https://doi.org/10.35336/VA-2023-2-01

CORONARY SINUS AS AN ANATOMICAL LANDMARK FOR ATRIAL TRANSSEPTAL PUNCTURE

L.P.Votyakov, M.V.Didenko, I.A.Menkov, G.S.Pasenov, G.G.Khubulava

Federal State Budgetary Military Educational Institution of Higher Education "Military Medical Academy named after S.M. Kirov" of the Ministry of Defense of the Russian Federation, Saint-Petersburg, 6 Academik Lebedev str

Aim. The study of interatrial septum (IAS) and coronary sinus (CS) syntopia in patients with atrial fibrillation (AF), who subsequently underwent pulmonary vein isolation with a cryoballoon and the determination of anatomical landmarks for puncture of the IAS.

Methods. The data of preoperative computed tomography of the heart of 25 consecutive patients with AF, who subsequently underwent pulmonary vein isolation with a cryoballoon, were analyzed. Angulations describing IAS orientation and CS direction were measured. The relationships between IAS orientation, CS direction and size of left atrium were subsequently analyzed.

Results. The mean angulations for IAS orientation and CS direction were 47.2±7.8° (range 27.6 - 57.3) and 47.2±7.8° (range 26.7 - 59.3) respectively. On the conventional clock face (direction of the flag of the puncture needle), these values corresponded to the following time: 4 h 34 min±15 min (from 3 h 55 min to 4 h 55 min) for the IAS orientation and 4 h 31 min±16 min (from 3 h 53 min to 4 h 54 min) for the CS direction. Statistically significant correlation was revealed between the IAS orientation and the CS direction ($r = 0.77$; $p < 0.001$). Linear regression analysis by the least squares method showed that the CS direction explains 60% of the observed variability in IAS orientation. The final regression equation for the relationship between the IAS orientation and the CS direction is presented as: IAS orientation = 12.76 + 0.75 × CS direction. Analysis of the relationship between the IAS orientation and the size of the left atrium did not reveal any significant correlation and dependence ($p=0.84$). All 25 patients who took part in the study underwent pulmonary vein isolation with a cryoballoon. Puncture of the IAS from the first time was successful in 100% of patients. In 24 patients (96%), it was possible to achieve grade 4 occlusion of the pulmonary veins, and a bidirectional block was confirmed when checking the electrical activity of PV. All cryoballoon ablation procedures were completed without complications.

Conclusion. In patients with AF, the CS direction can be a reliable predictor of the IAS orientation, which can be used in clinical practice. However, to verify the data and determine technical recommendations for transseptal puncture, additional clinical studies are needed.

Key words: interatrial septum; coronary sinus; atrial fibrillation; computed tomography; cryoballoon ablation

Conflict of Interests: none.
Funding: none.
Received: 18.07.2022 **Revision received:** 29.11.2022 **Accepted:** 19.12.2022
Corresponding author: Votyakov Lev, E-mail: levvotyakov98@gmail.com

L.P.Votyakov - ORCID ID 0000-0003-2627-6278, M.V.Didenko - ORCID ID 0000-0003-3966-5651, I.A.Menkov - ORCID ID 0000-0002-1569-2180, G.S.Pasenov - ORCID ID 0000-0002-7917-7276, G.G.Khubulava - ORCID ID 0000-0002-9242-9941

For citation: Votyakov LP, Didenko MV, Menkov IA, Pasenov GS, Khubulava GG. Coronary sinus as an anatomical landmark for atrial transseptal puncture. *Journal of Arrhythmology.* 2023;30(2): 5-10. https://doi.org/10.35336/VA-2023-2-01.

In modern clinical practice, puncture of the interatrial septum (IAS) has become a routine procedure, especially during arrhythmologic interventions. At the same time, it remains one of the most responsible procedures for the interventional physician and can be accompanied by severe complications. According to available data, the probability of life-threatening complications such as cardiac perforation and tamponade is 0.5-1.3% [1-8].

To safely perform IAS puncture, interventional cardiologists and arrhythmologists require a detailed understanding and knowledge of the anatomy of the heart and IAS. Direct visualization of the IAS using ultrasound techniques can be used to minimize procedure complications, but its implementation in some cases can be challenging [9]. At the same time, during the performance of this procedure, a catheter in the coronary sinus (CS) can be used as one of the anatomical landmarks [10]. J.Z. Dong et al. (2015) suggest that the site of IAS puncture should be located above the CS ostium, as it is usually at the same level as the lower border of the left atrium (LA) near the plane of the mitral valve annulus [9]. Nevertheless, only a few studies available in international databases have investigated the relationship between the orientation of the IAS and the direction of the CS. H. Sun et al. (2015) found a statistically significant correlation between the position of the IAS and the direction of the CS ($r = 0.928$; $P < 0.01$) [11]. However, this study only included patients with normal hearts and without atrial fibrillation (AF), and the relationship between the IAS and the CS was only assessed in the axial plane. In turn, Y. Wang et al. (2016) developed and proposed a method for determining the site of IAS puncture based on the analysis of multislice computed tomography (MSCT) data and X-ray imaging of patients [12]. Additionally, we did not find any studies in the available literature that investigated the relationship between these anatomical structures in patients undergoing cryoballoon pulmonary vein isolation (PVI) procedures.

The aim of this study was to investigate the relationship between the IAS and CS in patients with AF who underwent cryoballoon PVI and to determine anatomical landmarks for IAS puncture.

METHODS

Data from preoperative cardiac MSCT of 25 consecutive patients with AF who subsequently underwent cryoballoon PVI were analyzed. The investigation was performed using a computed tomography scanner (General Electric Revolution CT, USA), which allows for a complete heart scan with simultaneous acquisition of 512 slices per rotation of the X-ray tube. ECG-synchronized cardiac scanning was performed after intravenous bolus injection of contrast agent (Iopromide 370-100 mL) with acquisition of axial slices with a thickness of 0.6 mm. Despite the broad capabilities of obtaining high-quality images of the heart in patients with AF on this CT scanner, to minimize possible artifacts, we tried to adhere to the target heart rate of less than 65 beats per minute using beta-blockers. In 88% of cases, the study was performed in sinus rhythm.

It is known that during the puncture of the IAS, the introducer with the needle is rotated in such a way that its tip is approximately in the “4-5 o’clock” position of a hypothetical clock face. Thus, we used a line horizontal relative to the flat deck of the CT table as a reference point, equal to 0°, which corresponded to 3 o’clock on the hypothetical clock face, reference point 90° - 6 o’clock, and 180° - 9 o’clock.

As mentioned above, during puncture of the IAS, the catheter in the CS can be used as an additional anatomical landmark (Fig. 1). In this case, the direction of the interatrial septum and the coronary sinus will be mutually perpendicular. Therefore, on an axial CT scan, the horizontal line will reflect the line of entry of the inferior vena cava into the right atrium. Thus, the direction of the needle for puncture of the interatrial septum should be parallel to the direction of the catheter located in the coronary sinus.

To measure the orientation of the interatrial septum (angle α), the following steps were performed (Fig. 2a): 1) a slice in the axial plane with the most distinct visualization of the oval fossa was selected; 2) a line projected onto the IAS was drawn through the plane that separates the right and left atria. The plane was determined based on the differences in the density of blood in the atria; 3) a perpendicular was dropped from the right atrium to the location of the oval fossa along the line corresponding to 0° as described above; 4) angle α was measured between the perpendicular described in step 3 and the line drawn horizontally relative to the plane of the CT table (0°).

The direction of the CS (angle β) was determined as follows (Fig. 2b): 1) a slice was selected in the axial plane in which the CS was most clearly visualized; 2) a line was drawn that most accurately corresponded to the course of the CS and the position of the electrophysiological catheter during CS catheterization; 3) angle β was measured between the line described above and a line drawn horizontally relative to the plane of the CT table (0°).

Features of the puncture of the IAS and cryoballoon PVI

After analyzing preoperative MSCT data, a puncture of the IAS was performed, followed by subsequent cryoballoon PVI. After catheterization of the CS, a sensor for intracardiac echocardiography (ICE) was inserted.

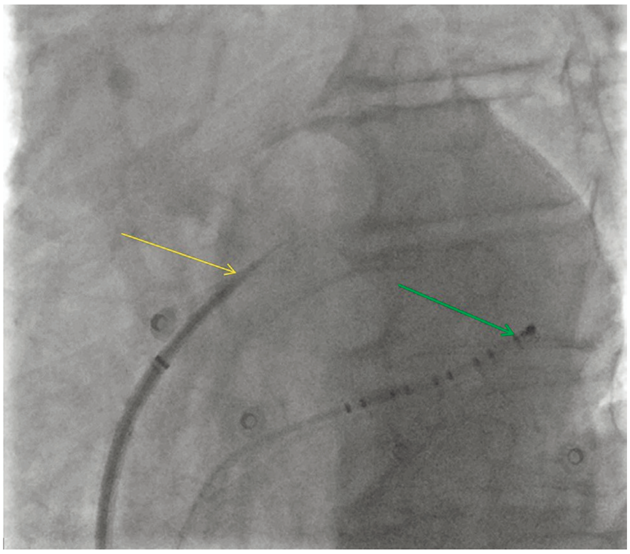

Fig. 1. The position of the catheter in the coronary sinus and the sheath with a needle during puncture of the interatrial septum. Yellow arrow - sheath with Brokenbrow needle, green arrow – catheter in the coronary sinus. The picture shows that the direction of the needle for puncture of the interatrial septum is almost parallel to the direction of the catheter, which is in the coronary sinus.

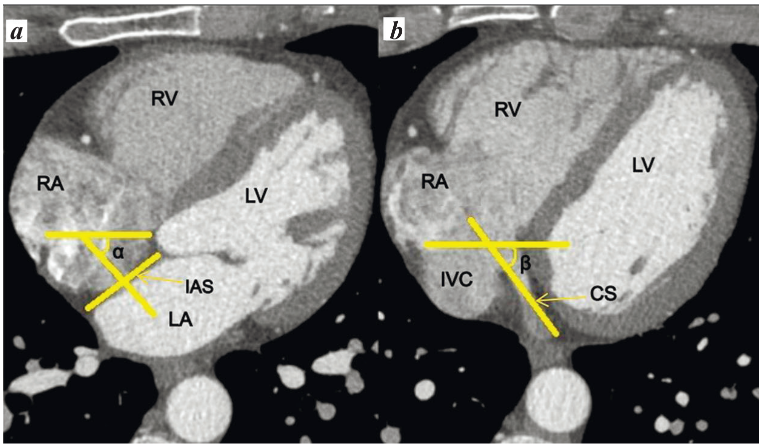

Fig. 2. Method for measuring the angles α and β. Explanations in the text. Note: IAS - interatrial septum; CS - coronary sinus; LA - left atria; LV - left ventricle; RA- right atria; RV - right ventricle; IVC - inferior vena cava.

Then, an introducer with a needle for transseptal puncture was inserted into the right atrium via the superior vena cava. In the left oblique projection, the introducer with the needle was rotated so that the rotation indicator on the needle was in the "4-5 o'clock" position of an imaginary clock face. After the second "jump", the direction of the needle should become almost parallel to the direction of the catheter in the CS. Then, under X-ray and intracardiac ICE guidance, a transseptal puncture was performed. Immediately after the puncture, 10,000 IU of heparin was administered. After that, occlusion and cryoballoon PVI were sequentially performed.

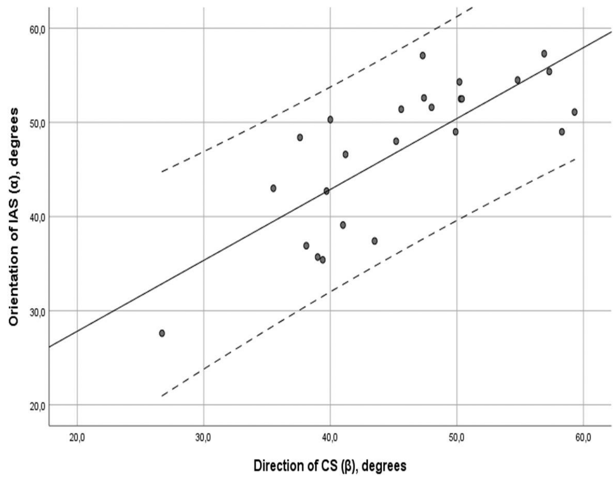

Fig. 3. Scatterplot of the relationship between the orientation of the IAS and the direction of the CS. Linear regression analysis showed a significant correlation between the position of the IAS and the direction of the CS. The dotted lines represent the 95% confidence interval. Pearson's correlation coefficient r = 0.77 (p < 0.001); IAS - interatrial septum; CS - coronary sinus.

Table 1.

Baseline characteristics of patients

Age, M ± SD	59.9±10.9
BMI, kg/m², M ± SD	30.8±4.7
Overweight, n (%)	8 (32)
Obesity, class I, n (%)	7 (28)
Obesity, class II, n (%)	5 (20)
Obesity, class III, n (%)	1 (4)
Atherosclerosis of the aorta and CA, n (%)	18 (72)
Hypertension stage I, n (%)	1 (4)
Hypertension, stage II, n (%)	10 (40)
Hypertension, stage III, n (%)	8 (32)
LVEF, %, M ± SD	60±11.5
CHF, NYHA class I, n (%)	5 (20)
CHF, NYHA class II, n (%)	10 (40)
Postinfarction cardiosclerosis, n (%)	3 (12)
Paroxysmal AF, n (%)	22 (88)
Persistent AF, n (%)	3 (12)
Anterior-posterior LA size according to echocardiogram	
30-40 mm, n (%)	9 (36)
41-46 mm, n (%)	10 (40)
47-52 mm, n (%)	6 (24)

Note: M ± SD - mean ± standard deviation; BMI - body mass index; CA - coronary arteries; LVEF - left ventricular ejection fraction; CHF - chronic heart failure; AF - atrial fibrillation; LA - left atrium.

Statistical analysis

All data are presented as mean ± standard deviation (M±SD). Distribution was assessed using the Shapiro-Wilk test and quantile-quantile plot. Pearson correlation coefficient (r) was used to evaluate the relationship between the orientation of the IAS and the direction of the CS. Linear regression analysis using the least squares method was then performed to determine the relationship between the angle α and the angle β. A significance level of $p < 0.05$ was considered statistically significant. All data were analyzed using SPSS 26 software (IBM Inc., Armonk, NY, USA).

RESULTS

Our study included 25 patients. Patient characteristics are shown in Table 1. Data on the angles α and β, which describe the orientation of the IAS and the direction of the CS, respectively, are presented in Table 2.

A statistically significant correlation was found between the orientation of the IAS and the direction of the CS (r=0.77; p<0.001; Fig. 3). Subsequently, a linear regression analysis using the least squares method was performed to predict the orientation of the IAS based on the direction of the CS. It was determined that the direction of the CS explains 60% of the observed variability in the orientation of the IAS ($r^2 = 0.60$). The final regression equation for the relationship between the orientation of the IAS and the direction of the CS can be represented as follows: Position of IAS = 12.76 + 0.75 × direction of CS.

It is worth noting that we did not find any correlation between the orientation of the IAS and the size of the LA (p=0.84). According to the echocardiography data, 36% of our patients had an anteroposterior LA dimension of 30-40 mm, 40% had a dimension of 41-46 mm, and 24% had a dimension of 47-52 mm (Table 1). Such a distribution is likely since most of the patients (88%) had paroxysmal tachysystolic AF, which usually does not cause a significant increase in the size of the LA [13].

Cryoballoon pulmonary vein isolation procedure. All 25 patients included in the study underwent cryoballoon PVI procedure. Puncture of the IAS was successful on the first attempt in 100% of patients. In 24 patients (96%), 4th degree occlusion of the pulmonary veins was achieved, and bidirectional block was confirmed by testing the PVs activity. In 1 patient (4%), it was not possible to position the cryoballoon in the right pulmonary veins due to the relatively large size of the left atrium (46 mm anterior-posterior diameter on echocardiography, left atrial volume of 142 ml on MSCT) and the presence of a small-diameter right accessory pulmonary vein. Therefore, a more detailed description of the CT anatomy of the right PVs is necessary for this patient. The right lobar branches originated from the atrium as separate trunks: the inferior lobar vein had a diameter of 15 mm over a length of 10 mm, including an independent S6 segment vein with a diameter of 8 mm and a length of 14 mm, the middle lobar vein had a diameter of

13 mm and a length of 12 mm, and the superior lobar vein was located in front of the inferior and middle veins with a diameter of 18 mm over a length of 28 mm. However, the left pulmonary veins were isolated in this patient, and ectopic activity in the right pulmonary veins was not detected. All cryoballoon PVI procedures were completed without complications.

DISCUSSION

It is important for the safe and successful execution of various invasive electrophysiological procedures to have a comprehensive knowledge of the anatomy of the heart, particularly the atria [14]. To perform transseptal puncture successfully, the physician must have a clear understanding and visualization of the anatomy of the IAS. As mentioned above, one landmark that can be used to determine the direction of the puncture needle is the catheter in the CS. However, it should be emphasized that the relationship between the IAS and the CS has only been studied to a limited extent in the available literature [11, 12]. In our study, for the first time, the relationship between these anatomical structures was investigated in patients who subsequently underwent cryoballoon PVI. In our investigation, the mean angle of the IAS orientation (angle α) was 47.2±7.8°. This value corresponded to the time of 4 hours 34 minutes ± 15 minutes on a hypothetical clock face. The obtained data are consistent with clinical practice, in which the introducer needle is rotated such that the rotation indicator is approximately in the “4-5 o’clock” position during IAS puncture [14, 15]. However, variability in the IAS orientation was observed, ranging from 27.6° to 57.3° (from 3 hours 55 minutes to 4 hours 54 minutes on the hypothetical clock face). Such variability in the orientation of the IAS was not unexpected. For instance, in the study by E.A. Fender et al. (2014) [17], the mean angle of the IAS was 60.6±10.6°, with a range from 29.5° to 88.7°. In the study by H. Sun et al. (2015) [11], the mean angle of the IAS was 36.8±7.3°, with a minimum value of 19.1° and a maximum of 53°. It should be noted that the latter study included patients without any cardiovascular pathology, which could have influenced the results. Meanwhile, the method proposed by Y. Wang et al. (2016) [12] for determining the optimal site of puncture of the IAS under fluoroscopic guidance uses the bifurcation point of the middle cardiac vein in the CS as a reference point. According to the authors, the most suitable puncture point was in the middle of the IAS, in its widest part. The variability of the IAS orientation observed in our study and in others emphasizes the importance of accurately determining the position of the IAS during invasive electrophysiological procedures. Therefore, establishing the relationship between the orientation of the IAS and an anatomical landmark such as the direction of the CS may be of invaluable importance in the practice of interventional cardiologists and arrhythmologists.

In this study, we found a significant linear correlation between the orientation of the IAS and the direction of the CS in patients with AF who underwent cryoballoon PVI. Despite the widespread use of computed tomography in cardiac research, the position of the IAS has been studied in only a few studies. The stable nature of the relationship across a wide range of values, with the CS direction explaining 60% of the variability in the orientation of the IAS junction ($r^2 = 0.60$), suggests that this relationship may have prognostic value for clinicians during interventional procedures. This relationship may be explained by the anatomical connection between these structures, as the CS ostium is located at the inferior aspect of the IAS, and thus it is expected to rotate along with the interatrial septum [13, 18]. However, the regression model built does not guarantee a linear relationship between the position of the IAS junction and the CS direction beyond our range of data.

Patients with obvious rotation of the IAS or an extremely small or large angle between the IAS and the horizontal line in the axial plane may have difficulties visualizing the IAS. Therefore, the relationship between the orientation of the IAS and the direction of the CS observed in our study may be of great value in providing a landmark for adjusting the projection angle of the IAS. Furthermore, an algorithm for puncturing the IAS under fluoroscopic control without transesophageal echocardiography has been developed, relying on the position of the catheter in the CS [10]. To confirm the safety of this method, this study was conducted. Thus, in the hands of experienced specialists and in large, specialized centers, it is possible to perform puncture of the IAS based solely on fluoroscopy data and the position of the catheter in the CS. However, further investigation of this issue is required.

Limitations. Our study had several limitations. First, the sample size was small, with only 25 patients included in the study. Second, the study design was retrospective and not multi-center. Additionally, we only investigated the relationship between the orientation of the IAS and the direction of the CS in the axial plane. Further studies focusing on the IAS and CS in other planes, such as the coronary plane, may reveal three-dimensional relationships between these structures.

CONCLUSION

The direction of the coronary sinus in patients with atrial fibrillation can be a reliable predictor of the orientation of the interatrial septum, which may have clinical significance for electrophysiological procedures. It is important to note that knowledge of the anatomy of the coronary sinus can help minimize complications during transseptal puncture. However, additional clinical studies are needed to verify these findings and establish technical recommendations for transseptal puncture.

Table 2.

Measurement results obtained using MSCT

Parameter	Value (degrees)	Variability (degrees)	Time* (hour: minute)
Orientation of IAS (α)	47.2±7.8	27.6-57.3	4:34±0:15
Direction of CS (β)	45.7±8.1	26.7-59.3	4:31±0:16

Note: IAS - interatrial septum; CS - coronary sinus; MSCT - multi-slice computed tomography; * - according to the conventional «clock face»

REFERENCES

1. Arbelo E, Brugada J, Hindricks G, et al. ESC-EURObservational research programme: the atrial fibrillation ablation pilot study, conducted by the European Heart Rhythm Association. *Europace*. 2012;14(8): 1094-1103. https://doi.org/10.1093/europace/eus153

2. Arbelo, E, Brugada, J, Hindricks G, et al. The Atrial Fibrillation Ablation Pilot Study: an European Survey on Methodology and results of catheter ablation for atrial fibrillation conducted by the European Heart Rhythm Association. *European Heart Journal*. 2014;35(22): 1466-1478. https://doi.org/10.1093/eurheartj/ehu001.

3. Arbelo E, Brugada J, Blomström-Lundqvist C, et al. Contemporary management of patients undergoing atrial fibrillation ablation: in-hospital and 1-year follow-up findings from the ESC-EHRA atrial fibrillation ablation long-term registry. *European Heart Journal*. 2017;38(17): 1303-1316. https://doi.org/10.1093/eurheartj/ehw564.

4. De Greef Y, Ströker E, Schwagten B, et al. Complications of pulmonary vein isolation in atrial fibrillation: predictors and comparison between four different ablation techniques: results from the MIddelheim PVI-registry. *Europace*. 2018;20(8): 1279-1286. https://doi.org/10.1093/europace/eux233.

5. Steinbeck G, Sinner MF, Lutz ., et al. Incidence of complications related to catheter ablation of atrial fibrillation and atrial flutter: a nationwide in-hospital analysis of administrative data for Germany in 2014. *European Heart Journal*. 2018;39(45): 4020-9. https://doi.org/10.1093/eurheartj/ehy452.

6. Fink T, Metzner A, Willems S, et al. Procedural success, safety and patients satisfaction after second ablation of atrial fibrillation in the elderly: results from the German Ablation Registry. *Clinical Research in Cardiology*. 2019;108(12): 1354-1363. https://doi.org/10.1007/s00392-019-01471-5.

7. Szegedi N, Széplaki G, Herczeg S, et al. Repeat procedure is a new independent predictor of complications of atrial fibrillation ablation. *Europace*. 2019;21(5): 732-7. https://doi.org/10.1093/europace/euy326.

8. Berger WR, Meulendijks ER, Limpens J, et al. Persistent atrial fibrillation: A systematic review and meta-analysis of invasive strategies. *International Journal of Cardiology*. 2019;278: 137-143. https://doi.org/10.1016/j.ijcard.2018.11.127.

9. Dong JZ, Ning M, Yu RH, et al. A simple method to localize transseptal puncture site during catheter ablation for atrial fibrillation. *European Heart Journal Supplements*. 2015;17(suppl_C):59-64. https://doi.org/10.1093/eurheartj/suv029

10. Yao Y, Ding L, Chen W, et al. The training and learning process of transseptal puncture using a modified technique. *Europace*. 2013;15(12): 1784-1790. https://doi.org/10.1093/europace/eut078.

11. Sun H, Wang Y, Zhang Z, et al. Predicting interatrial septum rotation: is the position of the heart or the direction of the coronary sinus reliable? Implications for interventional electrophysiologists from CT studies. *Pacing and Clinical Electrophysiology*. 2015;38(4): 514-9. https://doi.org/10.1111/pace.12590.

12. Wang Y, Chen G, Bai Y, et al. Transseptal puncture by CTP-2 method: Results from cardiac computed tomography analysis and clinical application. *Medicine*. 2016; 95(34).

13. Anderson RH, Webb S, Brown NA. Clinical anatomy of the atrial septum with reference to its developmental components. *Clinical Anatomy*.1999;12(5): 362-374. https://doi.org/10.1002/(SICI)1098-2353(1999)12:5<362::AID-CA6>3.0.CO;2-F.

14. Ardashev AV, Mangutov DA, Korneev NV, et al. The Experience of the Use of Intracardiac Echocardiography During Puncture of Atrial Septum. *Kardiologiia*. 2008;7: 25-9. (In Russ.).

15. Bockeria LA., Melikulov AKh., Kalysov KA. Interatrial septum puncture. *Annaly aritmologii*. 2015;12(4): 252-260. (In Russ.) https://doi.org/10.15275/annaritmol.2015.4.7.

16. Earley MJ. How to perform a transseptal puncture. *Heart*. 2009;95(1): 85-92. http://doi.org/10.1136/hrt.2007.135939.

17. Fender EA, Sibley CT, Nazarian S, et al. Atrial septal angulation varies widely in patients undergoing pulmonary vein isolation. *J Invasive Cardiol*. 2014;26(3): 128-31.

18. Anderson RH, Razavi R, Taylor AM. Cardiac anatomy revisited. *Journal of anatomy*. 2004;205(3): 159-177. https://doi.org/10.1111/j.0021-8782.2004.00330.x.