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RADIOLOGICAL METHODS IN THE DIAGNOSIS OF ATRIOVENTRICULAR SEPTAL DEFECT

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Abstract

The article is devoted to the optimization of radiation research methods in the diagnosis and evaluation of the effectiveness of surgical correction of atrioventricular septal defect. Congenital heart defects are among the most common cardiovascular abnormalities and represent a leading cause of death in infants during the first year of life. The article emphasizes the need for special attention to children with congenital heart disease, as well as adult patients with residual disorders such as pulmonary hypertension, atrioventricular valve insufficiency, arrhythmias, and others. Recommendations for organizing medical care for adults with congenital heart disease include coordinating the activities of regional centers, educational programs for patients and their families, as well as training cardiologists. The article highlights the importance of interaction between different levels of health systems to ensure effective treatment and follow-up of patients with congenital heart disease.

Keywords*: heart disease, congenital heart defects, heart valve disease, heart failure.*

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Резюме

ЛУЧЕВЫЕ МЕТОДЫ ИССЛЕДОВАНИЯ В ДИАГНОСТИКЕ АТРИОВЕНТРИКУЛЯРНОГО СЕПТАЛЬНОГО ДЕФЕКТА

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Статья посвящена оптимизации лучевых методов исследования в диагностике и оценке эффективности хирургической коррекции атриовентрикулярного септального дефекта. Врожденные пороки сердца представляют собой распространенную патологию сердечно-сосудистой системы, являющуюся одной из основных причин смерти детей первого года жизни. Статья подчеркивает необходимость особого внимания к детям с врожденным пороком сердца, а также взрослым пациентам с резидуальными расстройствами, такими как легочная гипертензия, недостаточность атриовентрикулярных-клапанов, аритмии и другие. Рекомендации по организации медицинской помощи взрослым с врожденным пороком сердца включают координацию деятельности региональных центров, образовательные программы для пациентов и их семей, а также подготовку кардиологов. Статья подчеркивает важность взаимодействия различных уровней систем здравоохранения для обеспечения эффективного лечения и наблюдения за пациентами с врожденным пороком сердца.

Ключевые слова: *болезни сердца, врожденные сердечные дефекты, заболевания сердечных клапанов, сердечная недостаточность.*

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Түйіндеме

АТРИОВЕНТРИКУЛЯРЛЫҚ СЕПТАЛЬДЫ АҚАУДЫ БАҒАЛАУДА СӘУЛЕЛІК ДИАГНОСТИКА ӘДІСТЕРІ

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Мақала атриовентрикулярлық септальды ақауды хирургиялық түзетудің тиімділігін диагностикалау мен бағалаудағы сәулелік зерттеу әдістерін оңтайландыруға арналған. Туа біткен жүрек ақаулары-өмірдің бірінші жылындағы балалардың өлімінің негізгі себептерінің бірі болып табылатын жүрек-қантамыр жүйесінің кең таралған патологиясы. Мақалада туа біткен жүрек ақауы бар балаларға, сондай-ақ өкпе гипертензиясы, атриовентрикулярлық клапанының жеткіліксіздігі, аритмия және т.б. сияқты қалқанша безінің бұзылуы бар ересек пациенттерге ерекше назар аудару қажеттілігі көрсетілген. Туа біткен жүрек ақауы бар ересектерге медициналық көмекті ұйымдастыру бойынша ұсыныстарға аймақтық орталықтардың қызметін үйлестіру, пациенттер мен олардың отбасыларына арналған білім беру бағдарламалары және кардиологтарды даярлау кіреді. Мақалада туа біткен жүрек ақауы бар науқастарды тиімді емдеу мен бақылауды қамтамасыз ету үшін денсаулық сақтау жүйесінің әртүрлі деңгейлерінің өзара әрекеттесуінің маңыздылығы көрсетілген.

***Түйін сөздер**: жүрек аурулары, туа біткен жүрек ақаулары, жүрек клапандарының аурулары, жүрек жеткіліксіздігі.*

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Introduction

Congenital heart defects (CHD) present a considerable challenge in the field of pediatric cardiology, impacting the health and survival rates of children in profound ways. Atrioventricular septal defect (AVSD) is a notable type of congenital heart disease (CHD) characterized by its complexity, which necessitates a thorough approach to diagnosis, management, and ongoing patient care. The optimization of radiological diagnostic techniques is critical in determining the efficacy of surgical AVSD repair and enhancing treatment results.

The purpose of this article is to evaluate contemporary techniques for the diagnosis and treatment of CHD, as well as the approaches to monitoring children and adult patients with residual issues following surgery. Recommendations for arranging medical treatment for individuals with CHD are reviewed, including not only clinical but also social and psychological elements of care for this patient population. The need of coordinating efforts at all levels of health care to guarantee appropriate treatment and monitoring of patients with CHD is stressed as a critical component of enhancing therapeutic results and quality of life in this group.

The review's objectives are to investigate the capabilities of radiation research methodologies in the diagnosis and assessment of the success of surgical repair of an atrioventricular septal defect utilizing echocardiography and CT angiocardiography.

Search Strategy: A literature review on the subject "Radiation research methods in the diagnosis of atrioventricular septal defect" was conducted using the Medline and PubMed databases. The search period was ten years (2013-2023), however, materials from 1989, 1996, and 2005 were also utilized since they contained conceptual information.

Inclusion criteria: Studies on the diagnosis and treatment of AVSD using radiological methods in both children and adults were included. Publications from 2013 to 2023 and earlier works with conceptual significance were considered.

Exclusion criteria: Studies without reference to AVSD or without imaging methods were excluded. Non-peer-reviewed sources and articles in languages inaccessible for analysis were not considered.

Keywords: heart disease, congenital heart defects, heart valve disease, heart failure.

Background

Congenital heart disease (CHD) is a prevalent pathology in cardiovascular illnesses and one of the leading causes of mortality in infants in their first year of life. The term "congenital" refers to a condition that exists at birth. The phrases "congenital heart defect" and "congenital heart anomaly" are often used interchangeably, although "defect" provides a more accurate description [12, 18, 27].

Congenital heart disease refers to a structural abnormality of the heart and major arteries that develops

during the embryonic stage, leading to various hemodynamic challenges. Consequently, these abnormalities may lead to heart failure and progressive changes in the body's tissues.

The clinical manifestations of congenital heart disease vary depending on the specific type of abnormality present.

Symptoms may be nonexistent or threatening. When symptoms appear, they are diverse and include fast breathing, cyanosis (blue skin), poor weight growth, and weariness. It is vital to remember that CHD is not accompanied by chest discomfort. CHD accounts for 40% of all congenital defects, which includes intrauterine fetal mortality and early miscarriages. The frequency of cardiac lesions in live-born neonates ranges from 8 to 14 occurrences per 1000 live births. CHD is responsible for at least 11% of newborn mortality and around 50% of all fatalities related to abnormalities. [12, 18]. In today's society, the number of adult patients with congenital heart abnormalities has increased significantly. Over the previous several decades, the proportion of persons identified with congenital heart disease has steadily increased in rich countries. In 1940, only 30% of individuals with coronary heart disease reached adulthood; now, that figure has risen to 85%. The number of adult patients living with coronary heart disease is expected to rise further as a consequence of advances in pediatric cardiology and medical therapy.

The atrioventricular septum is composed of two main components: atrial and ventricular. The atrial section, also known as the atrial segment of the atrioventricular canal, is located between the anterior and inferior margins of the fossa ovalis and the common atrioventricular canal. The endocardial cushion extends to the posterior wall of the common atrium, where it presents itself.

The ventricular section, also known as the entry segment of the ventricular septum, is made up of muscular tissue that lies underneath the tricuspid valve and continues forward toward the membranous septum. This structure develops as endocardial cushion tissue proliferates toward the heart's apex. When this component is lacking or underdeveloped, the ventricular septum seems to be projecting, resulting in an atrioventricular canal-type ventricular septal defect (VSD), also known as an inlet or posterior VSD. The degree of development of the intake septum varies, with some examples showing as a tiny and restrictive defect, while others are big and non-restrictive [12].

Atrioventricular septal defects

The following terms pertain to CHD: common atrioventricular canal, atrioventricular septal defects, atrioventricular defects, patent common atrioventricular canal, and endocardial cushion defect.

Atrioventricular canal (AVC) is a congenital heart defect characterized by a common atrioventricular (AV) valve ring, varying degrees of insufficiency in the mitral and tricuspid components, and the presence of a primary atrial septal defect (ASD) and an inflow ventricular septal defect (VSD) in complete AVC cases. Atrioventricular canals account for 2-6% of all congenital heart abnormalities (CHD). AVC comes in three forms: full, intermediate, and incomplete. Atrioventricular septal defect (ASD) affects more than 75% of people with Down syndrome [15,51,71].

Atrial septal defect (ASD) is one of the most common congenital heart abnormalities seen in adults. It occurs when the right and left atria do not close properly. Most ASDs are diagnosed and addressed in childhood. Individuals with atrial septal defects rarely exhibit symptoms during early childhood. On the other hand, babies have been seen to have episodes of congestive heart failure (CHF) and recurring pneumonia. Notable features include a unique right ventricular impulse and detectable pulsing of the pulmonary artery. The initial heart sound may be normal or divided, indicating that the tricuspid valve has closed [68]. Defects in both the atrial and ventricular septa describe AVSD, a congenital heart abnormality also known as a shared or partly separated atrioventricular connection. The conditions defining AVSD in its partial form include an atrial septal defect, many atrioventricular valves, an entrance ventricular septal defect, and a cleft in the mitral valve. Different forms of atrial septal defects are distinguished by a single common atrioventricular valve, an atrial septal defect, and a nonrestrictive inflow ventricular septal defect [2,5,23].

Morphological features of the defect. General morphological characteristics of all AVD forms:

1. Inadequate inflow segment of the interventricular septum (IVS) combined with the absence of a membranous septum, giving the IVS its unique "scoop-shaped" appearance.

2. The presence of a single atrioventricular valve, usually with five cusps.

3. The atrioventricular valve leaflets adhere abnormally to the interventricular septum edge.

4. A tricuspid shape of the left (mitral) portion of a single atrioventricular valve caused by a crack in the anterior mitral valve cusp.

5. The left (mitral) component of the common atrioventricular valve is displaced towards the left ventricular outflow tract (LVOT). 6. The inflow tract contracts, the LVOT elongates and becomes constricted, and the aortic root moves anteriorly and to the right.

7. A primary atrial septal defect (ASD) is present in the inferior portion of the interatrial septum, directly superior to the single atrioventricular valve. The cusps of the single atrioventricular valve form the inferior limit of the atrial septal defect (ASD) [16,48].

An atrioventricular defect (AVD) is a congenital cardiac condition marked by the complete or partial absence of the septal barrier between the atria and ventricles. A complete atrioventricular septal defect appears as a single, centrally located lesion in the heart septum. This congenital abnormality causes a significant blood shunt from the left to the right at both the atrial and ventricular levels of the heart.

Epidemiology and causes

AVSD has an estimated prevalence of 0.24 to 0.31 per 1,000 live births, with no significant gender differences [1,75]. This congenital heart abnormality is strongly associated to Down syndrome. Concurrent defects, such as ventricular hypoplasia and inherited disorders like Down syndrome, impair the long-term prognosis after AVSD repair; nonetheless, considerable advances in surgical treatments in recent decades have dramatically improved survival rates. The purpose of this research is to investigate the etiology, epidemiology, and pathophysiology of AVSD, as well as current treatment techniques, potential implications, and clinical significance [38, 39].

Throughout fetal development, the interatrial and interventricular septa progressively arise, allowing for the anatomical segmentation of the heart. Endocardial ridges form at the atrioventricular junction and extend perpendicularly to the septal structure inside the heart. These ridges are essential for accurately dividing the right and left heart chambers and developing two distinct atrioventricular valves: the tricuspid valve on the right and the mitral valve on the left. These valves allow for unidirectional blood flow from the atria to the ventricles. Impairments in endocardial ridge formation may induce irregularities in chamber division and valve development, resulting in atrioventricular septal defects. The size of the primary atrial septal defect (ASD) and the inlet ventricular septal defect (VSD) determines the severity of the defect [65].

Genetic mutations are the primary cause of AVSD, with the majority of cases connected with syndromic illnesses. An atrioventricular septal defect affects about one out of every six people with Down syndrome. Atrioventricular septal defects and other congenital cardiac abnormalities in this patient group have been linked mostly to the Down Syndrome Cell Adhesion Molecule (DSCAM) gene. Apart from syndromic linkages, autosomal dominant inheritance patterns have been noted in gene modifications linked to AVSD. Moreover, non-syndromic AVSD [43] has been associated to maternal diseases including obesity and prenatal hyperglycemia.

Pathophysiology

Early development of the atrioventricular septum and valves is mostly dependent on the bilateral mesenchymal structures known as endocardial cushions inside the common atrioventricular canal. At the end of the fourth week of pregnancy, the endocardial cushions begin to fuse together, forming a wall between the atrium and ventricle. When the fusion process is not completed correctly, AVSD may emerge to varying degrees. The atrioventricular valve's anatomy may produce both complete and partial atrioventricular systolic dysfunction. A complete atrioventricular septal defect is identified by three characteristics: the presence of a single common atrioventricular valve, an ostium primum atrial septal defect, and an inlet ventricular septal defect. A failed endocardial cushion fusion results in the absence of the atrioventricular septum [21].

A condition known as partial AVSD has an ostium primum atrial septal defect, an inlet ventricular septal defect, and a gap in the mitral valve. The atrioventricular valves remain distinct, which distinguishes this condition. This insufficiency occurs when the endocardial cushions do not fully blend together [26, 44].

Classification

Atrioventricular septal defects are a diverse set of congenital heart defects that differ in their anatomical arrangement, the presence and severity of septal and valvular abnormalities. Based on anatomical features, these can be classified as whole, partial, or intermediate types.

Rastelli's categorization is based on the attachment of the superior bridging leaflet to the interventricular septum and identifies three forms of AVSD [27,28,33].

● Type A: The bridging leaflet connects to the crest of the interventricular septum, resulting in a minor deficit.

● Type B leaflets adhere to an aberrant papillary muscle formation in the right ventricle, extending over the interventricular septum.

● Type C: The leaflet stays loose and does not connect to the septum, resulting in a significant deficiency.

Clinical presentation

The clinical expression of the AVSD is determined by the defect type, the level of blood shunting; valve functioning, and the presence of other abnormalities. Significant left-to-right shunting and pulmonary volume overload usually cause AVSD in infants and young children to manifest as signs of heart failure. According to Rigby (2021), these symptoms include tachypnea, insufficient weight gain, feeding difficulties, and substantial fatigue with modest activity.

Patients with a complete atrioventricular septal defect have more severe symptoms due to considerable volume overflow and early development of pulmonary hypertension. Cardiomegaly is often detected by clinicians during physical exams, which is supported by chest radiography data, according to *Boutayeb A. et al*. Auscultation may also reveal a systolic murmur caused by regurgitation via the common atrioventricular valve [9].

Partial AVSD, on the other hand, may be asymptomatic during infancy and remain undiagnosed until later in life, particularly when pulmonary hypertension or progressive valve dysfunction develops. According to *Van der Linde D. et al. (*2011), these patients may have little symptoms in the early stages but later develop exertional dyspnea, arrhythmias, and signs of right ventricular failure. [66]

The clinical course of AVSD is inextricably linked to the presence of concurrent illnesses. Atrioventricular septal defect (AVSD) is seen in 40-50% of Down syndrome cases, and it is often associated with other cardiac and extracardiac anomalies. According to *Craig B. et al*. (2006), these patients have an increased risk of developing pulmonary hypertension due to abnormal pulmonary vascular development [16].

Surgical treatment

Surgical repair of an atrioventricular septal defect (AVSD) is the conventional therapy for removing anatomical flaws, restoring normal hemodynamics, and limiting the development of pulmonary hypertension. The kind of AVSD, the patient's age, the extent of the defect, and any concomitant diseases all influence the surgical procedure used. The major method is biventricular repair, which entails closing both atrial and ventricular septal defects and reconstructing the atrioventricular valve [24]. According to *Atik E. et al.*, the two most widely employed procedures are double patch repair (Double Patch) and modified single patch repair [6, 46].

The double patch method uses two independent patches to repair the atrial and ventricular septal defects, resulting in exact anatomical restoration of the septa and valves. This method is recommended for individuals with significant abnormalities and complicated valve architecture. *Wang G. et al.* (2020) found that double patch repair promotes long-term structural stability while reducing the probability of residual defects [37,72].

In contrast, the modified single patch approach uses a single patch to correct both atrial and ventricular septal defects. This approach is less intrusive and requires less

cardiopulmonary bypass time, making it ideal for newborns and high-risk surgery patients. However, as *Husain A. et al* (2021) point out, the single patch approach may be less successful in situations of big defects or considerable valvular insufficiency [37].

Palliative surgical methods are used for individuals who have a functioning single ventricle and cannot be repaired completely. These instances need a tiered strategy that includes shunt treatments (e.g., the Blalock-Taussig shunt) to increase pulmonary blood flow and the Fontan surgery, which directs venous blood flow to the pulmonary arteries while bypassing the right heart. *Goo H.W. et al.* (2018) found that graded palliative operations are still a feasible choice for individuals with significant morphological defects that limit biventricular restoration. [30].

Postoperative follow-up is essential for determining the efficacy of surgical repair and identifying problems. The most frequent surgical complications are residual septal abnormalities, atrioventricular valve regurgitation, and arrhythmias. These problems often need extra surgical or medicinal interventions. According to *Song L.* et al. (2019), contemporary imaging methods like 3D echocardiography and CT provide early diagnosis and intervention in postoperative problems. [58].

Surgical therapy for AVSD has considerably decreased mortality and improved patients' quality of life. However, long-term results are determined by the accuracy of preoperative diagnoses, surgical method selection, and postoperative monitoring efficacy [12,50,35,36,70].

Suggestions for monitoring after surgery: During the first month following hospital release, a pediatric cardiologist should do weekly and, if required, more frequent evaluations using echocardiography and electrocardiography.

Depending on the severity of residual problems, a pediatric cardiologist may often recommend further monitoring with echocardiography and electrocardiography 1-2 times per year.

Children with residual problems (pulmonary hypertension, atrioventricular valve insufficiency, arrhythmia, etc.) need more regular monitoring [53,58,59].

Prognosis

An untreated atrioventricular septal defect (AVSD) has a bad outlook. Surgical intervention significantly enhances long-term survival rates, with more than 90% of patients surviving for up to 15 years post-treatment. Approximately 50% of affected neonates encounter complications such as pulmonary infections or cardiac failure, leading to mortality within the first year of life [30]. Survivors of infancy frequently develop permanent pulmonary vascular disease, potentially leading to shunt reversal. However, 9% to 10% of these patients need reoperation within the same time range owing to persistent or increasing abnormalities [17,29,58].

The defects are associated with each other. Although ventricular septal defect (VSD) is often seen as a single congenital aberration, it may also coexist with other structural heart problems. VSD is often a component of complicated congenital diseases like tetralogy of Fallot and transposition of the major arteries. It may also be associated with anomalies such as subaortic stenosis and aortic coarctation. In the presence of a subarterial VSD, increasing prolapse of the aortic valve leaflets—most typically affecting the right coronary cusp — can lead to deteriorating aortic valve insufficiency over time [45,65].

Diagnosis of atrioventricular septal defect. Based on heart failure symptoms and clinical examination findings, a cardiologist — a specialist in congenital heart defects — makes the diagnosis. Moreover, instrumental studies are necessary to support the diagnosis and consist in:

- Chest X-ray: An X-ray examination of the heart, blood vessels, lungs, and surrounding tissues.

- An electrocardiogram (ECG) identifies the cause of the rhythm as well as any abnormalities in the heart's electrical activity.

- echocardiography: in real time, using sound waves, a picture of the internal architecture of the heart is formed, and the speed, blood flow, and pressure in the heart chambers are measured.

- Cardiac catheterization assesses heart function, valve condition, pressure, oxygen content, and detects intracardiac shunting.

- angiocardiography is an invasive radiation diagnostic technology that involves infusing a radiopaque substance into the bloodstream to visually reveal the cavities of the heart and blood arteries.

There are additional non-ionizing radiation investigations, such as MRI and ultrasound, that may be used to diagnose and guide therapy. Ultrasound examination (ultrasound) is a commonly used form of instrumental diagnostics for numerous organs and tissues in the human body. This technology relies on ultrasonic waves' capacity to enter live tissue, with the speed of wave passage varying depending on the kind of tissue. A unique sensor in the ultrasound machine captures the reflected ultrasound and, using the data, creates a picture of the item under examination. Ultrasound offers several advantages over other diagnostic methods, including the ability to obtain information about organ size, shape, and morphology, minimal patient preparation, absolute safety for human health, and real-time research.

Medical imaging tools in clinical settings play an important role in determining a patient's overall diagnosis and treatment strategy. The usage of different imaging modalities in medical radiation is growing as technology progresses in the medical sciences. Medical imaging methods use a multidisciplinary approach to determine the correct diagnosis for a given patient in order to create a tailored treatment plan. These imaging methods may be used non-invasively to observe a person's interior organs without requiring surgery. They may be used to diagnose and treat a variety of conditions. Medical imaging approaches rely on radiation from the electromagnetic spectrum [41, 42, 52]. Ultrasound is one of many medical imaging procedures, including MRI, radiography, CT, and angiograms.

The approaches discussed above are highly beneficial for monitoring the patient's illness development after it has already been identified and/or is getting treatment. The great majority of imaging procedures rely on the use of X-rays and ultrasonography. These medical imaging techniques are employed at all levels of care. Furthermore, they play a vital role in public health and preventive medicine, as well as curative and, subsequently, palliative

care. The primary objective is to determine the proper diagnosis [5, 7, 10, 16, 31, 60]. Advantages and dangers of medical imaging using radiation:

Benefits

• Enables medical professionals to conduct thorough examinations of internal organs, circulatory system, tissues, and skeletal structures.

• Provides valuable data for determining surgical intervention needs.

• Uses fluoroscopic imaging to perform minimally invasive operations such as catheter insertion and stent implantation.

Hazards

• Surgery raises the risk of developing cancer in the long run.

• Contrast chemicals used in certain imaging modalities may cause allergic reactions in some individuals.

Fluoroscopy, utilized for surgical operations, might cause temporary skin irritation or hair loss due to higher radiation exposure compared to traditional imaging modalities.

Nuclear medicine and angiographic imaging can be classified into several types of biological process imaging. Radiopharmaceuticals are typically modest quantities of radioactive tracers that are utilized in molecular imaging. Magnetic resonance imaging (MRI) and ultrasound are two more non-radioactive imaging techniques. MRI employs powerful magnetic fields, which have no known long-term health consequences in humans. Diagnostic ultrasound (DUS) devices employ high-frequency sound waves to generate pictures of interior organs and soft tissues. Some medical imaging procedures employ radiation, such as X-rays, which are beamed onto the human body. As X-rays flow through the body, some are absorbed, and the resultant picture is detected on the other side [7,60,69].

Echocardiographic examination

Echocardiography is a form of ultrasonography that examines structural and functional changes in the heart and its valves. This approach offers information on the location, size, number of faults, the degree of volume overflow in the left ventricle, the severity of pulmonary hypertension, and other parameters. In cases of ventricular septal defect (VSD), echocardiography detects intermittent echo signals in the septal region, which indicate blood shunting and are visualized using color and continuous Doppler mapping modes.

As with any complete echocardiographic examination for congenital heart defects (atrioventricular septal defect), a step-by-step segmental analysis should be performed [4,47,54,57,62]. The most significant preoperative information for cardiac surgeons with such a diagnosis includes changes shown in Table 1.

Transesophageal echocardiography in patients with partial or unrepaired atrial septal defects (ASD) provides detailed visualization of defect boundaries, identifies the presence of ventricular septal defects (VSD), and assesses heart valve morphology and function, ventricular size, degree of subaortic stenosis (if present), pulmonary artery pressure, tricuspid regurgitation, and simultaneous measurement of systemic and pulmonary pressures [19,24,62].

If subaortic stenosis is diagnosed, Doppler echocardiography is performed. Echocardiography is useful for evaluating mitral valve function, detecting subaortic stenosis, identifying ventricular septal defects (VSD), and assessing arterial hypertension in patients who have recently had surgery [3, 4, 8, 60].

Table 1.

Echocardiographic Parameters for AVSD Assessment.

Category	Parameter
Atria	• Size of the atrias • Position of the interatrial • Size of the AVSD • Direction of the shunt
AVC anatomy	• Atrioventricular openings • Cusps • Superior communicating leaflet • Left mural leaflet • Chordae • Type • Left papillary muscles
AVC function	• Atrioventricular canal regurgitation • Localization and mechanism of regurgitation • Presence of the stenosis
Ventricles	• Right and left ventricles • Ventricular imbalance • Direction of the shunt • Gradient • Assessment of right ventricular pressure • Additional ventricular septal defects • Ventricular outflow tract obstruction • Severity and mechanism of obstruction
Subpulmonary infundibulum	• Right ventricular outflow tract obstruction
Aorta	• Presence of coarctation of the aorta

In addition, it is a crucial diagnostic and monitoring approach for atrial septal defect (ASD), allowing for timely intervention and therapy. [55,60,61]. Transthoracic echocardiography is the principal diagnostic tool for children, adolescents, and the majority of adults with good acoustic windows. The research needs the collection of the following data.

• Quantity and location of defects;

• Measurements of heart chamber dimensions;

• Evaluation of ventricular function;

• Determination of aortic valve insufficiency and/or tricuspid regurgitation;

• Identification of pulmonary artery stenosis;

• Systolic pressure measurement in the right ventricle.

Adults with an inadequate acoustic window may need transesophageal echocardiography.

Doppler echocardiography in surgical patients should concentrate on the following goals.

• detecting the existence, absence, and location of residual defects;

• measuring pulmonary artery pressure using the velocity of tricuspid or pulmonary regurgitation jets;

• diagnosing aortic insufficiency and pulmonary trunk stenosis;

• assessing ventricular function. [18,34,40,60].

Intraoperative echocardiography assessment. The objectives of the pre-bypass echocardiographic

examination. Preoperative information should be obtained largely by transthoracic echocardiography, with additional imaging as clinically indicated. As a result, the pre-bypass transesophageal echocardiography examination should concentrate on these specific aspects: The diagnosis, anatomy of the atrioventricular valve, and pathogenesis of atrioventricular valve regurgitation were all verified [20,22].

Transesophageal echocardiography is performed prior to bypass surgery. While transesophageal echocardiography is most often used for intraoperative evaluations, epicardial echocardiography is recommended when transthoracic echocardiography is not possible [49].

The primary positions in transesophageal echocardiography are:

1. Four-chamber view. This is one of the most essential methods of transesophageal echocardiographic examination for analyzing the common atrioventricular canal since it allows for the assessment of practically all components. This posture corresponds to the apical four-chamber view in transthoracic examination. Due to heart dilatation, particularly in the right ventricle, the multiplanar array may need to be rotated by 20-40° to acquire the most correct picture to increase the right ventricular chambers and the true 4-chamber section [14].

2. Five chamber view. The left ventricular outflow pathway is evaluated utilizing two-dimensional imaging and color Doppler mapping.

3. Long axis. Similar to the five-chamber picture.

4. Short-axis plane. An image of the aortic valve, as well as the right ventricular afferent and efferent tracts. When evaluating residual regurgitation and new stenosis of the right half of the common atrioventricular canal, the four-chamber view is enhanced [32,56,63].

2.2 Cardiac Computed Tomography: Diagnostic Challenges and Error

Computed tomography (CT) is a non-invasive imaging method that uses X-ray attenuation variations to generate high-resolution, submillimeter axial pictures of anatomical structures at various tissue densities. Iodine-based contrast agents are often used to improve organ contrast and distinguish between normal and diseased tissues. CT angiography is used to evaluate cardiovascular architecture by administering a contrast agent intravenously using a controlled injection method. This approach uses extensive post-processing and 3D reconstruction to create a three-dimensional (3D) depiction of the heart and main blood arteries [25,73]. ECG-gated imaging methods have advanced cardiac CT, allowing for more accurate evaluation of both structural and functional elements of the heart. With the increasing use of cardiac CT in coronary artery examination, radiologists regularly come across incidental discoveries of non-coronary congenital cardiac abnormalities that may have gone unnoticed [13,66,67]. According to estimates, around 3,000 adults per million people suffer from congenital heart disease (CHD) [52,74]. VSDs and ASDs account for roughly half of all congenital abnormalities in CHD patients [64]. While minor flaws may stay asymptomatic throughout life, major flaws may demand prompt medical attention.

Diagnosing Ventricular Septal Defects in Adults:

• Small VSDs, especially those with progressive aortic valve prolapse, can worsen aortic insufficiency over time.

• Undiagnosed pulmonary valve stenosis (RVS) in conjunction with VSD can lead to high flow velocities and tricuspid regurgitation, potentially resulting in a misdiagnosis of pulmonary hypertension.

• Subtricuspid VSD may cause incorrect left-to-right shunting.

Recommendations to Improve Continuity of Care and Medical Support for Adults with CHD:

I. Ensure Comprehensive and Accessible Medical Care:

1. Creating a healthcare system that ensures access to specialist CHD treatment while also meeting the medical, psychological, and social requirements of adult patients.

2. Creating and executing educational programs for CHD patients, families, and healthcare providers to provide a smooth transition from childhood to adult cardiac treatment.

3. Improving cardiology training programs (for both pediatric and adult cardiologists) to better grasp the specific etiology and treatment of CHD in adults.

4. Improving teamwork at all levels of the healthcare system (local, regional, and national) to meet the demands of the rising CHD population.

II. Organizational Framework for Adult CHD Care.

Coordination and Integration of Services:

1. Regional centers with specialized resources should manage CHD care for adults, ensuring continuity of care and ongoing patient monitoring.

2. Referral pathways to leading national cardiac surgery and cardiology institutions should be established for advanced treatment.

3. Pediatricians and pediatric cardiologists should ensure a structured transition of medical records to regional centers when patients transition to adult care.

4. Emergency medical teams should work with regional centers to ensure that adult CHD patients are effectively managed.

III. Medical Documentation and Access to Information: Adult CHD patients should get personalized "medical passports" with detailed medical information, emergency contacts, and care plans connected to regional CHD centers.

IV. Support for Patients with Additional Needs: Patients with CHD who have cognitive impairments or psychosocial issues should not have difficulty getting treatment. Caregivers must advocate for their patients' medical needs.

V. Outpatient Follow-Up and Medical Accessibility: Each CHD patient should be fully registered with a primary care physician. This guarantees that medical data are easily accessible and that local cardiologists and regional CHD centers may work together more effectively.

VI. Primary care doctors who care for adult CHD patients should have direct access to referral networks and inpatient services at specialist CHD facilities as needed [56].

Conclusions:

1. Optimization of radiological examination techniques: The use of modern radiological modalities such as radiography, CT angiography, and MRI is critical for diagnosing and assessing the effectiveness of surgical surgery for atrioventricular septal defect.

2. The importance of medical imaging: Techniques such as ultrasonography are critical for obtaining information

about the structure and function of the heart in individuals with congenital cardiac abnormalities.

3. A personalized therapy strategy necessitates the cooperation of several experts and healthcare levels to address the clinical, social, and psychological aspects of CHD patients.

4. Follow-up and monitoring: Medical imaging techniques are essential for post-surgical evaluations in patients with congenital heart disease (CHD), facilitating the assessment of disease progression and the effectiveness of treatments.

5. The necessity for additional research: Further research into optimizing radiological assessment procedures for congenital heart disease could enhance diagnosis, treatment, and prognosis, thereby improving the quality of life for affected individuals.

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References*:*

1. *Agopian A.J., Moulik M., Gupta-Malhotra M., Marengo L.K., Mitchell L.E.* Descriptive epidemiology of non-syndromic complete atrioventricular canal defects. Paediatric and Perinatal Epidemiology, 2012. 26(6), 515–524. https://doi.org/10.1111/ppe.12006

2. *Alhawri K.A., McMahon C.J., Alrih M.M., Alzein Y., Khan A.A., Mohammed S.K., et al*. Atrioventricular septal defect and tetralogy of Fallot—a single tertiary center experience: A retrospective review. Annals of Pediatric Cardiology, 2019. 12*(*2), 103–109. https://doi.org/10.4103/apc.APC_87_18

3. *Alizadehasl A., Amini-Salehi E., Jebelli S.F.H., Hosseini K., Aliabadi A.Y., Yazzaf R., Nobakht S.* Presentation of mitral valve cleft with concurrent atrial septal defect and ventricular septal defect detected by three-dimensional transesophageal echocardiography: A case report. Journal of Medical Case Reports. 2024. 3, 18-24. https://doi.org/10.1186/s13256-024-04704-y

4. Andersen N.D., Turek J.W. Echocardiographic assessment of complete atrioventricular canal defects: A balancing act. Seminars in Thoracic and Cardiovascular Surgery.2019;31(1):87–88. https://doi.org/10.1053/j.semtcvs.2018.11.005

5. *Arvig M.D., Lassen A.T., Gæde P.H., Laursen C.B.* Monitoring patients with acute dyspnoea with a serial focused ultrasound of the heart and the lungs (MODUS): A protocol for a multicentre, randomised, open-label, pragmatic and controlled trial. BMJ Open, 2020. 10*(*6), e034373. https://doi.org/10.1136/bmjopen-2019-034373

6. *Atik E., Binotto M.A., Barreto A.C.* Case 6/2019 - Total atrioventricular septal defect, 12 years after operative correction, no residual defects. Arquivos Brasileiros de Cardiologia.2019;113(5):1009–1012 https://doi.org/10.5935/abc.20190192

7. *Barlow G.M., Chen X.N., Shi Z.Y., Lyons G.E., Kurnit D.M., Celle L., Spinner N.B., Zackai E., Pettenati M.J., Van Riper A.J., Vekemans M.J., Mjaatvedt C.H., Korenberg J.R.* Down syndrome congenital heart disease: A narrowed region and a candidate gene. Genetics in Medicine, 2001. *3*(2), 91–101. https://doi.org/10.1097/00125817-200103000-00002

8. *Bharucha T., Sivaprakasam M.C., Haw M.P., Anderson R.H., Vettukattil J.J.* The angle of the components of the common atrioventricular valve predicts the outcome of surgical correction in patients with atrioventricular septal defect and common atrioventricular junction. Journal of the American Society of Echocardiography, 2008. 21*(*10), 1099–1104. https://doi.org/10.1016/j.echo.2008.05.006

9. *Boutayeb A.* Complete atrioventricular canal defect: Towards a more physiological repair. Heart, Lung and Circulation.2018;27(3):e4–e6 https://doi.org/10.1016/j.hlc.2017.05.136

10. *Calabrò R., Limongelli G.* Complete atrioventricular canal. Orphanet Journal of Rare Diseases, 2006. 1(1), 8. https://doi.org/10.1186/1750-1172-1-8

11. *Carabello B.A.* Mitral valve repair in the treatment of mitral regurgitation. *Current Treatment* Options in Cardiovascular Medicine, 2009. 11(5), 419–425. https://doi.org/10.1007/s11936-009-0045-1

12. *Chauhan S.* Atrioventricular septal defects. Annals of Cardiac Anaesthesia, 2018. 21*(*1), 1–3. https://doi.org/10.4103/aca.ACA_219_17

13. *Chen X.F., Jiang F., Li L., et al*. Application of low-dose dual-source computed tomography angiography in children with complex congenital heart disease. Experimental and Therapeutic Medicine. 2017;13(3):1177–1183. https://doi.org/10.3892/etm.2017.4591

14. *Cohen M.S., Jacobs J.P., Quintessenza J.A., Mavroudis C.* Morphometric analysis of unbalanced common atrioventricular canal using two-dimensional echocardiography. Journal of the American College of Cardiology, 1996. 28(4), 1017–1023. https://doi.org/10.1016/s0735-1097(96)00262-8

15. *Corno A.F., Kandakure P.R., Dhannapuneni R.R., Gladman G., Venugopal P., Alphonso N.* Multiple ventricular septal defects: A new strategy. Frontiers in Pediatrics, 2013. 1*,* 16. https://doi.org/10.3389/fped.2013.00016

16. *Craig B.* Atrioventricular septal defect: From fetus to adult. Heart, 2006. 92(12), 1879–1885. https://doi.org/10.1136/hrt.2006.093344

17. *Crawford F.A., Stroud M.R.* Surgical repair of complete atrioventricular septal defect. The Annals of Thoracic Surgery, 2001. 72*(*5), 1621–1628. https://doi.org/10.1016/S0003-4975(01)03170-8

18. *DaCruz E.M., Ivy D., Jaggers J.* Pediatric and congenital cardiology, cardiac surgery and intensive care. Springer London. 2014. https://doi.org/10.1007/978-1-4471-4619-3

19. *Deri A., English K.* Educational series in congenital heart disease: Echocardiographic assessment of left to right shunts: Atrial septal defect, ventricular septal defect, atrioventricular septal defect, patent arterial duct. Echo Research and Practice, 2018. 5(1), R1–R16. https://doi.org/10.1530/ERP-17-0062

20. *de Vlaming A., Sauls K., Hajdu Z., Visconti R. P., Mehesz A.N., Levine R.A., Norris R.A.* Atrioventricular valve development: New perspectives on an old theme. Differentiation, 2012. 84(1), 103–116. https://doi.org/10.1016/j.diff.2012.04.001

21. *Dummer K.B., Graham T.P., Triedman J.K., Fulton D.R., Kim M.S.* Pathophysiology and clinical features of

isolated ventricular septal defects in infants and children. UpToDate. 2012. Feb 2018. from https://www.uptodate.com

22. *Ebels T., Elzenga N., Anderson R.H.* Atrioventricular septal defects. Paediatric cardiology. 2010. pp. 553–589.

23. *Egbe A.C., Miranda W.R., Pellikka P.A., DeSimone C.V., Connolly H.M.* Prevalence and prognostic implications of left ventricular systolic dysfunction in adults with congenital heart disease. Journal of the American College of Cardiology, 2022. 79(14), 1356–1365. https://doi.org/10.1016/j.jacc.2022.01.040

24. *Espinola-Zavaleta N., Muñoz-Castellanos L., Kuri-Nivón M., Keirns C.* Understanding atrioventricular septal defect: Anatomoechocardiographic correlation. Cardiovascular Ultrasound. 2008. 6:33 https://doi.org/10.1186/1476-7120-6-33

25. *Ezzeldin DA, Hafez MS, Mansour A.* Multidetector computed tomography for patients with congenital heart disease: a multi-center registry from Africa and Middle East; patients' characteristics and procedural safety. Egypt Heart J. 2021;73(1):93. *doi:10.1186/s43044-021-00217-x*

26. *Faroux L., Guimaraes L., Wintzer-Wehekind J., Junquera L., Ferreira-Neto A. N., Del Val D., Muntané-Carol G., Mohammadi S., Paradis J.M., Rodés-Cabau J.* Clinical impact of conduction disturbances in transcatheter aortic valve replacement recipients: A systematic review and meta-analysis. European Heart Journal, 2020. 41(29), 2771–2781. https://doi.org/10.1093/eurheartj/ehz924

27. *Fernando R.J., Johnson S.D., Carter T.* Partial atrioventricular canal defect. Anesthesiology. Anesthesiology 2019; 131(4):p 896-897, https://doi.org/10.1097/ALN.0000000000002795

28. *Franklin R.C.G., Béland M.J., Colan S.D., Walters H.L., Aiello V.D., Anderson R.H., Bailliard F., Boris J.R., Cohen M.S., Gaynor J.W., et al.* Nomenclature for congenital and paediatric cardiac disease: The International Paediatric and Congenital Cardiac Code (IPCCC) and the Eleventh Iteration of the International Classification of Diseases (ICD-11). Cardiology in the Young, 2017.27(10), 1872–1938. https://doi.org/10.1017/S1047951117002244

29. *Gedikbaşı A., Oztarhan K., Yıldırım G., Gül A., Asar-Canaz E., Ceylan Y.* Atrioventricular and ventricular septal defects; Topographical analysis and impact of associated cardiac and extracardiac findings and postpartum outcome. Journal of the Turkish-German Gynecological Association, 2010. 11(1), 8–15. https://doi.org/10.5152/jtgga.2010.03

30. *Goo H.W.* Image quality and radiation dose of high-pitch dual-source spiral cardiothoracic computed tomography in young children with congenital heart disease: Comparison of non-electrocardiography synchronization and prospective electrocardiography triggering. Korean Journal of Radiology, 2018. 19(6), 1031–1041. https://doi.org/10.3348/kjr.2018.19.6.1031

31. *Gosnell J., Pietila T., Samuel B.P., Kurup H.K., Haw M.P., Vettukattil J.J.* Integration of computed tomography and three-dimensional echocardiography for hybrid three-dimensional printing in congenital heart disease. Journal of Digital Imaging. 2016;29(5):665–669. https://doi.org/10.1007/s10278-016-9879-8

32. *Hahn R.T., et al.* Guidelines for performing a comprehensive transesophageal echocardiographic examination: Recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. Journal of the American Society of Echocardiography, 2013. 26(9), 921–964. https://doi.org/10.1016/j.echo.2013.07.009

33. *He Q.L., Zhong F., Ye F., Wei M., Liu W.F., Li M.N., Li Q.B., Huang W., Sun L.B., Shu H.H.* Does intraoperative ulinastatin improve postoperative clinical outcomes in patients undergoing cardiac surgery: A meta-analysis of randomized controlled trials. BioMed Research International, 2014, 630-835. https://doi.org/10.1155/2014/630835

34. *Hegazy F.A., Mohamed Kamel S.M., Abdelhamid A.S., Aboelnasr E., Elshazly M., Hassan A.M.* Effect of postoperative high load long duration inspiratory muscle training on pulmonary function and functional capacity after mitral valve replacement surgery: A randomized controlled trial with follow-up. PLoS ONE, 2021. 16(8), e0256609. https://doi.org/10.1371/journal.pone.0256609

35. *Hendrikxs M.M., Mees U., Hill A.C., Egbert B., Coker G.T., Estridge T.* Evaluation of a novel sealant for inhibition of cardiac adhesions and clinical experience in cardiac surgery procedures. Heart Surgery Forum, 2001. 4(3), 204–209.

36. *Hoohenkerk G.J., Bruggemans E.F., Rijlaarsdam M., Schoof P.H., Koolbergen D.R., Hazekamp M.G.* More than 30 years' experience with surgical correction of atrioventricular septal defects. The Annals of Thoracic Surgery, 2010. 90(5), 1554–1561. https://doi.org/10.1016/j.athoracsur.2010.06.008

37. *Husain A.* Commentary: To band or not to band—is that really the question? Journal of Thoracic and Cardiovascular Surgery, 2021. 161(5), 1603–1604. https://doi.org/10.1016/j.jtcvs.2020.08.087

38. Ahmed I., Anjum F. StatPearls [Internet]. Treasure Island (FL): 2023. 131(2), 373-375. StatPearls Publishing. "Atrioventricular septal defect" by Intisar Ahmed and Fatima Anjum (aku.edu)

39. *Jacobs J.P., Burke R.P., Quintessenza J.A., Mavroudis C.* Congenital Heart Surgery Nomenclature and Database Project: atrioventricular canal defect. The Annals of thoracic surgery, 2000. 69(4 Suppl), S36–S43. https://doi.org/10.1016/s0003-4975(99)01235-7

40. *Jegatheeswaran A., Pizarro C., Caldarone C.A., Cohen M.S., Baffa J., Gremmels D.B., Overman D.M., McCrindle B.W.* Echocardiographic definition and surgical decision-making in unbalanced atrioventricular septal defect. Circulation, 2010. 122(21 Suppl), S209–S215. https://doi.org/10.1161/CIRCULATIONAHA.109.928325

41. Jones A.L., White B.R., Ghosh R.M., et al. Cardiac magnetic resonance predictors for successful primary biventricular repair of unbalanced complete common atrioventricular canal. Cardiology in the Young. 2024;34(2):387-394. https://doi.org/10.1017/S1047951123001786

42. *Kantor B., Nagel E., Schoenhagen P., Barkhausen J., Gerber T.C.* Coronary computed tomography and magnetic resonance imaging. Current Problems in Cardiology. 2009;34(4):145–217. https://doi.org/10.1016/j.cpcardiol.2008.12.002

43. *Kaza A.K., del Nido P.J.* Atrioventricular septal defects. Sabiston and Spencer's surgery of the chest. 2010.

(8th ed., pp. 1229–1268). Elsevier. https://doi.org/10.1007/978-1-4471-4619-3_16

44. *Kim J.S., Virágh S., Moorman A.F.M., Anderson R.H., Lamers W.H.* Development of the myocardium of the atrioventricular canal and the vestibular spine in the human heart. Circulation Research, 2001. 88(4), 395–402. https://doi.org/10.1161/01.RES.88.4.395

45. *Kirklin J.W., Barratt-Boyes B.G.* Atrioventricular septal defect. In J. W. Kirklin & B. G. Barratt-Boyes (Eds.), Cardiac surgery 2013. (4th ed., pp. 1229–1268). Wiley-Blackwell.

46. *Kishigami T., Ikushima E., Yasutsune T., Nishimura Y.* Surgical repair of partial atrioventricular septal defect in an adult patient: A case report. Journal of UOEH, 2019. 41(2), 239–242. https://doi.org/10.7888/juoeh.41.239

47. *Lai W.W., Geva T., Shirali G.S., Frommelt P.C., Humes R.A., Brook M.M., Pignatelli R.H., Rychik J.* Guidelines and standards for performance of a pediatric echocardiogram: A report from the Task Force of the Pediatric Council of the American Society of Echocardiography. Journal of the American Society of Echocardiography, 2006. 19(12), 1413–1430. https://doi.org/10.1016/j.echo.2006.09.001

48. *Linask K.K., Han M., Bravo-Valenzuela N.J.M.* Changes in vitelline and utero-placental hemodynamics: Implications for cardiovascular development. Frontiers in Physiology.2014;5:390. https://doi.org/10.3389/fphys.2014.00390

49. *Obadia J.F., Messika-Zeitoun D., Leurent G., Iung B., Bonnet G., Piriou N., Lefèvre T., Piot C., Rouleau F., Carrié D., et al.*. Percutaneous repair or medical treatment for secondary mitral regurgitation. New England Journal of Medicine, 2018. 379(24), 2297–2306. https://doi.org/10.1056/NEJMoa1805374

50. *Overman D.M., Baffa J.M., Cohen M.S., Mertens L., Gremmels D.B., Jegatheeswaran A., McCrindle B.W., Blackstone E.H., Morell V.O., Caldarone C., Williams W.G., Pizarro C.* Unbalanced atrioventricular septal defect: definition and decision making. World journal for pediatric & congenital heart surgery, 2010. 1(1), 91–96. https://doi.org/10.1177/2150135110363024

51. *Pugnaloni F., Versacci P., Marino B., Digilio M.C.* Atrioventricular canal defect is the classic congenital heart disease in Bardet–Biedl syndrome. American Journal of Human Genetics. 2021;85(3–4):101–102. https://doi.org/10.1111/ahg.12413

52. *Rajiah P., Schoenhagen P.* The role of computed tomography in pre-procedural planning of cardiovascular surgery and intervention. Insights into Imaging. 2013. https://doi.org/10.1007/s13244-013-0270-8

53. *Schumacher K., Marin Cuartas M., Meier S., et al.* Long-term results following atrioventricular septal defect repair. Journal of Cardiothoracic Surgery. 2023;18(1), 1-3. https://doi.org/10.1186/s13019-023-02355-6

54. *Schusterova I., Jakubova M., Vachalcova M., et al.* Three-dimensional transesophageal echocardiography in diagnosis of intermediate atrioventricular septal defect in the adult: Case report and literature review. Journal of Cardiothoracic Surgery. 2021. 16:209:1–7 https://doi.org/10.1186/s13019-021-01596-7

55. *Silvestry F.E., Cohen M.S., Armsby L.B., Burkule N. J., Fleishman C.E., Hijazi Z.M., Lang R.M., Rome J.J., Wang Y., Zahn E.M.* Guidelines for the echocardiographic assessment of atrial septal defect and patent foramen ovale: From the American Society of Echocardiography and Society for Cardiac Angiography and Interventions. Journal of the American Society of Echocardiography, 2015. 28(8), 910–958. https://doi.org/10.1016/j.echo.2015.05.015

56. *Simpson J., Lopez L., Acar P., Friedberg M., Khoo N., Ko H., Marek J., Marx G., McGhie J., Meijboom F., Roberson D., van den Bosch A., Miller O., Shirali G.* Three-dimensional echocardiography in congenital heart disease: An expert consensus document from the European Association of Cardiovascular Imaging and the American Society of Echocardiography. Journal of the American Society of Echocardiography, 2017. 30(1), 1–27. https://doi.org/10.1016/j.echo.2016.08.022

57. *Singh P., Mehta A., Nanda N.C.* Live/real-time three-dimensional transthoracic echocardiographic findings in an adult with complete atrioventricular septal defect. Echocardiography, 2010. 27(1), 87–90.https://doi.org/10.1111/j.1540-8175.2009.01129.x

58. *Song L., Ling Y., An Q.* Repair of partial atrioventricular canal defect in adult patients: Two-year follow-up outcomes of a retrospective study. Journal of Cardiothoracic Surgery. 2019. https://doi.org/10.1186/s13019-019-0931-x

59. *St. Louis J.D., Jodhka U., Jacobs J.P., He X., Hill K. D., Pasquali S.K., Jacobs M.L.* Contemporary outcomes of complete atrioventricular septal defect repair: Analysis of the Society of Thoracic Surgeons Congenital Heart Surgery Database. The Journal of Thoracic and Cardiovascular Surgery, 2014. 148(6), 2526–2531. https://doi.org/10.1016/j.jtcvs.2014.05.095

60. *St-Onge S., Amin S., Cianciulli A., Jolley M.A., Drouin S.* 3D Echocardiogram Visualization: A New Method Based on "Focus + Context". Proceedings of SPIE--the International Society for Optical Engineering, 2024. 12929, 12929. https://doi.org/10.1117/12.3006214

61. *Stone G.W., Lindenfeld J., Abraham W.T., Kar S., Lim D.S., Mishell J.M., Whisenant B., Grayburn P.A., Rinaldi M., Kapadia S.R., Rajagopal V., Sarembock I.J., Brieke A., Marx S.O., Cohen D.J., Weissman N.J., Mack M.* J. Transcatheter mitral-valve repair in patients with heart failure. New England Journal of Medicine, 2018. 379(24), 2307–2318. https://doi.org/10.1056/NEJMoa1806640

62. *Surkova E., West C., Flick C., Ilagan L., Gatzoulis M.A., Senior R., Li W.* Added value of three-dimensional transthoracic echocardiography in assessment of an adult patient with atrioventricular septal defect. Echocardiography.2019;36(4):809–812. https://doi.org/10.1111/echo.14300

63. *Szwast A.L., Marino B.S., Rychik J., Gaynor J.W., Spray T.L., Cohen M.S.* Usefulness of left ventricular inflow index to predict successful biventricular repair in right-dominant unbalanced atrioventricular canal. The American journal of cardiology, 2011. 107(1), 103–109. https://doi.org/10.1016/j.amjcard.2010.08.052

64. *Trichon B.H., Felker G.M., Shaw L.K., Cabell C.H., O'Connor C.M.* Relation of frequency and severity of mitral regurgitation to survival among patients with left ventricular systolic dysfunction and heart failure. The American Journal of Cardiology, 2003. 91(5), 538–543. https://doi.org/10.1016/S0002-9149(02)03301-5

65. *Tubman T.R.J., Shields M.D., Craig B.G., Mulholland H.C., Nevin N.C.* Congenital heart disease in Down's syndrome: Two-year prospective early screening study. BMJ, 1991. 302(6790), 1425–1427. https://doi.org/10.1136/bmj.302.6790.1425

66. Van der Linde D., Konings E.E.M., Slager M.A., Witsenburg M., Helbing W.A., Takkenberg J.J.M., Roos-Hesselink J.W. Birth prevalence of congenital heart disease worldwide: A systematic review and meta-analysis. Journal of the American College of Cardiology, 2011. 58(21), 2241–2247. https://doi.org/10.1016/j.jacc.2011.08.025

67. *Teun van der Bom T., Bouma B.J., Meijboom F.J., Zwinderman A.H., Mulder B.J.* The prevalence of adult congenital heart disease: Results from a systematic review and evidence-based calculation. American Heart Journal, 2012. 164(4), 568–575. https://doi.org/10.1016/j.ahj.2012.07.023

68. *Van Praagh R., Geva T., Kreutzer J.* Ventricular septal defects: how shall we describe, name and classify them? Journal of the American College of Cardiology, 1989. 14(5), 1298–1299. https://doi.org/10.1016/0735-1097(89)90431-2

69. *Veronese P., Guariento A., Cattapan C., Fedrigo M., Gervasi M. T., Angelini A., Riva A., Vida V.* Prenatal diagnosis and fetopsy validation of complete atrioventricular septal defects using the fetal intelligent navigation echocardiography method. Diagnostics (Basel), 2023. 13(3), 456. https://doi.org/10.3390/diagnostics13030456

70. *Vida V.L., Tessari C., Castaldi B., Padalino M.A., Milanesi O., Gregori D., Stellin G.* Early Correction of Common Atrioventricular Septal Defects: A Single-Center 20-Year Experience. The Annals of thoracic surgery, 2016. 102(6), 2044–2051. https://doi.org/10.1016/j.athoracsur.2016.09.020

71. *Wilson N.J., Gavalaki E., Newman C.G.* Complete atrioventricular canal defect in presence of Down syndrome (letter). The Lancet, 1985. 2, 834 p.

72. *Wang G., Ma K., Pang K., et al.* Modified single repair technique for complete atrioventricular septal defect: A propensity score matching analysis. Pediatric Cardiology. 2020.41(4):615–623. https://doi.org/10.1007/s00246-020-02292-4

73. *Yang J.C., Lin M.T., Jaw F.S., et al.* Trends in the utilization of computed tomography and cardiac catheterization among children with congenital heart disease. Journal of the Formosan Medical Association. 2015;114(11):1061–1068. https://doi.org/10.1016/j.jfma.2014.08.004

74. *Yoshitake S., Kaneko Y., Morita K., et al.* Visualization and quantification of the atrioventricular conduction axis in hearts with ventricular septal defect using phase contrast computed tomography. Journal of Thoracic and Cardiovascular Surgery. 2020;160(2):490–496 https://doi.org/10.1016/j.jtcvs.2020.02.036.

75. *Zhang F., Qi L., Zhao M., Han S., Zhang H., Wang G.* Global research landscape on the genetics of congenital heart disease: A bibliometric and visualized analysis via VOSviewer and CiteSpace. Medicine (Baltimore), 2024. 103(43), e40261. https://doi.org/10.1097/MD.0000000000040261

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