atrial fibrillation (AF) arrhythmia which commonly exists in the elderly population increases the risk of stroke and pulmonary embolism. Patients with this kind of tachyarrhythmia are constrained to respect anticoagulant treatment dependent on the presence of risk factors for thromboembolism. One of the factors facilitating thrombus formation is anatomical morphology of atrial appendages, where the blood flow is slowed during AF. According to the medical literature we can observe that thrombi can appear in both atria, although mainly in the left one [1]. Reversion of a sinus rhythm by electrical cardioversion brings the risk of embolism complications (stroke, pulmonary embolism) [2], especially when the arrhythmia lasts longer than 48 h or when there is no evidence of AF time. In such cases one of the imaging methods to qualify patients to electrical cardioversion is transoesophageal echocardiography (TEE) with left and right appendage views. According to many medical studies, very often physicians are unable to diagnose the contents of the appendages. They frequently observe in TEE some unidentified "echoes" in patients submitted to chronic anticoagulant therapy, describing them as thrombi [3]. For many years anatomopathologists and cardiologists have tried to explain the processes in hearts during arrhythmia. On the basis of anatomical studies focused on the right and left atria we know some described structures which are barriers and substrates responsible for sustaining arrhythmia [4]. Due to progression in electrophysiology studies and new electroanatomical techniques of heart potentials mapping we are able to find the focus of earliest potentials activation in paroxysmal atrial tachycardias, for instance — right atrial appendage (RAA) [5]. Radio-frequency (RF) ablation treatment of supraventricular tachyarrhythmias is very often unsuccessful [6–8] and cardiosurgical intervention is needed.

Address for correspondence:
Rafał Kamiński, MD, PhD, Department of Clinical Anatomy, Medical University of Gdansk, ul. Dębinki 1, 80–210 Gdańsk, Poland, e-mail: rafal.kaminski@gumed.edu.pl
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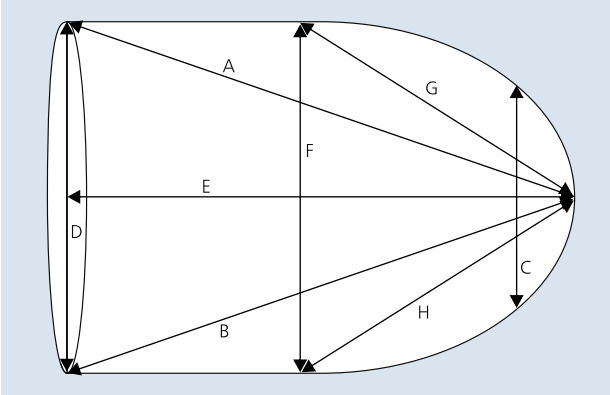

Figure 1. Diagram of right atrial appendage (RAA) dimensions; Diameters of RAA (A, B, C, D, E, F, G, H) — see text

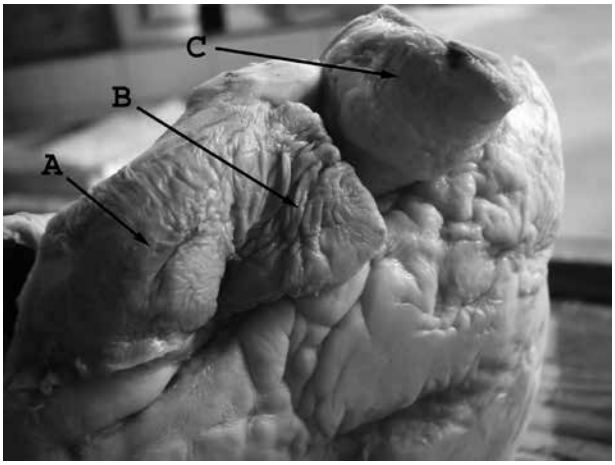

Figure 2. View of the right part of the heart; A — right atrial wall; B — isosceles triangle right atrial appendage; C — ascending aorta

METHODS

The studies were carried out on 40 human hearts of both sexes (25 male [M], 15 female [F]) from 18 to 72 years of age. Only hearts without macroscopic anomalies were included in the study. The hearts were fixed in a water solution of 4% formaldehyde. Classical anatomical studies and statistical analysis were applied. After preparation of the pericardium we evaluated the shape of RAA by taking photos (camera Canon PowerShot S5IS with 6.0 MP resolution, supermacro option). Afterwards we made a long lateral section from the apex of the right ventricular to the orifice of the vena cava superior, cutting the posterior cuspid of the tricuspid valve. In the next step we cut off the RAA and took eight measurements with an accuracy of ± 1 mm (Fig. 1). Dimension A (long upper edge) represented the distance between the upper edge of the appendage base (AB) and its apex; dimension B (long lower edge) — the distance between the lower edge of AB and its apex; dimension C — the distance between the upper and lower edge of RAA measured 2 mm from the apex, parallel to AB; dimension D (appendage base [AB], medial edge) — measured in the place where the appendage was connected to the atrium; dimension E (horizontal central length) — measured between the middle of the base to the apex; dimension F (vertical central length) — the vertical distance in the middle of the horizontal central length; dimension G (short upper edge) — measured from the upper end of F dimension to the apex; and dimension H (short lower edge) — measured from the lower end of F dimension to the apex. To evaluate the inner part of the examined appendages we made anatomical models using special liquid silicon (MM 922 and fixing agent B-5). After 12 h of fixation we received constant models of RAA. Microscopic studies were conducted on 20 human RAAs of both sexes (M 10, F 10) from 18 to 72 years of age. To prepare specimens we used liquid paraffin to fix the tissue, which was afterwards cut to 10-μm layers on microtome (Leica) and stained by Masson and Goldner modification. The slides were viewed by binocular microscope (Leica 2000) with 10–400 times magnification.

RESULTS

On the base of aquired diameters (Table 1) we observed the notable regularity in shape of RAA, which was close to an isosceles triangle with a slightly longer lower edge, mean approx. 1.6 mm (Fig. 2). In all examined hearts we noticed the plain external surface of RAA without clearly visible muscle fibres, otherwise the internal surface of the RAA looked like it was pleated with many pectinate muscles (Fig. 3A, B). In all RAAs we observed muscle bundles building the right part

Table 1. Right atrium appendage values

	A [mm]	B [mm]	C [mm]	D [mm]	E [mm]	F [mm]	G [mm]	H [mm]
Arithmetic mean	23.7	25.3	12.4	26.6	21.6	19.2	11.9	13.8
Standard deviation	3.8	4.2	2.8	4.3	3.4	2.8	2.2	2.5
Maxima value	32	38	18	36	29	24	16	19
Minima value	15	18	6	20	16	14	7	9

In our study we obtained the following results: long upper edge (A) range: 15–32 mm, mean 23.7 mm; long lower edge (B) range: 18–38, mean 25.3 mm; lateral edge (C) range: 6–18 mm, mean 12.4 mm; medial edge (D) range: 20–36 mm, mean 26.6 mm; horizontal central length (E) range: 16–29 mm, mean 21.6 mm; vertical central length (F) range: 14–24 mm, mean 19.2 mm; short upper edge (G) range: 7–16 mm, mean 11.9 mm; short lower edge (H) range: 9–19 mm, mean 13.8 mm.

Figure 3. **A**. Inner surface of right atrial appendage showing pectinate muscles; **B**. Inner part of right atrial appendage

Figure 4. Inner surface of right atrial appendage; A — terminal crest; B — sagittal bundle

of the appendage wall and other ones connecting the walls, which ran separately through the chamber of RAA. Moreover, we noticed sagittal bundle connecting terminal crest with apex of RAA in all examined hearts (Fig. 4). On the basis of our silicon models we discovered irregularity and accidental run of muscle fibres (Fig. 5A, B). In microscopic view we discovered longitudinal and perpendicular fibres separated by

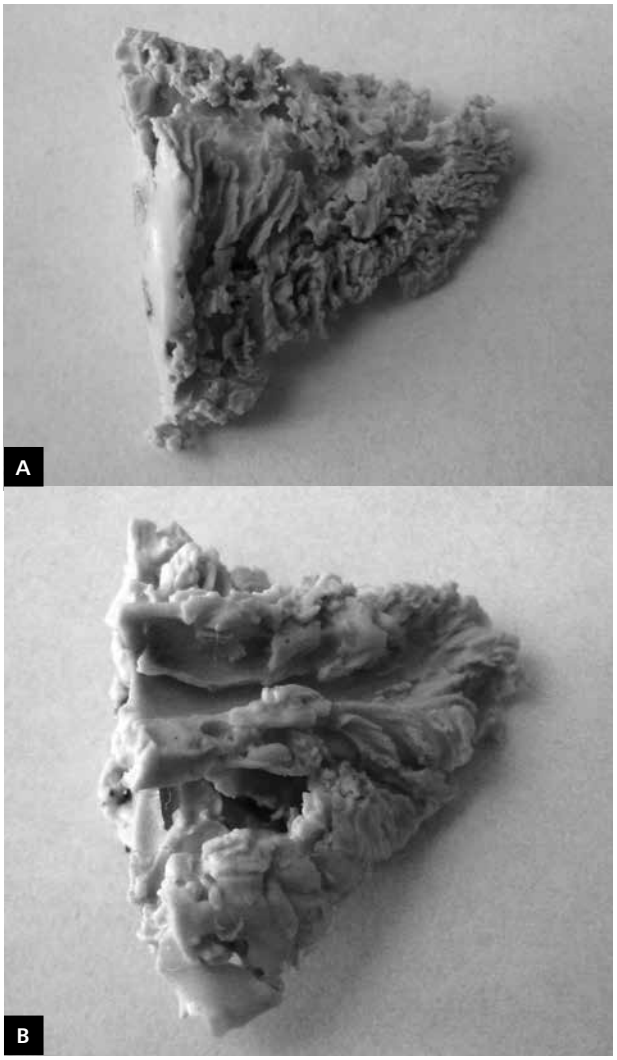

Figure 5. **A**, **B**. Silicone cast

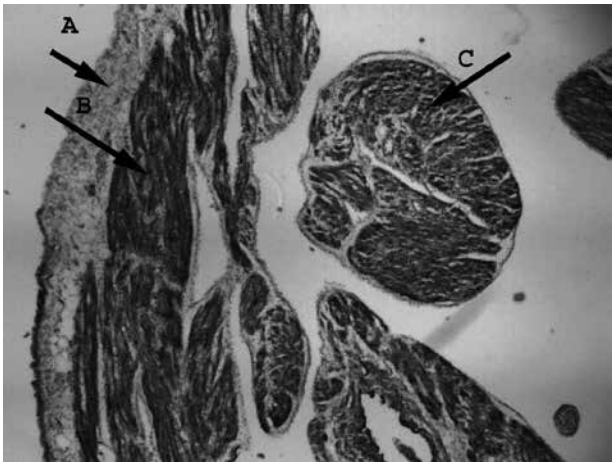

Figure 6. Longitudinal section of right atrial appendage stained in Mason and Goldner modification, magnification 40×; A — connective tissue; B — longitudinal muscle fibres; C — perpendicular muscle fibres

Table 2. Area of right atrial appendage (RAA) calculated by Heron's formula

	Mean	Maxima	Minima	Standard deviation
Area of RAA [cm^2]	2.73	5.3	1.3	0.07

The calculated mean area of the triangle: 2.73 cm^2 (Heron's formula).

connective and fatty tissue (Fig. 6). Using the Heron's formula we observed that mean RAAs surface was 2.73 cm^2 (Table 2).

DISCUSSION

In the available literature we found very little information about RAA morphology. The only practical publication that did not stray from our subject was an analysis of RAA morphology with regard to thrombi formation during AF, which was published in the "American Journal of Cardiology" in 1999 [1]. The studies describing the morphology of the appendage were done on the basis of echocardiography imaging and regarded only people with chronic AF. In this study carried out on 102 patients, only in 90 cases was it possible to describe the morphology of RAA using echocardiography imaging. It proved that patients with AF had lower attachment of tricuspid valve, bigger area of RAA, and smaller ejection fraction (EF) compared to patients with sinus rhythm (SR). Those anomalies in patients with AF were probably responsible for the presence of thrombus in RAA and left atrial appendage (LAA), in 6 and 11 cases, respectively. It transpired that patients with AF and the presence of thrombus in RAA had decreased EF and improper morphology of the atrium — enlarged area of appendage. Thanks to TEE studies it was discovered that the maximal area of RAA in the group of patients with SR was 4.7 ± 1.6 cm^2 and in the group of patients with AF it was 5.6 ± 1.9 cm^2. In our study we discovered that the mean area of RAA was 2.73 ± 0.07 cm^2. Because we did not know the history of the patients in our group, we can assume that they did not suffer from chronic AF. Only in three cases we found an appendage with an area greater than 5 cm^2, which can suggest chronic AF history. We would like to point out that the measurements we received could be slightly reduced because we studied tissue that was fixed in formalin. Similarly to the cited publication, we also found regularity of the RAA shape, which was close to an isosceles triangle with a slightly longer lower edge (+1.73 mm). Unfortunately, other publications compared the morphology of LAA [9–12]. In 1997 in "Circulation" a comparison of LAA morphology using echocardiography imaging was published [9]. Similarly to us, the authors made measurements of LAA presenting far fewer dimensions. In their study they described the length and width of LAA as 2.29–2.53 cm and 1.38–1.83 cm, respectively. Compared to our study, RAA measurements were similar (1.6-2.9 cm and 1.4–2.4 cm, respectively). Moreover, they discovered that the length and width of LAA were increasing each year (0.041 cm and 0.030 cm, respectively) in a group of male patients < 20 years old, but in a group of patients > 20 years old, and females, the growth was significantly less (0.0040 cm and 0.0019 cm per year, respectively). In our study we did not pay attention to certain differences dependent on age because we studied hearts from a wide range of ages (18 to 72 years old). Another publication from 2003 compared LAA in post-mortem studies and in TEE imaging [11]. Twelve patients were examined before (TEE) and after death (autopsy). The authors discovered that in both situations there was significant correlation between specified dimensions of LAA. In TEE study stated that the size of appendage entrance was from 11 to 26 mm, whereas the distance from entrance to apex was in the range of 27–41 mm. In our study regarding RAA, the dimension of the entrance was 20–36 (mean 26.60) mm and the length was 16–29 (mean 21.64) mm. Manolis et al. [12] measured the orifice of RAA in 23 human hearts and showed that the mean orifice size was 20.0 mm. They divided hearts into two groups depending on age. They discovered that RAA orifice in hearts over 70 years old was smaller then in the younger group: 18.0 mm vs. 21.0 mm, respectively. One of the latest publications, from 2008, is a study regarding the morphology of LAA *in vivo* using advanced three-dimensional computed tomography (3D-CT) in patients with AF [13]. The obtained results show good correlation between CT and TEE because the long axis of LAA in TEE was 26.2 ± 4.1 cm whereas in 3D-CT it was 20.0 ± 3.7 mm. Additional measurements were as follows: mean width 23.5 ± 4.2 mm and mean depth 25.1 ± 6.3 mm. Compare to our study, the long axis is equivalent to our horizontal central length, which was 21.64 ± 3.41 mm, which is comparable with the above-mentioned results. When we compare short axis, in our study — dimension F (vertical central length), it was 19.24 ± 2.75 mm, and maximal width in 3D-CT was similar to our measurement. The depth in 3D-CT was the longest line inside LAA, and it was equal to our A or B dimension and — 23.72 ± 3.85 mm and 25.28 ± 4.18 mm, respectively. They were comparable with results obtained by the cited study authors.

CONCLUSIONS

1. RAA has a triangle shape with a mean area about 3 cm^2.
2. Inner surface of RAA is composed of many muscle fibres.
3. Sagittal bundle — structure connecting RAA apex with terminal crest could be responsible for propagation of focal atrial arrhythmia localised in the right appendage.
4. Pectinate muscle existing in RAA could be responsible for unsuccessful RF ablation treatment of arrhythmia originating in RAA.

Conflict of interest: *none declared*

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Budowa makro- i mikroskopowa uszka prawego przedsionka u człowieka

Rafał Kamiński[1], Marek Grzybiak[1], Ewa Nowicka[1], Adam Kosiński[1], Ewa Lewicka[2], Alicja Dąbrowska-Kugacka[2], Dariusz Kozłowski[2]

[1]Zakład Anatomii Klinicznej, Gdański Uniwersytet Medyczny, Gdańsk

[2]Klinika Kardiologii i Elektroterapii Serca, Gdański Uniwersytet Medyczny, Gdańsk

Streszczenie

Wstęp: Migotanie przedsionków (AF), arytmia bardzo powszechna u osób w podeszłym wieku, bardzo często prowadzi do powikłań zatorowo-zakrzepowych. Wśród wielu przyczyn odpowiedzialnych za tworzenie się skrzeplin jest budowa anatomiczna przedsionków, a szczególnie ich uszek. Arytmia pozostawiona i leczona farmakologicznie skupia się głównie na kontroli rytmu komór, jednak nie prowadzi do znacznego zwiększenia wydolności serca. Alternatywą leczenia jest kardiowersja elektryczna, która wiąże się z ryzykiem udaru przy błędnej kwalifikacji pacjenta.

Cel: Celem pracy było zbadanie pod względem anatomicznym uszka prawego przedsionka.

Metody: Badania zostały przeprowadzone na materiale 40 serc ludzkich w przedziale wiekowym 18–72 lat (25 mężczyzn i 15 kobiet). Do badania kwalifikowano tylko te narządy, w których nie stwierdzono żadnych zmian patologicznych. Stosowano klasyczne metody badań anatomicznych i analizę statystyczną.

Wyniki i wnioski: Stwierdzono, że prawe uszka przedsionków mają kształt zbliżony do trójkąta równoramiennego. W obrębie uszka prawego przedsionka znajdują się pęczki włókien mięśniowych budujących jego ścianę i pęczki tworzące gęstą sieć wewnątrz jamy uszka. Wyodrębniono jeden główny pęczek łączący grzebień graniczny z wierzchołkiem uszka. W badaniach mikroskopowych stwierdzono podłużne włókna mięśniowe budujące ścianę uszka oraz poprzeczne pęczki łączące ściany uszka.

Słowa kluczowe: uszko prawego przedsionka, migotanie przedsionków

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Adres do korespondencji:
dr n. med. Rafał Kamiński, Zakład Anatomii Klinicznej, Gdański Uniwersytet Medyczny, ul. Dębinki 1, 80–210 Gdańsk, e-mail: rafal.kaminski@gumed.edu.pl

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