Atrial septal defect closure in adults: A ten-year experience

Fermeture de la communication interauriculaire à l'âge adulte : Expérience de 10 ans

Selim Boudiche[1], Sana Chatti[2], Rami Amroussia[2], Fathia Mghaieth[1], Jalel Ziadi[2], Abdeljelil Farhati[1], Mohamed Ben Hammamia[2], Mohamed Ali Tekaya[1], Sana Ouali[1], Faker Guedira[2], Raouf Denguir[2], Mohamed Sami Mourali[1]

1-Cardiology department, La Rabta Hospital / Tunis El Manar University / Faculty of Medicine of Tunis
2-Cardiovascular surgery department, La Rabta Hospital / Tunis El Manar University / Faculty of Medicine of Tunis,

RÉSUMÉ

Introduction : Les communications interauriculaires (CIA) constituent la cardiopathie congénitale la plus fréquente chez l'adulte et le type ostium secundum (OS) en est la forme la plus courante. Le bénéfice de sa fermeture à l'âge adulte est resté longtemps controversé.
But: Evaluer les résultats de la fermeture des CIA-OS chez l'adulte.
Méthodes: Etude de cohorte rétrospective, sur une période allant de 2008 à 2018. Tous les adultes (?20 ans) ayant bénéficié d'une fermeture de CIA-OS ont été inclus. Les critères de jugement étaient le succès de fermeture ainsi que l'évolution du statut fonctionnel et l'incidence de nouvelles arythmies à 12 mois.
Résultats: Cinquante patients ont été recrutés. Une dyspnée (? NYHA II) a été notée chez 58% et une arythmie chez 18% des patients. La faisabilité d'une fermeture percutanée était de 50%. Le taux de succès de fermeture était de 100%. La chirurgie était associée à une morbidité postopératoire élevée avec une hospitalisation plus longue (20 contre 4 jours, p<0,001). À 12 mois, une amélioration du statut fonctionnel a été observée chez 79%. L'incidence de nouvelles arythmies était de 5%. Une diminution significative de la dilatation des cavités droites ainsi que de la pression artérielle pulmonaire ont été rapportées.
Conclusions: Les résultats immédiats de la fermeture des CIA-OS chez l'adulte sont satisfaisants. La fermeture percutanée est associée à une moindre morbidité hospitalière. A long terme, une amélioration significative du statut fonctionnel a été observée cependant la survenue possible de nouvelles arythmies impose un suivi rapproché.

Mots-clés
Communications interauriculaires ; adulte ; fermeture percutanée ; chirurgie

SUMMARY

Introduction: Atrial septal defects (ASD) constitute the most frequent congenital heart disease in adults and ostium secundum (OS) the most common type. Benefit of its closure in adulthood has long been controversial.
Aim: To evaluate outcomes of OS-ASD closure in adults.
Methods: Retrospective cohort study, over a ten-year period from 2008 to 2018. All adults (≥20 years old) who benefited from OS-ASD closure were included. Study endpoints were closure success rate, functional status evolution and incidence of new arrhythmias at 12 months.
Results: Fifty patients were recruited. Dyspnea (≥ NYHA II) was noted in 58% and arrhythmia in 18% of patients. Feasibility of a percutaneous closure was 50%. Closure success rate was 100%. Surgery was associated with high postoperative morbidity with longer hospitalization stay (20 vs. 4 days, p <0.001). At 12 months, an improvement in functional status was observed in 79%. Incidence of new arrhythmias was 5%. A significant decrease in right cavities dilation as well as pulmonary arterial pressure has been reported.
Conclusions: Immediate results of OS-ASD closure in adults are satisfactory. Percutaneous closure is associated with reduced hospital morbidity. At 12 months, a significant improvement in functional status was observed however the possible occurrence of new arrhythmias imposes a close follow-up.

Key-words
Atrial septal defects; adult, percutaneous closure, surgery

INTRODUCTION

Atrial septal defect (ASD) is the first diagnosed grown-up congenital heart disease (1) and ostium secundum is the most common form (2).

At the opposite of pediatric population, it is clearly recommended to close ASD with significant shunt, regardless of symptoms, in order to prevent complications and improve functional outcome (3,4), ASD closure was long time controversial when diagnosed late in adulthood and many questions remained open as to the benefit / risk ratio of their closure at an advanced age (5).

We aimed through this study to assess immediate and long-term results of OS-ASD closure in adults.

METHODS

Study design

This was a retrospective cohort study led in the cardiology and cardiovascular surgery departments over a 10-year investigation period from 2008 to 2018.

Study population:

We included all adult patients (age greater than or equal to 20 years as defined by the World Health Organization (6)) with OS-ASD echocardiography and having undergone percutaneous or surgical closure of their defect. Patients with OS-ASD associated with other congenital or acquired heart disease were not included. We excluded patients lost to follow-up (n=3) as well as patients whose follow-up was less than 12 months (n=2).

Technical considerations

Transthoracic and transoesophageal echocardiograms were performed before interventions for ASD assessment, right heart measurements, pulmonary arterial pressure evaluation and associated abnormalities rule-out. Three-dimensional echocardiography was recently introduced in our department, allowing accurate patient selection for percutaneous or surgical ASD closure in complex cases (large defect, rim deficiency, multiple defects). Coronary angiography was indicated following current guidelines before closure strategy decision. Choice between catheter or surgical closure technique depended essentially on size and number of defects, rims' quality and presence of severe tricuspid regurgitation. ASD with diameter ≤40 mm and sufficient borders (≥5 mm) except for the aortic rim were closed percutaneously.

Follow-up:

A minimum follow-up period of 12 months was required. Clinical follow-up was provided by consultation reports or by referent physicians. As part of this follow-up, an interrogation targeting functional status and palpitations, a physical examination, an electrocardiogram and an echocardiogram (before discharge and between 3 and 6 months) were at least carried out. Holter monitoring guided by clinical history was performed during follow-up for new paroxysmal arrythmia assessment.

Primary endpoints:

Our primary endpoints were immediate outcome of OS-ASD closure in adults in terms of success rates and procedure related morbidity and mortality. The long-term results were judged on the evolution of functional status (New York Heart Association (NYHA) classification) and the possible occurrence of new supraventricular arrhythmias.

Secondary eindpoints:

Secondary endpoints were changes in echocardiographic parameters (right ventricle (RV) mid-cavitary diameter, right atrium (RA) area and systolic pulmonary arterial pressure (SPAP)).

Statistical analysis:

Categorical variables were presented by simple and relative frequencies. They were compared using Chi-square or Fisher tests. Quantitative variables were presented as means with standard deviations or medians with interquartile intervals. Subgroups were compared using the Student's t test or the Mann Whitney-U test. The degree of significance was set at 0.05.

RESULTS

Baseline characteristics:

We recruited 50 patients. Baseline characteristics were summarized in the table 1. Mean age was 37 ± 14 years with extremes ranging from 20 to 73 years. Seventy-two percent of the patients were female. Arterial hypertension was the most common comorbidity (20%). At diagnosis, 58% of patients were symptomatic of dyspnea (≥ NYHA II). NYHA class III dyspnea was noted in ten patients (20%).

Thirty-five patients (70%) were symptomatic of palpitations and prevalence of documented arrhythmias was 18%.

Finally, three patients (6%) had ischemic stroke history.

At the pre-closure echocardiographic assessment, mean defect diameter was 25.8 ± 9.9 mm. Left ventricular ejection function was preserved with an average of 65.7 ± 10.4%. Impact of the shunt on the cardiac cavities was assessed by mid-RV diameter and RA atrium area, estimated respectively at 41 ± 5.8 mm and 28.6 ± 7.4 cm². The mean level of SPAP was 46.3 ± 14.1 mmHg.

Table 1: Baseline characteristics.

	Overall N=50	Surgical closure N=25	Percutaneous closure N=25	
Age (years)	37 ± 14	41 ± 16	33 ± 11	0.036
Females	36 (72%)	19 (76%)	17 (68%)	0.52
Hypertension	10 (20%)	4 (16%)	6 (24%)	0.48
Diabetes	5 (10%)	3 (12%)	2(8%)	1
Dyslipidaemia	6 (12%)	3 (12%)	3 (12%)	1
Functional status (NYHA classification)				
NYHA I	21 (42%)	9 (36%)	12 (48%)	-
NYHA II	19 (38%)	9 (36%)	10 (40%)	
NYHA III	10 (20%)	7 (28%)	3 (12%)	0.04
Palpitations	35 (70%)	19 (76%)	16 (64%)	0.14
Chest pain	6 (12%)	2 (8%)	4 (16%)	0.38
Stroke	3 (6%)	1 (4%)	2 (8%)	0.55
Cardiac rhythm				
Sinus	41 (82%)	19 (76%)	22 (88%)	0.46
Atrial fibrillation	8 (16%)	6 (24%)	2 (8%)	-
Atrial flutter	1 (2%)	0 (0%)	1 (4%)	
Echocardiographic parameters				
LVEF (%)	65.7 ± 10.4	64.6 ± 9.1	66.8 ± 8.4	0.54
ASD diameter (mm)	25.8 ± 9.9	31.6 ± 8.8	20.1 ± 7.2	<0.0001
Mid-RV diameter (mm)	41.0 ± 5.8	43.0 ± 4.6	39.2 ±3.6	<0.0001
RA surface (cm2)	28.6 ± 7.4	34.1 ± 5.2	23.5 ± 4.3	<0.0001
SPAP (mmHg)	46.3 ± 14.1	49.4 ± 11.3	44.8 ± 9.1	0.143

NYHA: New York Heart Association; LVEF: left ventricle ejection fraction; ASD: atrial septal defect; RV: right ventricle; RA: right atrium; SPAP: systolic pulmonary arterial pressure.

Procedural data:

Feasibility of percutaneous repair was 50%. A clear trend towards catheter closure from 25% in the first quartile to 59% of cases between first and last quartile of the investigated period was noted. In comparison, ASD defect diameter was larger in surgical patients than percutaneously treated patients (31.6 ± 1.7 vs. 20.1 ± 7.2 mm, p<0.001).

All catheter-based closures were performed with Amplatzer ™ Atrial Septal Occluder (Saint Jude / Abbott Medical) type device. The median diameter of prostheses was 26 mm [IQR: 22-31]. A 40-mm device was needed in 2 patients (8%). Femoral access was used in all cases with sheath size varying from 8 to 12 French. A balloon assisted technique was helpful in 4 cases (16%) allowing adequate positioning of the left disc in the setting of large prosthetic size. A home-made fenestration was performed in one patient prior to device implantation with the aim to avoid acute pulmonary oedema after ASD closure because of elevated left ventricular filling pressure due to hypertensive and arrhythmia induced cardiomyopathy. In all cases, procedure was monitored by transthoracic echocardiography only, without recourse to general anaesthesia. This was possible thanks to ASD assessment by transoesophageal and / or 3-dimensional echocardiography prior to procedure or by sizing balloon during procedure. The median duration of the procedure was 40 minutes [IQR: 38-50].

Among surgical patients, sternotomy was performed in 96% and right anterolateral thoracotomy was used in only one case. Bovine pericardium was used in a majority of 52% of cases while autologous or prosthetic patches were used in 32% and 16% of cases respectively. Discharge fenestration was performed in four patients (16%) with because of right ventricular dysfunction or severe pulmonary arterial hypertension. Two patients (8%) underwent tricuspid annuloplasty for severe tricuspid regurgitation. A catecholamine support was mandatory after extracorporeal circulation in 12 patients (48%) with documented preoperatively right ventricular dysfunction. The median durations of cardiopulmonary bypass and aortic cross-clamping were 37 minutes [IQR: 30-42] and 22 minutes [IQR: 20-26].

Immediate results:

Both techniques were effective. They were associated with a 100% closure success rate. Among the 25 operated patients, a high in-hospital morbidity was noted (5 cases of infectious pneumonitis, 3 cases of sternitis, 2 cases of mediastinitis and 2 cases of postoperative atrial fibrillation). This postoperative morbidity resulted in longer hospital stay than in percutaneous group (with a median of 20 vs. 4 days, p<0.0001). No in-hospital deaths were noted.

Long-term outcomes:

Long-term outcomes in overall population, surgical and percutaneous closure groups, are summarized in table 2. Majority of initially symptomatic patients (dyspnea ≥ NYHA II) noticed functional improvement (23 out of 29, 79%). The remaining fifth (21%) have kept the same level of dyspnea according to the NYHA classification (Figure 1).

Table 2: 12-month follow-up clinical, electrocardiographic and echocardiographic evolution in overall population, surgical and percutalneous closure groups (before and after atrial septal defect closure.

	Overall N=50		Surgical closure N=25		Percutaneous closure N=25	
	Before	After	Before	After	Before	After
Functional status (NYHA classification)						
NYHA I	21 (42%)	44 (88%)	9 (36%)	23 (92%)*	12 (48%)	21 (84%)*
NYHA II	19 (38%)	5 (10%)	9 (36%)	1 (4%)	10 (40%)	4 (16%)
NYHA III	10 (20%)	1 (2%)	7 (28%)	1 (4%)	3 (12%)	0 (0%)
New onset of SVT	-	2 (4%)	-	1 (4%)	-	1 (4%)
SVT recurrence after cardioversion	-	2 (4%)	-	2 (8%)	-	0
Echocardiographic parameters						
Mid-RV diameter (mm)	41.0±5.8	31.4±7.1	43.0±4.6	33.6±6.1*	39.2±3.6	30.5±7.2*
RA surface (cm2)	28.6±7.4	22.1±5.2	34.1±5.2	23.1±6.3*	23.5±4.3	21.3±4.6*
SPAP (mmHg)	46.3±14.1	33.3±7.3	49.4±11.3	34.2±5.6*	44.8±9.1	32.0±7.5*

*No significant differences were observed between surgical and percutaneous groups at 12-month follow-up as for NYHA I achievement or echocardiographic parameters.

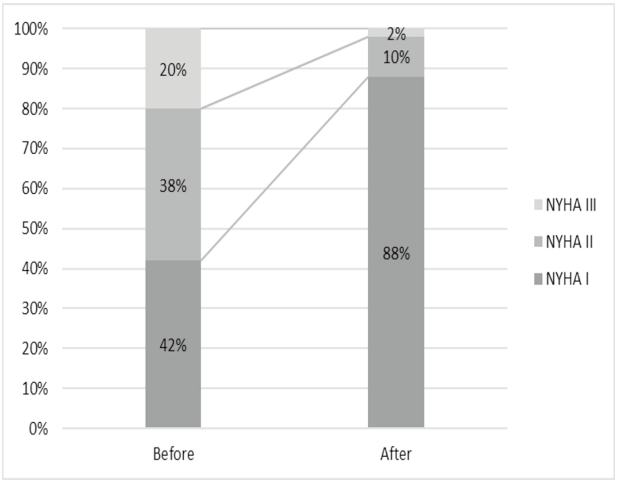
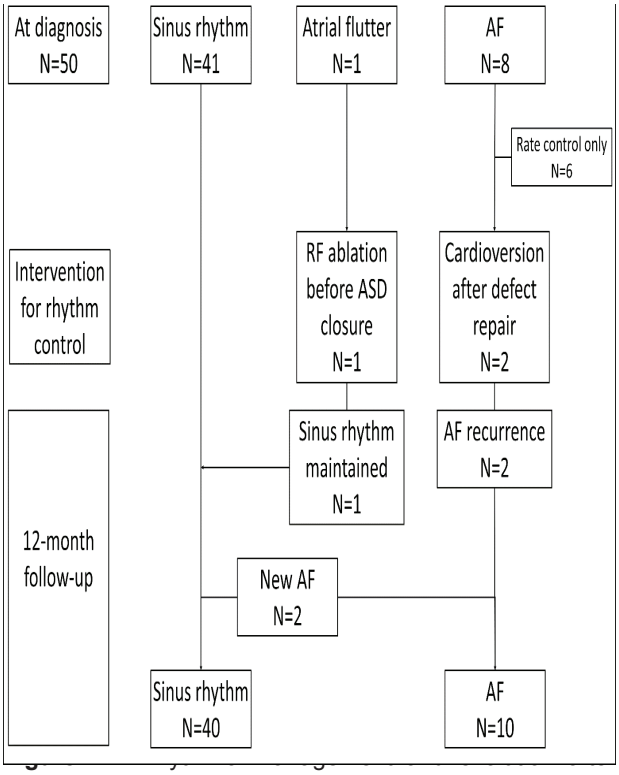


Figure 1: Functional status evolution after atrial septal defect closure in adults, n=50.

Among the 41 patients initially in sinus rhythm, incidence of new supraventricular tachycardias was 5% (2 patients) during the year of follow-up (Figure 2).



atrial septal defect closure in adults, n=50.

A significant improvement in the echocardiographic parameters was noted after the ASD closure (control echocardiograms carried out between 3 and 6 months). A statistically significant decrease in mid-RV diameter (from 41.0 ± 5.8 mm to 31.4 ± 7.1 mm, p<0.001) and RA area (from 28.6 ± 7.4 cm² to 22.1 ± 5.2 cm², p<0.001) as well as SPAP (from 46.3 ± 14.1 mmHg to 33.3 ± 7.3 mmHg, p <0.001) were reported (Figure 3).

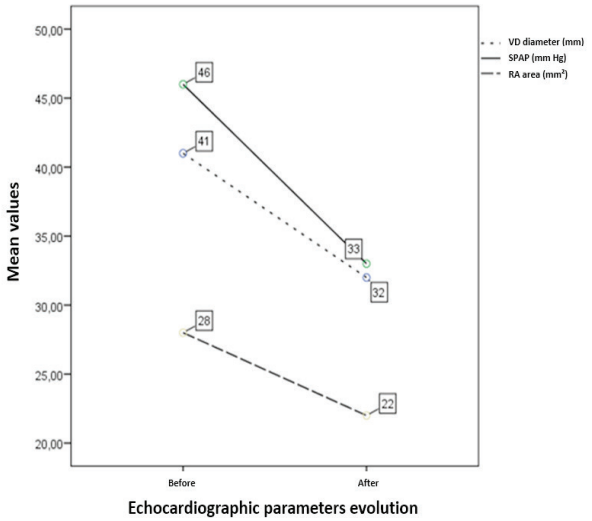


Figure 3: Echocardiographic parameters evolution at 12-month follow-up after atrial septal defect closure, n=50.

DISCUSSION

This study reported the 10-year experience of ASD closure in adults in the cardiology and cardiovascular surgery departments of our institution. Main findings were: a) At diagnosis, 58% of patients were symptomatic of dyspnea (≥ NYHA II) and prevalence of supraventricular arrythmia was 18%. b) Feasibility of percutaneous closure was 50%. c) A clear trend towards percutaneous closure during the last quartile of the investigated period was noted. d) Both techniques were safe and effective with a 100% success closure rate and no in-hospital death. e) High post-operative morbidity was noted after surgical repair resulting in significatively longer hospital stay than percutaneous group (20 vs. 4 days, p<0.0001). f) At 12-month follow-up, functional improvement in dyspnea was observed in 79% of initially symptomatic patients. g) Of the 41 patients initially with sinus rhythm, incidence of new arrhythmias was 5% in the year of follow-up despite ASD closure. h) A significant improvement in RV and RA sizes associated with a decrease in SPAP levels were reported at 3 to 6-month echocardiographic controls.

As for baselines characteristics and similarly to our study population, Atashband el al. found in a comprehensive analysis of 23 studies including 1958 patients, with OS-ASD closed percutaneously in adulthood (≥18 years old), a 68% female predominance, a 49% prevalence of dyspnea (≥ NYHA II) and 16% of atrial arrhythmias (7).

Currently, percutaneous closure feasibility is reaching more than 80% for unselected OS-ASDs (8–12). This was allowed by introduction of three-dimensional echocardiography for precise anatomical characterization of ASD shape and rims size and advances in catheterization technique with larger (up to 40 mm) and multifenestrated – “cribriform” Amplatzer™ devices (8,9). In the large Italian series, Butera et al. recruited prospectively 1 013 consecutive patients with OS-ASD and overall feasibility of percutaneous closure was 80,5%. This technique was more likely possible in adults than in paediatric patients (81.2% vs 69%, p<0.001) since ASD diagnosed in younger patients were larger and more complex requiring more often surgery (11). In our series, percutaneous closure was feasible in only 50% with a trend towards percutaneous interventions noted in the last quartile of the investigated period with growing operator’s experience.

In our study population, success rate of ASD closure was 100%, with no complications after percutaneous repair but high post-operative morbidity after surgery.

Unreported in our small sized sample series, unsuccessful percutaneous closure was described in 3% of adult patients in the large comprehensive analysis published by Atashband el al. where subsequent surgical repair was needed 1.2% (7). In this review paper, serious complications of device closure were rare and were in relation with device embolization or dislodgement (0.8%) and device thrombosis (0.4%) (7).

As noted in our study, large scale series comparing surgery and catheter-based interventions have reported similar success rates and mortality, but lower morbidity and hospital stay shorter with percutaneous closure (11,13).

Our 12-month follow-up revealed significant functional gain in terms of dyspnea despite late ASD closure in adulthood. This substantial improvement was demonstrated even in patients who considered themselves initially asymptomatic (14) and was reported by several studies

regardless of age of intervention (7,15–18) supporting current recommendations (10,19). In our study as well as in Humemberger et al. publication (17), clinical gain was associated with echocardiographic parameters improvement regarding RV and RA sizes and SPAP levels. In study population, incidence of new arrhythmias after ASD closure was 5% and atrial fibrillation recurred in all two patients in whom cardioversion was initially successfully attempted after ASD repair within the year of follow-up. In the literature, natural history of atrial arrhythmia and related thromboembolic events seems not be affected if ASD closure was performed after 40 years of age (5,17,18,20–22). Thus, patients with documented or suspected arrhythmia should be assessed for ablation prior to ASD closure because access to left atrium will be more difficult even feasible. Per-operative ablation can also be considered at the time of surgery. After late ASD closure in adulthood, patients should be closely followed for arrhythmias by history, ECG, and Holter monitoring if indicated (10).

Study limitations:

Besides being the first and largest Tunisian series of ASD closure in adults representing 10-year experience of cardiology and cardiovascular surgery departments, the retrospective design, the small simple size and the short follow-up duration (12 months) were main limitations of this study.

CONCLUSIONS

Immediate results of OS-ASD closure in adults are satisfactory. Percutaneous closure is associated with reduced in-hospital morbidity. At 12 months, a significant gain in functional status was observed. Echocardiographic parameters regarding right heart cavities sizes and pulmonary pressure levels were also improved. Possible occurrence of new arrhythmias imposes a close follow-up despite successful defect repair.

REFERENCES

1. Marelli AJ, Ionescu-Ittu R, Mackie AS, Guo L, Dendukuri N, Kaouache M. Lifetime prevalence of congenital heart disease in the general population from 2000 to 2010. Circulation 2014;130:749–56. doi:10.1161/CIRCULATIONAHA.113.008396.
2. Perloff JK. Surgical closure of atrial septal defect in adults. N Engl J Med 1995;333:513–4. doi:10.1056/NEJM199508243330809.
3. Murphy JG, Gersh BJ, McGoon MD, Mair DD, Porter CJ, Ilstrup DM, et al. Long-term outcome after surgical repair of isolated atrial septal defect. Follow-up at 27 to 32 years. N Engl J Med 1990;323:1645–50. doi:10.1056/NEJM199012133232401.
4. Roos-Hesselink JW, Meijboom FJ, Spitaels SEC, van Domburg R, van Rijen EHM, Utens EMWJ, et al. Excellent survival and low incidence of arrhythmias, stroke and heart failure long-term after surgical ASD closure at young age. A prospective follow-up study of 21-33 years. Eur Heart J 2003;24:190–7. doi:10.1016/s0195-668x(02)00383-4.
5. Attie F, Rosas M, Granados N, Zabal C, Buendía A, Calderón J. Surgical treatment for secundum atrial septal defects in patients >40 years old. A randomized clinical trial. J Am Coll Cardiol 2001;38:2035–42. doi:10.1016/s0735-1097(01)01635-7.
6. WHO | Definition of key terms. WHO n.d. https://www.who.int/hiv/pub/guidelines/arv2013/intro/keyterms/en/ (accessed August 26, 2019).
7. Atashband A, Lakkis N. First Comprehensive Analysis of Outcomes in Adult Patients after Percutaneous Closure of Isolated Secundum Atrial Septal Defects. Cardiovasc Hematol Agents Med Chem 2015;13:63–9.
8. Fraisse A, Latchman M, Sharma S-R, Bayburt S, Amedro P, di Salvo G, et al. Atrial septal defect closure: indications and contra-indications. J Thorac Dis 2018;10:S2874–81. doi:10.21037/jtd.2018.08.111.
9. Faccini A, Butera G. Atrial septal defect (ASD) device trans-catheter closure: limitations. J Thorac Dis 2018;10:S2923–30. doi:10.21037/jtd.2018.07.128.
10. Baumgartner H, Bonhoeffer P, De Groot NMS, de Haan F, Deanfield JE, Galie N, et al. ESC Guidelines for the management of grown-up congenital heart disease (new version 2010). Eur Heart J 2010;31:2915–57. doi:10.1093/eurheartj/ehq249.
11. Butera G, Romagnoli E, Carminati M, Chessa M, Piazza L, Negura D, et al. Treatment of isolated secundum atrial septal defects: impact of age and defect morphology in 1,013 consecutive patients. Am Heart J 2008;156:706–12. doi:10.1016/j.ahj.2008.06.008.
12. Spies C, Timmermanns I, Schräder R. Transcatheter closure of secundum atrial septal defects in adults with the Amplatzer

septal occluder: intermediate and long-term results. Clin Res Cardiol 2007;96:340–6. doi:10.1007/s00392-007-0502-3.
13. Du ZD, Hijazi ZM, Kleinman CS, Silverman NH, Larntz K, Amplatzer Investigators. Comparison between transcatheter and surgical closure of secundum atrial septal defect in children and adults: results of a multicenter nonrandomized trial. J Am Coll Cardiol 2002;39:1836–44. doi:10.1016/s0735-1097(02)01862-4.
14. Brochu M-C, Baril J-F, Dore A, Juneau M, De Guise P, Mercier L-A. Improvement in exercise capacity in asymptomatic and mildly symptomatic adults after atrial septal defect percutaneous closure. Circulation 2002;106:1821–6. doi:10.1161/01.cir.0000029924.90823.e0.
15. Chen M, Feng X, Sun J, Wang Q, Zhang P, Wang J, et al. Risk factors responsible for atrial fibrillation development between symptomatic patients with concealed or manifest atrioventricular accessory pathways. IJC Heart & Vasculature 2015;7:69–75. doi:10.1016/j.ijcha.2015.02.010.
16. Nyboe C, Fenger-Grøn M, Nielsen-Kudsk JE, Hjortdal V. Closure of secundum atrial septal defects in the adult and elderly patients. Eur J Cardiothorac Surg 2013;43:752–7. doi:10.1093/ejcts/ezs405.
17. Humenberger M, Rosenhek R, Gabriel H, Rader F, Heger M, Klaar U, et al. Benefit of atrial septal defect closure in adults: impact of age. Eur Heart J 2011;32:553–60. doi:10.1093/eurheartj/ehq352.
18. Gatzoulis MA, Redington AN, Somerville J, Shore DF. Should atrial septal defects in adults be closed? Ann Thorac Surg 1996;61:657–9. doi:10.1016/0003-4975(95)01043-2.
19. Stout KK, Daniels CJ, Aboulhosn JA, Bozkurt B, Broberg CS, Colman JM, et al. 2018 AHA/ACC Guideline for the Management of Adults With Congenital Heart Disease: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol 2019;73:1494–563. doi:10.1016/j.jacc.2018.08.1028.
20. Konstantinides S, Geibel A, Olschewski M, Görnandt L, Roskamm H, Spillner G, et al. A comparison of surgical and medical therapy for atrial septal defect in adults. N Engl J Med 1995;333:469–73. doi:10.1056/NEJM199508243330801.
21. Gatzoulis MA, Freeman MA, Siu SC, Webb GD, Harris L. Atrial arrhythmia after surgical closure of atrial septal defects in adults. N Engl J Med 1999;340:839–46. doi:10.1056/NEJM199903183401103.
22. Mantovan R, Gatzoulis MA, Pedrocco A, Ius P, Cavallini C, De Leo A, et al. Supraventricular arrhythmia before and after surgical closure of atrial septal defects: spectrum, prognosis and management. Europace 2003;5:133–8. doi:10.1053/eupc.2002.0294.