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Diagnosis and Surgical Treatment of a Foramen Ovale Defect in Older Patients Complicated by Pulmonary Artery Hypertension

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Abstract: Atrial septal defect (ASD) is one of the most common congenital heart defects in adult patients, accounting for all congenital heart defects — ASD) is one of the most common congenital heart defects in adults, accounting for 10–15 percent of all congenital heart defects and 25–30 percent of congenital heart defects diagnosed for the first time in adulthood. Its long-term undiagnosed course leads to chronic increases in pulmonary blood flow, causing pulmonary vasculature remodeling and the development of pulmonary artery hypertension (PAH), which significantly complicates the treatment strategy. This article reviews modern diagnostic methods for BADN complicated by PAH in adult patients—transthoracic and transesophageal echocardiography, right heart catheterization, assessment of pulmonary vascular resistance (PVR) — as well as treatment tactics, including percutaneous and surgical closure, and the "treat and repair" strategy used in severe PAH cases, are analyzed. In a retrospective registry of 632 patients, PH20 (mean pulmonary arterial pressure >20 mm Hg) was identified in 56.8% of patients before BADN closure, In the study of 117 patients, PAH normalization was observed in 80% of cases after transcatheter closure, and in a meta-analysis of 1,073 patients, PH prevalence decreased from 44% to 18% post-closure. The results obtained confirm the clinical importance of early diagnosis of BADN complicated by PAH and the selection of individualized treatment tactics.

Keywords: atrial septal defect, pulmonary artery hypertension, congenital heart disease, echocardiography, right heart catheterization, transcatheter closure, surgical treatment, pulmonary vascular resistance, Eisenmenger syndrome.

Introduction

Atrial septal defect (ASD) is a congenital heart defect characterized by a pathological hole in the septum between the atria, with an incidence at birth of 2–2.5 cases per 1,000 live births. BADN accounts for 10–15 percent of all congenital heart defects and 25–30 percent of congenital heart diseases diagnosed for the first time in adulthood, making it the most common congenital heart anomaly in adults. A characteristic clinical feature of the disease is that small to moderate defects can remain asymptomatic for many years, as the heart murmur is low-intensity and patients are not diagnosed in childhood[1].

In BADN, right-to-left shunting results in chronic volume overload of the right heart chambers and pulmonary circulation. Over time, this condition leads to pulmonary vascular endothelial injury, leukocyte activation, and mediator release, resulting in vascular smoothing and subsequent intimal hyperplasia. As a result, pulmonary vascular resistance (PVR) increases, leading to pulmonary arterial hypertension (PAH). According to various studies, the prevalence of PAH in

untreated BAD patients has been reported to be wide—starting from approximately 29 percent—based on the results of more than 30 studies published up to 2017, this wide variation in the rate is explained by differences in diagnostic criteria and patient selection[2].

The development of PAH significantly worsens the prognosis for patients with BADN: it is associated with reduced physical activity, decreased quality of life, and, in severe cases, an increased risk of death. In approximately 10% of patients with congenital heart disease, the development of PAH has been observed, which increases the likelihood of functional limitation eightfold. Therefore, the timely diagnosis of BADN complicated by PAH and the correct selection of treatment tactics are considered one of the pressing issues in modern cardiology and cardiac surgery[3-4].

The aim of the study is to analyze the modern diagnostic methods for BADN complicated by PAH in adult patients and the effectiveness of surgical and transcatheter treatment strategies based on the statistical results of clinical studies published in international open-access journals.

Research objectives: 1) To elucidate the epidemiological indicators of BADN and PAH, as well as their etiopathogenetic mechanisms; 2) analyze the diagnostic value of modern diagnostic methods—echocardiography, right heart catheterization, and techniques for assessing pulmonary vascular resistance; 3) criteria for selecting treatment tactics, including percutaneous and surgical closure, and consideration of the "treat and close" strategy; 4) comparative analysis of results from various clinical studies and development of practical recommendations.

Literature Review

Extensive research has been conducted in the international medical literature on the association between BADN and PAH. In their classic review, T. Geva, J.D. Martins, and R.M. Wald described the significance of PFO in adult practice, including the reasons for late diagnosis and the association between shunt size and the development of PAH.

Important data on the epidemiology of PAH in the setting of BADN were presented in a study published on the PMC platform in 2018: it described the pathogenesis of PAH as chronic damage to the pulmonary vascular endothelium, the pathogenesis of PAH was explained by chronic injury of the pulmonary vascular endothelium, leukocyte activation, and mediator release, and it was also noted that in 6% of adult patients with surgically closed BADN, grade 4–6 histopathological changes according to Heath-Edwards were identified on lung biopsy[5-6].

In the article by E. Zarambaitė and colleagues dedicated to the clinical case description, the "treat and repair" strategy in BADN complicated by severe PAH is described in detail. The authors emphasize that BADN accounts for 10–15 percent of all congenital heart diseases, and PAH develops in approximately 10 percent of patients with congenital heart disease, increasing the risk of functional limitation eightfold. In cases of severe PAH and high pulmonary vascular resistance, surgical closure is not performed immediately; first, specialized PAH-targeted drug therapy is administered, and then, once hemodynamic parameters have improved, the defect is surgically closed[7].

In a retrospective registry study published in the AHA journal Circulation: Cardiovascular Interventions, 632 adult patients who underwent percutaneous closure of a secundum atrial septal defect at a single center between 1998 and 2016 were analyzed. According to the study results, 56.8% of patients (359) had a preprocedural PH20 state (mean pulmonary arterial pressure >20 mm Hg), and the mean follow-up period was 7.6 ± 4.6 years. Patients with PH20 were significantly older (mean 56.5 vs 43.1 years, $p<0.001$) and had a higher prevalence of arterial hypertension (54.3% vs 21.6%, $p<0.001$)[8].

In a PMC-published study on transcatheter closure efficacy, 119 patients with BADN and PAH were divided into three groups based on their pulmonary vascular resistance (PVR) levels. According to the study results, PAH normalization was observed in 80 percent of patients overall after transcatheter closure: normalization was observed in 100% of the mild PVR group, 56.2% of the moderate PVR group, and only 28.6% of the severe PVR group. According to the ROC

analysis, a PASP (pulmonary arterial systolic pressure) value above 67.5 mm Hg had high accuracy in predicting the development of rPAH (AUC=0.944; sensitivity 0.922; specificity 0.933)[9].

A systematic review and meta-analysis published by the European Respiratory Society summarized data from 15 studies involving a total of 1,073 patients. According to the results, the pooled composite assessment rate of PH resolution after percutaneous BADN closure was 44 percent (95% confidence interval 29–60%). to 18 percent (95% confidence interval 8–27%), which confirms the potential for reversal of PAH with timely invasive treatment[10].

In a long-term follow-up study from 1980 to 2023 at Istanbul University Cerrahpasa Cardiology Institute, 19.7% of adult BADN patients (n=74) were diagnosed with PH, of whom 60 were diagnosed via right heart catheterization and 14 via echocardiography. In the study, the mean tricuspid annular plane systolic excursion (TAPSE) was 21.0 mm, The TAPSE/sPAP ratio was 0.64±0.24, demonstrating the importance of these parameters in assessing right ventricular function.

According to clinical recommendations developed by the American College of Cardiology, In adult patients with BAD, diagnostic catheterization is used only when pulmonary artery hypertension, left heart disease, or coronary artery disease in elderly patients is suspected. Anti–PAH drug therapy pulmonary vascular resistance in patients with pulmonary vascular resistance (PVR) ≥5 Wood units (WU), and if PVR ≥5 WU persists despite therapy, it is recommended to discontinue BADN and continue advanced PAH therapy[11].

Research Methodology

In this study, clinical data related to atrial septal defect (ASD) and pulmonary arterial hypertension (PAH) were compared. Data from patients older than 18 years were included in the study. The analysis included assessments of systolic and mean pulmonary arterial pressure (sPAP, mPAP), pulmonary vascular resistance (PVR), the TAPSE index, and the Qp:Qs ratio. The obtained results were compared based on echocardiography and right heart catheterization data, and treatment efficacy was assessed by NYHA functional class, the six-minute walk test, and PAH normalization markers.

Results and Discussion

The analyzed sources confirm the high clinical significance of BADN in adult cardiology. According to a 50-year follow-up study published in the Journal of the American Heart Association (JAHA, 2022), BADN has an incidence of 2.5 cases per 1,000 live births, and in 25–30% of these patients, the condition is first diagnosed in adulthood. In an epidemiological study conducted in Kuwait (PMC, 2021), BADN was recorded as the most common congenital heart defect among adults (21.5%)[12].

Regarding the development of PAH, the figures cited in the sources reflect a specific range of prevalence. The table below compares the prevalence of PAH and key demographic indicators from studies conducted in different countries over various years:

Table 1. Key statistical indicators of various clinical studies on BADN complicated by PAH

Tadqiqot manbai (yil)	Bemorlar soni	PAH/PH tarqalishi	O‘rtacha yosh / kuzatuv
AHA Circ. Cardiovasc. Interv. (2021)	632	56,8% (PH20)	56,5 yosh (PH20 guruhi); FU 7,6±4,6 y.
PMC, transkateter tadqiqot (2023)	119	100% boshlang‘ich PAH	rPAH bashorati: AUC 0,944
ERS tizimli sharh va meta-tahlil (2020)	1073	44% → 18% (yopilishdan keyin)	15 tadqiqot umumlashtirilgan

Tadqiqot manbai (yil)	Bemorlar soni	PAH/PH tarqalishi	O‘rtacha yosh / kuzatuv
Cerrahpasha instituti, BMC (2025)	376 (74 PH)	19,7%	1980–2023 y. kuzatuv
Heart Surgery Forum (fenestratsiya, 2009)	16	100% og‘ir PAH	34,9±13,5 yosh; FU 34,5±13,1 oy

In the diagnostic phase, transthoracic echocardiography (TTE) is the first-line, most widely used, and noninvasive method. As shown in the Istanbul study, a systolic pulmonary arterial pressure (sPAP) ≥40 mmHg is accepted as an echocardiographic criterion, although right heart catheterization is sometimes required for definitive diagnosis. In the analyzed cohort, 60 of the 74 PAH cases (81%) were diagnosed by catheterization, while 14 (19%) were diagnosed by echocardiography alone, confirming the role of catheterization as the “gold standard”[13].

Among noninvasive methods, the TAPSE/sPAP ratio (ratio of tricuspid annular plane systolic excursion to estimated pulmonary arterial systolic pressure) is cited as a promising indicator for assessing right ventricular–pulmonary artery coupling (RV-PA coupling). A 2024 study published in PMC showed that a TAPSE/ePASP ratio of ≤0.34 has good sensitivity in predicting PVR > 5 Wood units, This allows for the early identification of high-risk patients through this non-invasive method[14].

Right heart catheterization remains the “gold standard” for PAH diagnosis because it allows for the direct measurement of mean pulmonary arterial pressure (mPAP), pulmonary vascular resistance (PVR), and the Qp:Qs ratio. According to the American College of Cardiology (ACC, 2022) recommendations, catheterization is not required for all BADN patients, but is indicated on a case-by-case basis in patients with suspected PAH, those with left heart disease, or the elderly. PVR ≥5 Wood units is an important threshold for selecting a treatment strategy: in patients with a lower value, closure of the defect is safe, whereas in those with a higher value, specific anti-PAH therapy is required first[15].

Transcatheter (percutaneous) closure is the first-line method in BADN complicated by mild to moderate PAH, as it is characterized by being less invasive, with a shorter hospital stay and a low complication rate. In a study conducted in Pakistan (PMC, 2020) in 30 patients, the mean systolic pulmonary arterial pressure decreased from 49.8±16.3 mmHg to 37±11.4 mmHg ($p<0.001$) on catheterization at 6 months after percutaneous closure, by echocardiography, from 58.8±14.3 mmHg to 34.5±7.2 mmHg ($p<0.001$); 90% of patients had an improvement in functional class, and no deaths were recorded at six months.

In cases complicated by severe PAH (PVR > 5 WU), the traditional approach was to completely forgo closure of the defect, but in recent years the “treat and repair” strategy has been widely adopted as an alternative solution. In this strategy, specialized pulmonary vasodilator therapy (e.g., endothelin receptor antagonists, phosphodiesterase-5 inhibitors) is initially used, and once hemodynamic parameters (to a PVR level <5 WU) have improved, the defect is closed surgically or by transcatheter methods. E. Zarambaitė et al. (2022) described a clinical case where this very approach was used and resulted in a successful outcome[16].

For patients with severe PAH and high surgical risk, the technique of placing a fenestrated (perforated) occluder is of particular importance. In a study published in The Heart Surgery Forum (2004–2009, 16 patients), BADN was closed using a fenestrated patch; Patients ranged in age from 6 to 57 years (mean 34.9±13.5 years), and the follow-up period was 9–59 months (mean 34.5±13.1 months). The mean preoperative pulmonary arterial resistance was 9.8 ± 2.9 Wood units—a high value characteristic of the severe PAH group. Similarly, in a study published in the journal Cardiology Young (2023), in 5 patients with decompensated heart failure and severe PAH (mean age 48.8±13.5) The 6-minute walk test and oxygen saturation significantly improved ($p=0.0001$) after the fenestrated BADN occluder was used, and pulmonary vascular resistance and pressure

decreased significantly (p=0.009)[17].

Table 1 summarizes the key clinical outcomes by treatment methods:

Table 1. Key statistical indicators of various clinical studies on BADN complicated by PAH.

Davolash usuli	Bemorlar/tadqiqot	Asosiy natija	Statistik ko‘rsatkich
Standart perkutan yopish	30 bemor (PMC, 2020)	sPAP pasayishi (EKG bo‘yicha)	58,8→34,5 mmHg, p<0,001
Transkateter, PVR bo‘yicha guruhlar	119 bemor (PMC, 2023)	PAH normalizatsiyasi	Yengil 100%, og‘ir 28,6%
Fenestratsiyalangan okklyuder	16 bemor (HSF, 2004–09)	Uzoq muddatli barqarorlik	FU 34,5±13,1 oy
“Davola va yop” strategiyasi	Klinik holat (Medicina, 2022)	Muvaffaqiyatli jarrohlik	Hemodinamika normalizatsiyasi
Perkutan yopish (meta-tahlil)	1073 bemor, 15 tadqiqot (ERS)	PH tarqalishi pasayishi	44%→18% (95% CI 8–27%)

If BADN remains untreated for a long time and PVR reaches an irreversible stage, the direction of blood flow reverses—from right to left—and Eisenmenger syndrome develops. In such cases, closing the defect is not indicated but rather contraindicated, because the right heart has become unable to overcome pulmonary resistance, and closing the defect would worsen right heart failure and increase the risk of death. In such patients, the primary treatment approach is specialized PAH-targeted pharmacotherapy, and in severe cases, surgical options such as lung transplantation or a Potts shunt remain.

According to a PMC review of interventional and surgical techniques, atrial septostomy and the Potts shunt can be useful as a temporary bridging modality until lung transplantation, In severe cases, veno-arterial extracorporeal membrane oxygenation (VA-ECMO) serves as the definitive bridging therapy. Furthermore, implantation of atrial flow regulator (AFR) devices was performed in 36 patients with a 100 percent success rate and 100 percent device patency at three months, indicates that this device is safe and effective in patients with severe PAH refractory to medical therapy.

Thus, the analysis conducted shows that the choice of treatment tactics in CTEH complicated by PAH requires a strictly individualized approach: in mild-to-moderate PAH, standard transcatheter closure is performed with sufficient efficacy, severe, However, in reversible PAH, a “treat and seal” strategy or fenestrated devices are used, and in cases of severe, irreversible PAH (Eisenmenger syndrome), closure of the defect is abandoned, opting for medical and, when necessary, transplant therapy.

Conclusion

Atrial septal defect (TOF) is the most common congenital heart disease in adults, and its delayed diagnosis leads to the development of pulmonary arterial hypertension (PAH) in 20% to 57% of patients. Although echocardiography is considered the primary and effective screening method for the initial diagnosis of the disease, right heart catheterization remains the “gold standard” for accurately assessing pulmonary blood vessel pressure and pulmonary vascular resistance (PVR). Treatment strategy must be determined based on each patient's individual hemodynamic parameters, particularly the level of PVR. In mild cases with pulmonary vascular resistance below 5 Wood units (WU), standard closure of the defect demonstrates high efficacy of 80–100 percent.

In severe but reversible cases with a PVR above 5 WU, an initial “treat and seal” strategy using specific medications or the use of specialized fenestrated devices is recommended**.**

However, if the disease is severely advanced, irreversible processes in the pulmonary blood vessels — If Eisenmenger syndrome has developed, surgical closure of the defect is absolutely contraindicated, and such patients are managed only with specialized drug therapy or lung transplantation. In conclusion, the key to successfully treating BADN complicated by PAH is early disease detection and tailoring the treatment strategy to the patient's individual hemodynamic status.

References

[1] E. Zarambaitė, G. Ramantauskaitė, A. Krivickienė, A. Siudikas, S. Miliauskas, and E. Ereminienė, "The treatment strategy for the atrial septal defect in the presence of severe pulmonary hypertension," Medicina, vol. 58, no. 7, p. 892, Jul. 2022.

[2] T. Geva, J. D. Martins, and R. M. Wald, "Atrial septal defects," The Lancet, vol. 383, no. 9932, pp. 1921–1932, Jun. 2014.

[3] C. J. Kim, "Long-term outcomes in adult patients with pulmonary hypertension after percutaneous closure of atrial septal defects," Circulation: Cardiovascular Interventions, vol. 14, no. 11, Nov. 2021.

[4] Y. J. Zhang, "Outcomes in patients with pulmonary arterial hypertension underwent transcatheter closure of an atrial septal defect," BMC Cardiovascular Disorders, vol. 23, no. 1, p. 182, Apr. 2023.

[5] A. C. M. J. van Riel, "Prevalence and outcomes of pulmonary hypertension after percutaneous closure of atrial septal defect: a systematic review and meta-analysis," European Respiratory Review, vol. 29, no. 158, p. 200099, Dec. 2020.

[6] H. C. Kuijpers, "Cause-specific mortality of patients with atrial septal defect and up to 50 years of follow-up," Journal of the American Heart Association, vol. 11, no. 21, Nov. 2022.

[7] T. S. Goldberg, "Pulmonary arterial hypertension in adults with atrial septal defect," Progress in Cardiovascular Diseases, vol. 61, no. 5-6, pp. 412–418, Dec. 2018.

[8] C. S. Rhee and A. N. Zaidi, "Atrial septal defect in adulthood: Ten points to remember," American College of Cardiology, Jul. 2022. [Online]. Available: https://www.acc.org/

[9] X. Wang, "The association of right ventricular-pulmonary arterial coupling and pulmonary vascular resistance in adult patients with uncorrected atrial septal defect," Frontiers in Cardiovascular Medicine, vol. 11, Jun. 2024.

[10] M. S. Ahmed, "Immediate and short-term outcome of percutaneous atrial septal defects closure in adult patients," Cureus, vol. 12, no. 11, Nov. 2020.

[11] J. N. Plymale, "Risk factors for pulmonary hypertension in adults after atrial septal defect closure," The American Journal of Cardiology, vol. 123, no. 6, pp. 980–984, Mar. 2019.

[12] G. Yong, P. Khairy, P. De Guise, A. Dore, F. Marcotte, L. A. Mercier, S. Noble, and R. Ibrahim, "Pulmonary arterial hypertension in patients with transcatheter closure of secundum atrial septal defects: A longitudinal study," Circulation: Cardiovascular Interventions, vol. 2, no. 5, pp. 455–462, Oct. 2009.

[13] H. L. Zhang, "Surgical strategy in patients with atrial septal defect and severe pulmonary hypertension," The Heart Surgery Forum, vol. 15, no. 2, pp. 91–95, Apr. 2012.

[14] A. N. B. Singh, "Interventional and surgical treatments for pulmonary arterial hypertension," Journal of Clinical Medicine, vol. 10, no. 15, p. 3342, Aug. 2021.

[15] M. Al-Bustan, "Epidemiology of adult congenital heart disease among the general population in Kuwait," BMC Cardiovascular Disorders, vol. 21, no. 1, p. 165, Apr. 2021.

[16] K. Tanaka, "‘Two-step’ percutaneous procedure for repairing the atrial septal defect with severe pulmonary hypertension: a case report," BMJ Case Reports, vol. 16, no. 1, Jan. 2023.

[17] J. M. Oliver, "Atrial natriuretic peptide and three-dimensional echocardiography after transcatheter closure of atrial septal defect," Revista Española de Cardiología, vol. 61, no. 5, pp. 490–497, May 2008.