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Hemodynamic features of pregnant women with atrial septal defect in the third trimester of pregnancy: A literature review

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Abstract. Due to the decline in mortality rates among children with heart disease, a significant number of such children have reached reproductive age. However, since knowledge about the impact of pregnancy on haemodynamics in women with heart disease is limited, this study is extremely relevant. The study aimed to provide a comprehensive review of current scientific sources and consolidate the knowledge gained on haemodynamic features in pregnant women with atrial septal defects. Several methods were used in the study: analysis, including comparative analysis, synthesis, bibliography, systematisation, and categorisation. A two-stage approach in the form of a systematic literature review was also used. The complex haemodynamic changes that occur in pregnant women, both in normal and pathological conditions, in particular in pregnant women with atrial septal defect, are considered. The question is specified as to why hemodynamic changes become most significant in the third trimester of pregnancy, their impact on the course of pregnancy, and the outcome of labor completion. The topic of acute and chronic complications of atrial septal defect and modern principles of their prevention and treatment are covered. Special attention is paid to the methods of correction of this heart defect, considering their advantages, disadvantages and possible complications. The experience of perinatal centres in several European countries in managing pregnancies in women with cardiovascular disease, in particular with atrial septal defects, is reviewed. Gaps in knowledge about the prevalence of these defects and risk factors were filled. The study addressed the lack of a comprehensive view of this problem: from pathophysiological basis and epidemiology to treatment and modification of risk factors. The study is of great practical value for healthcare professionals, as it can serve as a basis for the development of preventive programmes and other interventions for pregnancies of women with congenital cardiovascular disease

Keywords: congenital malformations; gestation; cardiovascular complications; risk factors; open oval window; pulmonary hypertension

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Introduction

Maternal and child health is one of the most important aspects of health care, both at the individual and population levels, as it largely shapes the health of the nation. In this context, congenital malformations (CM) are of particular importance, which is directly related to the significant share of this group of pathologies in the structure of morbidity and mortality in the neonatal period. Healthcare professionals often consider the CM issue in the short term, neglecting the long-term consequences, such as the development of chronic diseases and a deterioration in quality of life. Congenital heart disease (CHD) accounts for the largest share of the CM structure, including pathologies that are accompanied by a violation of the integrity of the heart chambers, such as atrial septal defects (ASD). Modern methods of early diagnosis and treatment can largely avoid the consequences in the short term, which leads to a reduction in neonatal mortality. This allows a significant proportion of patients to reach reproductive age. It is during this period that the long-term CM consequences, including CHD, come to the fore, which causes the problem of pregnancy management with this comorbidity, as gestation is a significant risk factor for decompensation of heart disease. The main problem with past studies on this topic was their narrow focus, with researchers looking at the problem from a particular part of it, such as epidemiology or pathophysiological aspects of haemodynamic changes. As scientific materials were accumulated, it became necessary to form a comprehensive and comprehensive view of the problem.

This issue was discussed by Ukrainian researchers on several occasions. As such, V. Yaroslavskyi & Yu. Tsysar reviewed the general theoretical basis of the problem, superficially touching upon the epidemiology and clinical CHD manifestations [1]. Hemodynamic changes during pregnancy in healthy women and those with CHD were also highlighted, especially in the third trimester of pregnancy, as this period is characterised by the greatest hemodynamic changes. S. Triska *et al.* highlighted the practical aspects of pregnancy management in women with CHD, also devoting a separate paragraph to acquired heart disease [2]. The authors emphasised the importance of risk stratification in all pregnant women, and the order and stages of their hospitalisation in healthcare facilities, depending on the identified risk group. I. Kravchuk *et al.* focused on the impact of acquired heart disease on pregnancy, particularly in women with thrombophilia, leaving aside aspects of congenital heart disease [3]. Scientists have noted that haemodynamic disorders that occur in pregnant women with heart disease significantly increase the risk of complications such as weakness of labour, bleeding, and newborn asphyxia. In particular, the study found that thromboembolic complications were the most dangerous. V. Kryvetskyi *et al.* noted that some CHD, even despite advances in modern diagnostic technologies, may remain undetected for long periods, especially in the case of ASD, as some types of this defect are not accompanied by significant haemodynamic disorders in physiological conditions [4]. In some cases, ASD is manifested during pregnancy, due to increased haemodynamic changes in the third trimester of pregnancy. T. Shevchenko *et al.* emphasise that computed tomography is the most optimal method for the effective diagnosis of ASD, although this method is not as widely used in this area as, for example, ultrasound methods [5]. It is important to note that this method has certain limitations in terms of availability and a certain group of contraindications, which also leads to the predominant use of other methods of instrumental research to detect ASD. This, in turn, can lead to undiagnosed haemodynamically insignificant defects. Late detection of ASD can pose risks to pregnancy.

Thus, given the medical and social significance of this problem, the aim of this study is a comprehensive review of the literature and consolidation of existing knowledge on the features of haemodynamics in pregnant women with ASD, especially in the third trimester of gestation and clinical manifestations of the identified disorders. Additional tasks include studying the epidemiology of CHD, its impact on the course of pregnancy and identifying the main risk factors associated with this group of pathologies. A detailed study of this problem can be used to develop optimal approaches to the management of pregnancy and childbirth in women with ASD, improving the quality of their lives and the health of their children.

An extensive and exhaustive scientific literature search was conducted using the analysis and bibliographic method in biomedical scientific and practical resources, including Science Direct, CINAHL, PubMed, Cochrane Library, Web of Science, Ovid, JSTOR, Psychology Database, and EMBASE. Various combinations of keywords and phrases related to the issue of ASD and risk factors, such as "atrial septum", "pregnancy", "haemodynamics", "developmental pathology", "newborns", "risk factors", and others, were used. The search covered scientific materials published in the period from 2018 to 2023, including both basic researches, for which a wider time frame was chosen, and current scientific publications. To refine the focus of the research, the results of this search were adjusted to focus on scientific articles published in journals specialising in biomedicine, leaving aside the socio-economic aspect of the topic. Studies were analysed that comprehensively covered both the issues of ASD and haemodynamic changes in pregnant women in normal and pathological conditions. As a result of this work, more than 100 scientific papers were analysed. Subsequently, 47 of the best scientific papers were selected using exclusion criteria. The main directions for further research were outlined using the synthesis method. The same methods were used to systematise and classify the collected information. The systematisation and categorisation methods resulted in a structured data system that greatly simplified the analysis and interpretation of information on ASD and related risk factors. In addition to the above, the study used a two-stage approach based on the proven bibliographic and analytical methods proposed by S.K. Boell & D. Cecez-Kecmanovic [6]. The application of this allowed for a comprehensive aggregation, systematisation, classification, and analysis of sources on the issue.

Congenital Heart Defects: Defect Variants, Clinical Manifestations, Risk Factors and Diagnostic Methods

According to the study by N. Khudoykulova, congenital heart disease is one of the most common anomalies in newborns, occurring in the range of 4 to 10 cases per 1000 live births [7]. Among the most common congenital heart defects are the following: interventricular septal defects, atrial septal defects, transposition of the great vessels, patent ductus arteriosus, and Phalo group defects. Among patients with congenital heart defects, 47% are detected during prenatal screening in a maternity hospital or other healthcare facility, and 93% of cases are detected before the age of 1 year. 60-65% do not survive the first year of life due to the lack of necessary surgical correction, as highlighted in their work by T. Protsak & K. Khovanets [8]. The structure of congenital heart defects includes congenital stenosis of the aortic mouth, coarctation of the aorta, Fallot's group defects, atrial septal defect, patent ductus arteriosus, and ventricular septal defect, as shown in Figure 1. Thus, ASD is one of the most common heart defects and, given the high prevalence of this group, CM in general [9].

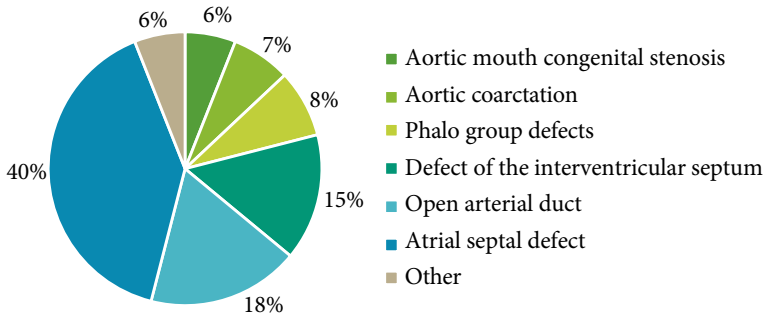

Figure 1. Congenital heart disease nosological structure
Source: Compiled by the authors based on [8, 9]

There are four different types of atrial septal defects, although only two of them are of significant practical importance in the context of pregnancy. The most common of these is a secondary defect, which is located only at the level of the foramen ovale and is usually found in adult patients. Primary atrial septal defect, in turn, accounts for only 15-20% of all cases and is usually detected in childhood. This type of ASD is often combined with congenital mitral valve insufficiency, which continues to progress over time despite correction in childhood. This is accompanied by the development of decompensated mitral insufficiency, which was noted by C. Frescura & G. Thiene [10].

Given the high prevalence and medical significance of both developmental disorders in general and congenital heart diseases in particular, scientists continue to focus on the factors that contribute to the development of these pathologies. This issue covers a wide range of risk factors, from genetically determined to iatrogenic. As such, B.D. Gelb highlighted the topic of genetic determination of CHD and emphasised the use of modern genetic achievements as both early diagnosis of these malformations and prevention of their development [11]. The issue of the drug effect on the risk of developing birth defects was investigated by X. Wen *et al.* [12] and N. Mallah *et al.* [13], focusing on the use of macrolides and opioid analgesics, respectively. Such studies and the implementation of their results in medical practice may help to avoid iatrogeny. Researchers also paid attention to the maternal somatic state as a risk factor for congenital heart disease. Z. Liang *et al.* examined the impact of obstetric and gynaecological pathology on the risk of developing CHD in the example of endometriosis, the researchers emphasised the need for detailed diagnosis and subsequent correction of reproductive system pathologies during pregnancy planning [14]. According to N.Z. Costa *et al.* [15] and M.J. de Ramírez-Altamirano *et al.* [16], environmental factors, in particular chemicals such as agropesticides and heavy metals, are risk factors for the development of CHD in some cases.

J.O. Seyi-Olajide *et al.* highlighted the importance of developing and implementing screening programmes for the early diagnosis of CHD [17]. The researchers noted that there is a certain gap between the quality of such programmes in high-, middle- and low-income countries. In middle- and low-income countries, the primary early CHD diagnosis tool is ultrasound, which requires neither significant material resources nor significant qualifications of medical personnel. At the same time, as noted by Y. Xia *et al.* noted that in high-income countries, modern screening programmes tend to use innovative diagnostic methods, such as the identification of biomarkers in pregnant women's blood [18].

Hence, CHD is the most common group of congenital malformations, with ASD taking the leading place among them. The ASD structure is not homogeneous and consists of four types, the most common of which is a secondary atrial septal defect, which is characterised by late diagnosis. ASD can also be combined with other heart defects, the most significant of which is congenital mitral valve insufficiency. The combination of these defects can lead to the development of decompensated mitral insufficiency. Given the medical and social significance of CHD, several studies have

been conducted on the factors of development of this group of pathologies, identifying a wide range of factors, from genetic to iatrogenic. The most common method of diagnosing CHD, including ASD, is ultrasound diagnostics. However, in high-income countries, innovative methods such as the detection of specific biomarkers in pregnant women's serum are being integrated into screening programmes.

Physiological Changes in the Cardiovascular System During Pregnancy

The woman's body undergoes significant changes during pregnancy that are not related to the CHD. The increase in blood volume in the bloodstream, mainly due to plasma, is positively correlated with gestational age, which peaks in the third trimester. This causes the development of gestational haemodilution, which is accompanied by changes in placental circulation due to a decrease in blood viscosity. Also, heart failure is quite common, which is caused by the inability of the heart muscle to adapt to the increased volume of the bloodstream, which significantly affects the placental circulation. Anaemia in combination with increased oxygen demand of the heart muscle can lead to a mismatch between the demand and blood supply, which can aggravate the existing phenomena of ischaemia in the form of exacerbation or manifestation of coronary heart disease, as highlighted in the study by M. Konovalova & N. Mykhailovska [19]. There is an increase in cardiac output of up to 50% in the third trimester, which is associated with an increase in left ventricular end-diastolic volume. The stroke volume and heart rate are also positively correlated with gestational age. These changes are not uniform; a significant increase in both indicators can be observed during the first 8 weeks of gestation, after which their levels do not change significantly over 20 weeks, as noted by N.H. Troiano [20]. Remodelling of cardiac activity begins in the first weeks of pregnancy and is associated with an increase in left ventricular end-diastolic volume. J. Ren *et al.* noted that in physiological pregnancy, both systolic and diastolic blood pressure decrease [21]. Pressure indicators undergo the greatest changes in the second trimester of pregnancy. There is also reason to believe that changes occur at the level of the vascular bed: venous blood volume and vein distension increase, basal oxygen consumption increases by about 50 mL/min, which is due to increased lung ventilation. Changes in respiratory parameters are associated with the central effect of progesterone, increased angiotensin II levels, and changes in blood osmolarity, as demonstrated by R.M. Sima *et al.* [22]. Some extracardiac factors, such as the position of the pregnant woman in space, also affect cardiac output. Thus, uterine enlargement can lead to a decrease in cardiac output by compressing the vena cava and aorta when the pregnant woman is in the supine position. This compression leads to a decrease in venous return and a 20-30% decrease in cardiac output. In the supine position, a woman may develop hypotension syndrome in the later stages of pregnancy. On the other hand, cardiac output is optimal when a woman is on her side. Childbirth also contributes to an increase in cardiac output. In the first hour after birth, cardiac output increases by about 22%. As noted by Z.N. Pascual & M.D. Langaker, within 2-4 weeks after delivery, the index gradually decreases and returns to normal levels approximately 6 weeks after birth [23]. During pregnancy, the ratio of the activity of the coagulation and anti-coagulation systems of the blood is also disturbed, with the dominance of the former, as studied in detail by B.B. Warren *et al.* [24]. This is primarily due to an increase in the concentration of such coagulation factors as VII, VIII, IX, X, and XII. At the same time, fibrinolysis is inhibited by a decrease in the concentration of protein S, which ultimately leads to the inhibition of fibrinolysis. These changes lead to the development of hypercoagulability and a natural increase in the risk of thrombotic and thromboembolic complications, and this risk persists for 6 weeks after delivery.

A study conducted by M. Bester *et al.* [25] demonstrated that pregnant women undergo a significant restructuring of the autonomic nervous system, characterised by a decrease in the tone of the parasympathetic and an increase in the tone of the sympathetic nervous systems. These changes lead to changes in heart rate variability, which is a sensitive marker of the functioning of the autonomic nervous system. In addition, in pregnant women, there is a decrease in the reactivity of the autonomic nervous system, which can negatively affect the implementation of adaptive mechanisms of the cardiovascular system during pregnancy, which is especially dangerous for pregnant women with CHD.

As such, pregnancy is accompanied by significant changes in the cardiovascular system. Hemodynamic changes are characterised by an increase in blood volume, cardiac output, and heart rate. The increase in blood volume is caused by hypervolaemia, which occurs mainly due to an increase in the amount of plasma. The increase in cardiac output is due to an increase in left ventricular end-diastolic volume, and the increase in heart rate is a compensatory response to the increase in blood vessel volume. Cardiac remodelling, which is characterised by an increase in the mass of the left ventricle and its chambers, also occurs as a result of the heart's adaptation to increased stress. A shift in haemostasis towards hypercoagulation due to an increase in the concentration of blood coagulation factors and a decrease in fibrinolysis activity. This shift is physiologically caused by the prevention of bleeding during labour. Changes in autonomic regulation, characterised by a weakening of parasympathetic and strengthening of sympathetic influences, occur due to an increase in the level of catecholamines produced by the adrenal glands. In women with CHD, the above changes can lead to decompensation of cardiac pathology and the development of pregnancy complications, as discussed in the next section.

Clinical and Haemodynamic ASD Complications in Pregnant Women

Sometimes, due to minor and nonspecific clinical manifestations in the form of fatigue and impaired exercise

tolerance, ASD is not diagnosed for a long time. Uncorrected ASD is accompanied by the movement of blood along a pressure gradient from the left atrium to the right atrium, which causes an enlargement of the right atrium and, subsequently, the right ventricle. This can also lead to the development of secondary tricuspid valve failure, as noted by V.T. Binh *et al.* [26]. These haemodynamic changes are significantly exacerbated in the third trimester of pregnancy when the volume of circulating blood increases by approximately 50%. Almost half of patients with late-diagnosed ASD suffer from heart rhythm disturbances, which in some cases may be the main manifestation of the pathology. Given the phenomenon of left-to-right shunting and turbulent blood flow due to heart rhythm disturbances, the risk of thromboembolic events is significant. In some cases, ASD is diagnosed only after the onset of complications, such as acute cerebrovascular accident, which is based on the phenomena of paradoxical embolism, as described in detail by V. Muroke *et al.* [27]. P. Sjöberg *et al.* noted that during pregnancy, patients with uncorrected ASD have a 4-5% increased risk of cardiac arrhythmias due to increased circulating blood volume and additional stretching of the heart chambers [28]. In addition, physiological tachycardia in the second half of pregnancy, given the already existing arrhythmia, can lead to severe paroxysmal arrhythmias. Given the increased activity of the anti-clotting and inhibition of the fibrinolytic blood systems that progress during pregnancy, the risk of paradoxical embolism through the left-to-right shunt increases significantly in the third trimester of gestation. This risk, depending on the stage of pregnancy, is 2-5%.

Uncorrected ASD is often accompanied by the development of chronic pulmonary circulatory disorders. It has been proven that 6-35% of patients develop pulmonary hypertension as a result of left-to-right shunting due to the presence of a connection between both atria. It is especially important that the development of pulmonary hypertension only initially depends on the phenomena of left-to-right shunting. Subsequently, as morphological, and functional changes in the pulmonary vessels progress, hypertension continues to exist regardless of certain cardiac circulatory events. Thus, timely surgical intervention is aimed at preventing the development of severe pulmonary hypertension, as emphasised by C.J. Cool *et al.* [29]. This condition is associated with an increased risk of disability and death. According to the study by E.A. Bradley & A.N. Zaidi, prevention of the progression of morphological changes in medium and small calibre pulmonary vessels is the main predictor for surgical correction of ASD, although in the presence of advanced pulmonary hypertension, correction of ASD may not affect the severity and progression of secondary disease [30]. A. Potapchuk *et al.* [31] and E. Kadirogullari *et al.* [32] concluded that modern advances in early diagnosis, especially with the use of ultrasound methods, have significantly improved the prognosis of patients with pulmonary hypertension, in particular, due to ASD. In turn, H.F. Qiu *et al.* [33] and J.H. Seol *et al.* [34] examined the problem through the prism of heart surgery and found that modern surgical interventions have reduced the percentage of patients with pulmonary hypertension in the postoperative period compared to previous years.

Pulmonary hypertension is accompanied by dilation of the pulmonary artery, which can lead to compression of the coronary vessels. In most cases, the left main coronary artery, which originates from the left coronary leaflet of the aortic valve and divides into the left circumflex artery and the left anterior descending artery along its path, is compressed. This is especially important as these arteries supply the myocardium of the left ventricle and atrium. The clinic of left main coronary artery compression resembles that of acute coronary syndrome, which significantly complicates differential diagnosis and can lead to ineffective care. This complication is especially relevant in pregnancy, especially in the third trimester, when in the case of pulmonary hypertension with overflow of the bloodstream, the pulmonary artery is particularly enlarged, as discussed by R.D. Zwijnenburg *et al.* [35]. Pulmonary hypertension, especially its resistant forms, is a contraindication to pregnancy due to obstetric and cardiac complications. For women who do become pregnant, premature termination of pregnancy is recommended, as emphasised by various groups of researchers, such as M. Ladouceur *et al.* [36] and A. Shevchenko & Yu. Krut [37].

According to S. Malakhova *et al.*, most women with ASD have an optimal pregnancy outcome, except for those diagnosed with pulmonary hypertension [38]. In this context, it is important to compare pregnancy outcomes in women who have undergone correction of ASD and those who have not. In the first case, a higher risk of eclampsia and pre-eclampsia, low birth weight, and intrauterine death was found compared to the general population, which is associated with insufficient placental blood supply due to the presence of left-to-right shunting, aggravated by haemodynamic changes in the third trimester of pregnancy. In turn, those women who were surgically treated for this reason did not have significant differences from the average population, although an increased risk of heart rhythm disorders was found, which is directly related to the fact of cardiac surgery.

It is also necessary to emphasise that risk stratification is particularly important in the context of pregnancy in women with ASD, as they are more vulnerable to common risk factors. As noted by M. Khara *et al.*, attention should be paid to the presence of comorbidities, in particular gestational diabetes [39]. N. Loia *et al.* [40] recommended a set of pregravid preparation measures to avoid hypovitaminosis and other nutritional conditions, and fetotoxicity and teratogenicity of some drugs used to treat pulmonary hypertension, in particular in women with ASD, as emphasised by O. Aleksieiev [41].

Given all of the above, some important aspects should be emphasised. In general, ASD is not a particularly dangerous heart defect; a significant proportion of people can live for decades without ever knowing they have this pathology. Nevertheless, ASD has a formidable complication, as this

defect, like other diseases and conditions accompanied by changes in haemodynamics, is prone to gradual progression. In this case, this complication is pulmonary hypertension. Pregnancy is a physiologically complex and multifaceted process that causes changes in almost all organs and systems of the body, several of which are associated with haemodynamics, leading to a worsening of disorders in women with ASD. Haemodynamic disorders peak in the third trimester of pregnancy. These changes during this period can lead to placental circulatory disorders, although pregnancy is usually optimal in women with ASD. The most dangerous changes in haemodynamics occur when a pregnant woman with ASD develops pulmonary hypertension, in which case termination of pregnancy is recommended.

Thus, the above material demonstrates that ASD, although one of the least haemodynamically significant heart defects, nevertheless leads to left-to-right blood shunting, which is very difficult to diagnose due to nonspecific and vague clinical manifestations. During pregnancy, a woman's body undergoes several changes, including those directly related to haemodynamics: an increase in circulating blood volume due to plasma, haemodilution, a tendency to thrombosis and fibrinolysis disorders. These changes develop gradually, reaching their peak in the third trimester of pregnancy. These metamorphoses can exacerbate haemodynamic disorders in women with uncorrected ASD, which carries a risk of placental circulatory disorders. In turn, women who have undergone surgical correction are only more likely to develop heart rhythm disorders. In general, women with ASD have an optimal pregnancy outcome, except for the development of the most dangerous complication of ASD, pulmonary hypertension.

Experience of Perinatal Centres in Managing Pregnancy in Women with Congenital Cardiovascular Disease

Besides, some other aspects of the problem deserve further attention, such as the impact on the haemodynamics of morphologically similar defects that are also associated with the atrial septum, the most up-to-date recommendations for the management of this pathology and consideration of information from perinatal centres in some European countries. The most pathogenetically similar heart defect to ASD is the patent foramen ovale (PFO). B. Zhang *et al.* noted that PFO is a defect that occurs in approximately 25% and is a preserved opening through which left-to-right shunting occurs in the foetal period [42]. PFO, as well as ASD, usually does not cause serious haemodynamic disorders, although they are more severe in patients with the first pathology. L. Chen *et al.* note that hemodynamic changes during pregnancy, especially in the third trimester, are accompanied by a deepening of pathological changes caused by left-to-right shunting in the case of PFO, which is accompanied by an increased risk of heart failure and placental circulatory failure [43]. The most dangerous and, at the same time, the most common complication of the PFO is the development of paradoxical embolism and, as a result, ischaemic stroke. Given the changes in the coagulation system during pregnancy, the risk of acute cerebrovascular disorders is particularly high during this period. Thus, the authors recommend that the defect be corrected during pregnancy planning, especially if there is a history of acute cerebrovascular disorders. In the case of an uncorrected defect, prophylactic aspirin use is recommended starting from the second trimester of pregnancy to reduce the risk of thrombosis. Thus, PFO and ASD are defects with a common location, a common type of bypass surgery, and a similar effect of pregnancy on the course of pathology. In both cases, haemodynamic changes become significant only in the third trimester of pregnancy, remaining insignificant in normal conditions. Both pathologies are characterised by a mild clinical course, the most dangerous manifestation of which is complications, for PFO – acute cerebrovascular accident, and for ASD – pulmonary hypertension. This material, unlike the present study, also does not provide information on haemodynamic changes in pregnant women, both in physiological conditions and in cases of pathology.

An exhaustive analysis of the clinical course and treatment strategies for ASD was done by M. Brida *et al.* [44]. The authors emphasise that the current paradigm in the treatment of ASD is the surgical correction of the defect before the age of 25, which allows both to avoid the development of pulmonary hypertension or thromboembolic complications and to leave time for pregnancy planning. The procedure is performed both with the help of a catheter and directly surgically. Recent advances have significantly improved the catheter-based procedure, and this method of intervention is now the preferred method for most patients with ASD. This procedure has a smaller range of potential complications, lower risk, shorter postoperative period, and faster recovery. The procedure is carried out under the careful supervision of additional examination methods: ultrasound or X-ray. In modern conditions, many instruments based on permanent materials are used, but the latest in this field is plastic surgery by implantation of biological implants capable of controlled degradation and gradual replacement with cardiac tissue. In turn, surgical intervention is used in cases where it is impossible to perform defect repair using a catheter. It is usually performed in the case of massive defects, and the intervention is carried out with the help of a heart-lung machine, using a midline sternotomy approach. The procedure is highly effective, with a mortality rate of less than 1% and a 7% risk of complications. Nevertheless, in the postoperative period, there is a risk of developing heart rhythm disturbances due to the disruption of the structure of the cardiac conduction system and the occurrence of postoperative scars. Thus, the aforementioned material confirms the recommendations made in this study regarding the need to correct the defect before pregnancy. The present work is strictly practically oriented to the field of cardiac surgery and therefore omits several aspects demonstrated in this study, in particular, an exhaustive analysis of haemodynamic changes and the impact of these changes on the foetal condition.

The issue of changes in haemodynamics caused by cardiovascular disease during pregnancy and their potential impact on the course of pregnancy was studied by European scientists. W. Drenthen *et al.* examined data from perinatal centres in the Netherlands and Belgium, focusing on risk factors that may be caused by cardiovascular disease, including ASD, in pregnant women [45]. The researchers found cardiovascular complications in 7.6% of pregnant women, with heart failure and rhythm disturbances predominating; eclampsia (12%) and pre-eclampsia (4.1%) prevailed among obstetric complications that occurred in 24% of cases; neonatal complications occurred in 25% of paradigms, with preterm birth and birth of underweight children predominating; neonatal mortality was 4%. Danish researchers led by S. Udholm *et al.* studied the course of pregnancy in women with ASD and found that although the perinatal outcomes of the pathology in women with the disorder and the control group were similar, women with ASD had a threefold higher risk of developing pre-eclampsia [46]. A significant proportion of women with ASD used artificial insemination methods. J. Roos-Hesselink *et al.* in a multicentre study analysed information on 5739 cardiovascular disease-associated pregnancies from around the world, including the Netherlands, Belgium, Norway, and the United Kingdom [47]. 60% of pregnant women had cardiovascular disease, and these patients, in particular those with ASD, were at high risk. Among them, 11% of pregnancies were accompanied by the development of heart failure, and 16% in the early postpartum period. Foetal pathology was observed in at least 21% of cases, more than half of which were premature births; caesarean section was used in 9% of cases, 16% of which were for cardiac reasons, more than half of which were due to pulmonary hypertension.

As such, these studies complement the material on the risks associated with the cardiovascular system CM, their causes, and consequences in the example of perinatal centres in Europe. These studies were mostly strictly epidemiological, omitting several issues: the pathophysiological basis of the pathological process, and methods of its diagnosis and correction, which is demonstrated in this material.

Conclusions

Congenital defects of the cardiovascular system are the most common and socially significant among congenital malformations, and one of the most common is congenital atrial septal defect. Based on the data of many studies, it can be stated that under normal conditions, this defect does not lead to significant haemodynamic disorders and is manifested only in the case of a prolonged uncorrected course with the development of pulmonary hypertension or in the case of complex multisystemic changes, as in pregnancy. Changes in systemic haemodynamics in pregnant women are positively correlated with gestational age, reaching their peak in the third trimester of pregnancy. Changes in the form of an increase in total blood volume, a tendency to thrombosis and fibrinolysis aggravate the haemodynamic disorders inherent in congenital atrial septal defect by left-to-right shunting. These changes are clinically manifested by thromboembolic complications, heart failure, and placental circulatory disorders, although most women have an optimal pregnancy and delivery.

The most serious complication of a defect that has not been corrected for a long time is the development of pulmonary hypertension, which is especially dangerous during pregnancy and is a direct indication of its termination. In the case of pulmonary hypertension caused by atrial septal defect, this condition directly depends on cardiac haemodynamics only at the initial stages of its development. In the case of a long course, morphological and functional changes in the pulmonary vessels persist and progress regardless of the correction of the heart wall defect.

The current paradigm in the treatment of this defect is atrial septal defect repair, which reduces the risk of significant haemodynamic disorders during pregnancy. The most modern method in this area is balloon surgery with the use of biological implants. Surgical interventions in this regard should be performed when planning a pregnancy under the age of 25, which helps to avoid undesirable consequences in the third trimester of pregnancy or during childbirth. Interventions are recommended to be performed using balloon plastics, as this minimises the risk of developing cardiac arrhythmias in the future. Nevertheless, large defects can currently be corrected only with the help of full-fledged surgery.

The experience of perinatal centres in Europe in managing pregnancy in women with congenital cardiovascular disease in general and atrial septal defects, in particular, is also considered. Due to the pathogenetic and morphological similarities, additional attention was also paid to the issue of pregnancy in women with an open oval window. Further research in this area should be aimed at solving the problem of pregnancy in women with uncorrected atrial septal defects complicated by pulmonary hypertension.

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None.

Conflict of Interest

The authors declare no conflict of interest.

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Особливості гемодинаміки вагітних з дефектом міжпередсердної перетинки у III триместрі вагітності: огляд літератури

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Анотація. У зв'язку зі зниженням показника смертності серед дітей з вадами серця, значна кількість таких дітей досягли репродуктивного віку. Однак, оскільки знання щодо впливу вагітності на гемодинаміку у жінок із серцевими вадами обмежені, дане дослідження є вкрай актуальним. Метою роботи був всебічний огляд сучасних наукових джерел та консолідація отриманих знань щодо особливостей гемодинаміки у вагітних з дефектами міжпередсердної перетинки. Під час проведення дослідження було використано ряд методів: аналіз, зокрема порівняльний, синтез, бібліографія, систематизація та категоризація. Також було залучено двоетапний підхід у вигляді систематизованого огляду літератури. Розглянуто комплекс гемодинамічних змін, що виникає у вагітних, як у нормі, так і при патології, зокрема у вагітних з дефектом міжпередсердної перетинки. Конкретизоване питання, чому гемодинамічні зміни набувають найбільшого значення у III триместрі вагітності, їх вплив на перебіг вагітності та результат завершення пологів. Висвітлено тему гострих та хронічних ускладнень дефекту міжпередсердної перегородки та сучасні принципи їх попередження та лікування. Окрему увагу приділено методам корекції зазначеної вади серця з урахуванням їх переваг, недоліків та можливих ускладнень. Розглянуто досвід перинатальних центрів ряду країн Європи у веденні вагітностей у жінок з вадами серцево-судинної системи, зокрема з дефектами міжпередсердної перетинки. Заповнено прогалини у знаннях щодо розповсюдженості даних вад та факторів ризику. Під час проведення дослідження вирішено проблему відсутності всебічних поглядів на дану проблему: від патофізіологічних основ та епідеміології, до лікування та модифікації факторів ризику. Дослідження має широку практичну цінність для медичних працівників, так як воно може слугувати основою для розробки профілактичних програм та інших інтервенцій щодо вагітностей жінок з вродженими вадами розвитку серцево-судинної системи

Ключові слова: вроджені вади розвитку; гестація; серцево-судинні ускладнення; фактори ризику; відкрите овальне вікно; легенева гіпертензія