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REVISIÓN

Adult Congenital Heart Disease (ACHD)

Cardiopatía congénita en el adulto

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ABSTRACT

Due to the ongoing success in the management of congenital heart disease, the number of survivors has grown steadily over the last decades. As such, the number of adults has surpassed the total number of children with congenital heart disease. The growth of this population creates new health care demands that include ease of access, a well-organized transition pathway as well as multidisciplinary and specialized care which currently is not universally available in adult centers.

In this review, we provide background information and general consideration for the management of these patients as well as specific nuances related to management of the most common lesions. More importantly, emphasis should be placed on the recognition of these patients as a special population and the necessary requirements to organize their care so effective transition and multidisciplinary care could be delivered.

RESUMEN

Dado el éxito en el manejo de las cardiopatías congénitas en las últimas décadas, el número de pacientes adultos sobrevivientes de una cardiopatía congénita ha superado el número de niños con tal condición. El crecimiento progresivo de esta población adulta ha creado nuevos requerimientos en el sistema de salud, incluyendo fácil acceso, un programa de transición bien establecido, así como la disponibilidad de un grupo multidisciplinario para proveer cuidado especializado. Dichas condiciones que frecuentemente no existen en la mayoría de los centros de medicina adulta.

Esta revisión intenta proveer información general así como información más específica en lo que se refiere a las condiciones que se presentan con mayor frecuencia.

Queremos recalcar la necesidad de reconocer la complejidad de estos pacientes y la necesidad de establecer una transición adecuada a un sistema que pueda dar el cuidado multidisciplinario y especializado que estos pacientes requieren.

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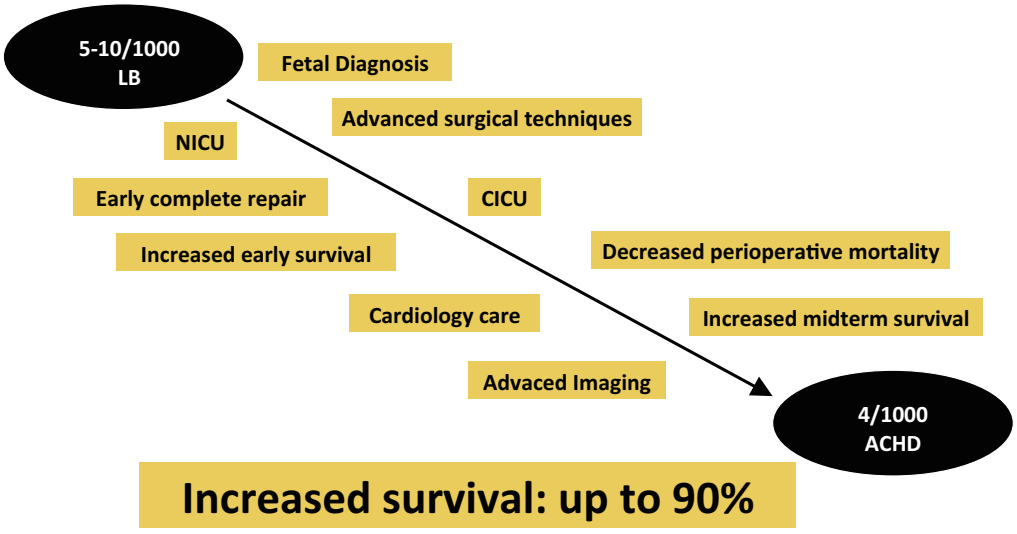
INTRODUCTION

Congenital heart disease (CHD) is the most common form of congenital defects with an incidence of 9.4/1000 live births[1]. With advances in the medical field from fetal diagnosis to early complete repair and improved post-operative care (Figure 1) significant improvement in survival has been achieved, allowing 97% of CHD patients to reach adulthood[2]. As a consequence, currently there are more adults than children with congenital heart disease. It is estimated that there are more than 2 million adults with congenital heart disease in the United States and this number is increasing by about 5% every year. With increased survival and experience, it has become clear that congenital heart disease is a lifelong condition associated with multiple complex health care needs. However, this population faces multiple barriers to receiving optimum care. Although the heterogeneity of this condition underscores the importance of continued follow up, access remains an elusive goal, considering that many patients are affected by poor insurance coverage, lack of experts in this field, and geographical barriers. In addition, the lack of well-established registries and studies focusing on this patient population and their needs further complicates the scenario. A recent study has highlighted that only one tenth of patients with adult congenital heart disease (ACHD) are managed at an accredited ACHD center and only a small percentage of these patients adhere to annual follow-up and imaging recommendations. In addition, it was also found that there was a higher burden of complex cardiac comorbidities, an increased use of Medicaid insurance and higher resource utilization at ACHD centers compared to non-ACHD centers[3].

Moreover, with increased longevity it has become apparent that patients with ACHD require specialized management when confronted with even routine non cardiac related interventions. Due to complex physiology and frequent residual hemodynamic burden, even simple non cardiac surgeries like appendectomy require management by a multidisciplinary team of specialized providers, including anesthesiologists, cardiologists, and cardiac intensivists with expertise in congenital heart disease. In addition, careful attention and consideration should be given to the patient's cardiac physiology and lifestyle, including competitive sports participation and career choices. Several patients with ACHD are not best suited for occupations involving certain activities like heavy lifting or working in certain outdoor environments. Lastly, significant challenges do exist when it comes to the reproductive and sexual health of these patients, due to psychosocial issues, secondary effects of medications, and overall cardiac physiology.

Patients with ACHD are at a higher likelihood of developing earlier cardiovascular diseases due to multiple factors. These include sedentary lifestyle or exercise intolerance, lack of healthy lifestyle choices and deep-seated concerns for the negative effect of exercise including sudden cardiac death. While there may be concerns for cardiac complications such as arrhythmias, myocardial ischemia, inability to increase cardiac output, exacerbation of heart failure and aortic dissection, patients with ACHD should not be discouraged to exercise and risk-benefit profiles should be carefully evaluated. The exercise plans should be individualized for every patient based on the nature and severity of their congenital defect, status of the repair, presence of residual lesions, and associated comorbidities such as pulmonary or skeletal involvement[4].

Figure 1. Increased Survival of CHD patients



LB: live birth; NICU: neonatal intensive care unit; CICU: cardiac intensive care unit; ACHD: adult congenital heart disease

CLASSIFICATION OF ACHD

The most recent American Heart Association/ American College of Cardiology (AHA/ACC) guidelines published in 2018 include a new classification system of ACHD which incorporates the anatomic complexity and the physiological status of the patient. The anatomic classification includes 3 classes: Class I simple, Class II moderate complexity and Class III great complexity. The physiological component of the classifications is similar to the AHA heart failure classification and consist of 4 stages: A-D. In addition, it also accounts for other factors that contribute to the functional status of the patient. These include presence of valvular disease, pulmonary hypertension, arrhythmias, aortic dilation, end-organ function, and cyanosis[5].

ACHD CENTER: COMPOSITION

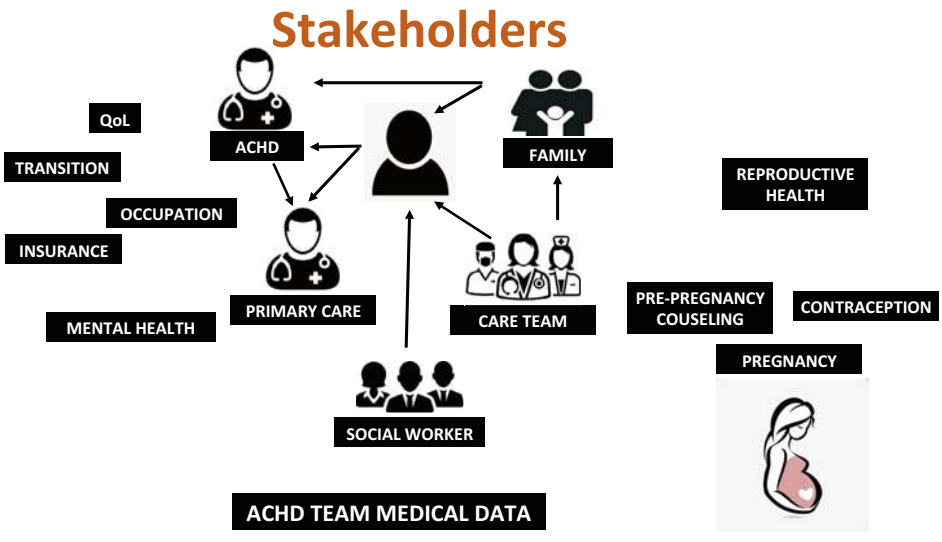
As the ACHD population continues to increase, the need for specialized ACHD care centers is becoming increasingly important. Currently there are 44 accredited ACHD programs in 27 states of the United States[6]. Though the number has increased over the years, the lack of these specialized centers in every state represents a significant challenge for patients, especially those belonging to vulnerable ethnicities and underserved populations[7]. A study by Thakkar et al. delineates steps to establish an ACHD specialized center, ranging from an outpatient setup to an advanced inpatient setup able to support a multitude of complex needs for this population; including involvement of multiple disciplines[8]. According to the AHA/ACC guidelines, ACHD centers should have ACHD certified cardiologists, congenital cardiac surgeons, nurses and nurse practitioners and cardiac anesthesiologists with CHD training. In addition, there should be a multidisciplinary involvement with specialists for high-risk obstetrics, pulmonary hypertension, heart failure/ heart transplantation, genetics, pathology, hepatology; social services; rehabilitation; psychological services; and financial counselors (Figure 2). There should also be imaging modalities readily available such as trans thoracic (TTE) and transesophageal (TEE) echocardiography, interventional catheterization, electrophysiology/pacing/implantable cardioverter defibrillator (ICD) implantation, exercise testing, radionucleotide, cardiac MRI, cardiac CT and nuclear medicine.

CLINICAL PRESENTATION OF ACHD

Patients with ACHD can have a combination of presenting signs and symptoms based on the type of cardiac lesion, its natural history, the long-term effects of corrective or palliative intervention(s) and the presence of hemodynamically important residual lesions. The most common symptoms include palpitations, and exercise intolerance. In addition, patients may present secondary issues related to endocarditis or pulmonary hypertension. Those with palliated or unrepaired CHD may present with cyanosis. Careful evaluation through history and physical exam needs to be done to ensure optimum care. Various diagnostic modalities are used to determine the nature of the disease and its impact on circulatory physiology, hence guide management. These include EKG, chest x-ray (CXR), echocardiography, cardiac MRI, cardiac CT with angiography, exercise tests (including cardiopulmonary exercise tests) and cardiac catheterization which may be diagnostic and therapeutic.

Specialized multidisciplinary care is also required by females with congenital heart disease who present during pregnancy. During this state, a series of profound physiologic changes of the circulation occur, including increased metabolic demands, increase in

Figure 2. Stakeholders of management of ACHD patients



total circulating volume, decrease in systemic vascular resistance, fluid retention and weight gain. These can have negative effects on cardiac function and result in significant morbidity for the mother and the fetus including cardiac arrhythmias and thromboembolic complications[9]. Moreover, patients with a single ventricle and those following an atrial switch procedure, who have a right ventricle as a systemic ventricle may not be able to handle the hemodynamic burden of pregnancy. Additionally, patients with left ventricular outflow tract obstruction and pulmonary hypertension represent a high-risk group for pregnancy and therefore require specific counseling and management (Figure 3).

SHUNT LESIONS

Patients with atrial septal defect, (ASD) ventricular septal defect (VSD), atrioventricular (AV) canal and patent ductus arteriosus (PDA) typically present in infancy with left to right shunt associated with congestive heart failure. When these lesions are repaired early and in the absence of a residual lesions, these patients have low risk for future interventions. In contradistinction, patients with unrepaired shunt lesions are prone to develop pulmonary hypertension and ultimately Eisenmenger syndrome, with its inherent limitation on life expectancy, placing these patients into the high-risk group. It is important to obtain a complete clinical history to understand the symptomatology at the time of presentation and the timing of intervention. Echocardiography can often provide detailed information about anatomy, presence of residual lesions and signs of pulmonary hypertension. Depending on the underlying anatomy, patients have the potential to present with specific issues during follow up after repair. Patients with AV canal defect are more likely to exhibit recurrent AV valve regurgitation and left ventricular outflow tract obstruction, while those with residual VSDs are at risk for endocarditis[10], in addition, some patients may present with an RV muscle bundle following VSD closure. Alternatively, once a PDA is closed in a timely fashion, it should not cause any additional morbidity.

TETRALOGY OF FALLOT; (TOF)

Tetralogy of Fallot is the most common cyanotic congenital heart defect. Due to the anterior malalignment of the infundibular septum, the patient has a large VSD with overriding aorta and right ventricular outflow tract obstruction. The degree of right ventricular outflow tract obstruction (RVOTO) determines the pathophysiology. With minimal RVOTO the patient presents with congestive heart failure (pink ToF), whereas cyanosis increases when the RVOT obstruction becomes more significant. A full repair will consist of closure of the VSD and relief of RVOTO which can often lead to wide open pulmonary insufficiency.

In extreme forms, there is complete atresia of the pulmonary valve, commonly associated with hypoplastic, sometimes discontinuous central pulmonary arteries and numerous aortopulmonary collaterals. While depending on the circumstances some patients with ToF may undergo the placement of systemic to pulmonary artery shunt to promote growth of the native pulmonary arteries prior to consideration for complete repair, the majority undergo complete repair in early infancy. The management of ToF with pulmonary atresia is very different and is often discussed as a separate entity.

Adults with ToF can have multiple issues that may require a re-intervention. The presence of chronic pulmonary insufficiency leads to RV dilation, progressive decrease in ventricular function and life-threatening arrhythmias, which can have an impact on life-expectancy[11]. Cardiac magnetic resonance imaging (cMRI) is a useful for serial assessments of right ventricular size, function, and burden of ventricular fibrosis (late enhancement) in these patients. Pulmo-

Figure 3. Risk markers for morbidity and mortality

High Risk

- **Pulmonary hypertension**
- **Cyanotic congenital heart disease**
- **Severe systemic ventricular dysfunction**
- **Severe obstructive valvular disease or severe conduit obstruction**

Moderate Risk

- **Prosthetic valve or conduit**
- **Systemic-to-pulmonary shunt**
- **Moderate systemic ventricular dysfunction**
- **Moderate obstructive valvular disease or moderate conduit obstruction**

nary valve replacement (PVR) is indicated when patients are symptomatic, or alternatively when the RV end-diastolic volume index (RVEDVi) reaches 160 ml/m^2 and or right ventricular end-systolic volume (RVESVi) reaches 80 ml/m^2, or RVEDVi > x 2 LVEDVi by cMRI in asymptomatic patients[5,12-16]. PVR can be performed surgically or by interventional catheterization. In the latter scenario, this is facilitated in patients who already have a conduit between the right ventricle and the pulmonary artery. In addition, due to recurrent or residual stenosis patients with ToF frequently require rehabilitation of their branch pulmonary arteries, which are most commonly performed by interventional catheterization.

Patients with ToF can also be affected by rhythm issues ranging from sick sinus syndrome to ventricular tachycardia and ventricular fibrillation. Although the presence of these arrhythmias places these patients at a higher risk for sudden death, particularly among those repaired in an earlier era, those undergoing an initial palliative shunt and those with a wide QRS complex, commonly can be effectively managed by timely insertion of pacemakers and/or defibrillator.

Pregnancy is usually well tolerated by patients following repair of ToF; however, there are risks for the mother (heart failure, severe pulmonary regurgitation or subpulmonary ventricular dysfunction and smoking history) and the fetus (cyanotic heart disease, mechanical valve prosthesis, multiple pregnancy, cardiac medications, use of warfarin) as well as risk to the fetus of having CHD and prematurity[17]. The Registry on Pregnancy and Cardiac Disease (ROPAC) acknowledges that women with heart failure are often delivered preterm to shorten the period of volume load and in order to institute more aggressive therapy for the treatment of heart failure, however, the decision for early delivery may have a negative impact on the offspring in the longer term. Alternatively, fetal death and intrauterine growth retardation occurred more often in patients with heart failure, which illustrates the difficult balance between early delivery and prolonging pregnancy in this high-risk situation.

Therefore, these patients require close monitoring during their pregnancy including close assessment of the fetus for congenital heart disease.

TRANSPOSITION OF THE GREAT ARTERIES

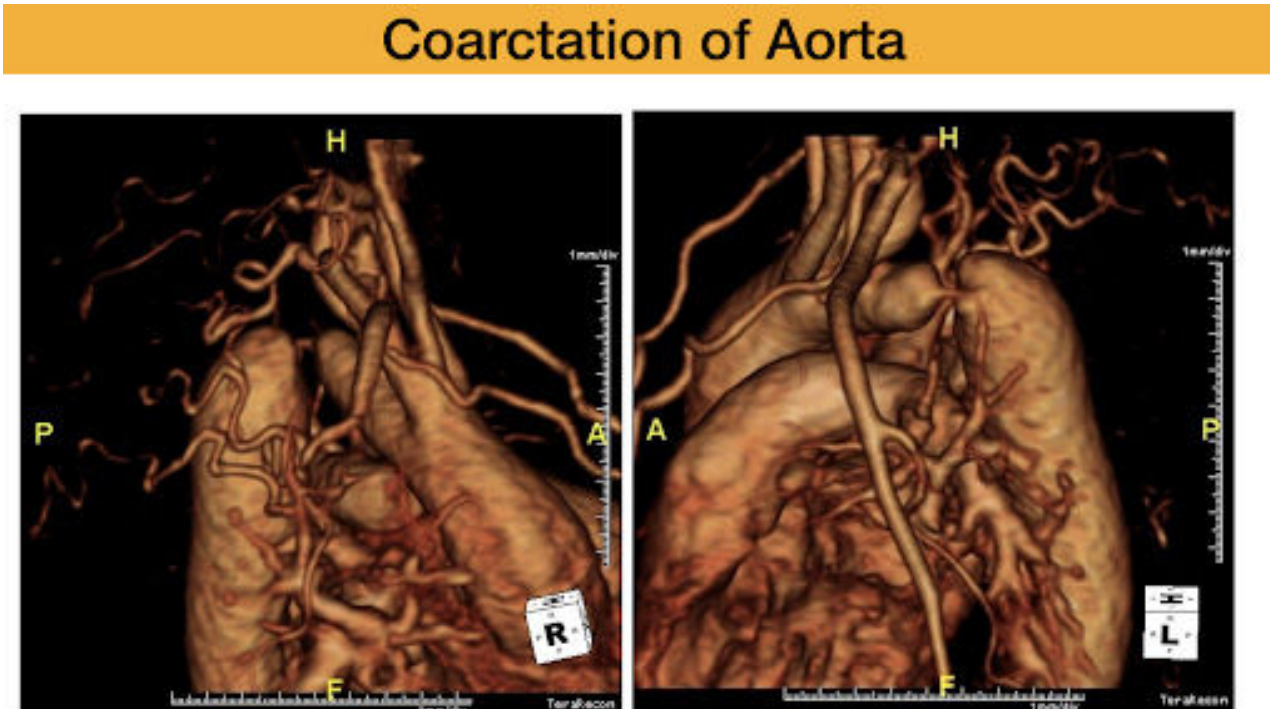
Dextro-transposition of great arteries (dTGA) consists of ventriculo-arterial discordance with the aorta arising from the right ventricle and the pulmonary artery from the left ventricle. This creates a circulation in parallel with the desaturated blood returning to the body and the fully saturated blood returning to the lungs. This circulation is incompatible with life unless there is anatomical shunt to allow mixing of desaturated and saturated blood, which can be at the level of the ductus arteriosus, atrial septal defect and ventricular septal defect. Without an intervention there is approximately 90% mortality at one year of age. The two main surgical procedures to address this lesion are atrial switch (Mustard/Senning) or arterial switch procedure (Jatene). In the former the systemic venous return is re-routed through a series of complex intra-atrial baffles, so that systemic venous return goes to the ventricle connected with the pulmonary artery and the pulmonary venous return to the ventricle connect to the aorta. However, this procedure leaves the patient with the morphologic right ventricle as the systemic ventricle and the morphologic left ventricle as the pulmonary ventricle. During follow up of these adults, several issues can present. These include baffle leaks, leading to cyanosis due to right to left shunting. In addition, due to extensive atrial suture lines, many patients develop atrial tachyarrhythmia, which could be addressed by complex ablations, insertion of pacemakers and sometimes defibrillators[18,19]. However, the most significant challenge is the management of systemic right ventricle failure, which generally presents several decades after the initial procedure, eliminating the option of left ventricular (LV) retraining to utilize the LV as the systemic pump. In this scenario, patients who present with RV failure should be promptly referred to expert teams and considered for heart transplantation. Undoubtedly, pregnancy can be particularly challenging and requires specialized management in these patients.

The Jatene procedure, popularized and embraced since the mid-1980's, consists of an arterial switch and coronary button transfer, making the circulation physiologic and positioning the LV as the systemic ventricle. The long-term issues of an arterial switch appear to have a lower incidence and consist of a) neo aortic root dilatation, occasionally associated with semilunar valve regurgitation, b) supravalvar pulmonary stenosis and c) ostial stenosis of the coronary arteries. Generally, patients after an arterial switch have a life without restrictions and women can carry pregnancies with minimal problems to the mother and the fetus.

COARCTATION OF THE AORTA

Coarctation of the aorta is (CoA) caused by narrowing of the thoracic aorta in the vicinity of the distal arch and proximal descending aorta. The infantile type (pre ductal) of coarctation is commonly associated with hypoplasia of the transverse arch, presents in the newborn period, and requires surgical correction during the newborn period or infancy. As early correction eliminates the obstruction and has the potential for growth, patients usually do well and have a lower incidence of hypertension, particularly if corrected in the first weeks of life. Alternatively, post ductal coarctation juxta can be missed and detected later in life. These patients often present as hypertensive adults and develop extensive collaterals between the proximal and distal segments sometimes evident by rib notching on a CXR (Figure 4). As these

Figure 4. Coarctation in an adult showing multiple collaterals



cases frequently present a discrete narrowing, they can be managed by interventional stenting of the aorta in the region of the coarctation. Nevertheless, if patients present beyond infancy, they can have issues with long term hypertension[20].

In addition, CoA is frequently associated with a bicuspid aortic valve (BAV), which is the most common form of CHD, affecting nearly 2% of the population. A BAV can be anatomically bicuspid or can be functionally bicuspid[21].The patients with BAV exhibit an aortopathy, characterized by cystic media changes that cause aortic dilatation, independent of degree of aortic stenosis or regurgitation. This requires close surveillance of the ascending aortic dimensions, as a diameter greater than 5.0 cm is associated with increased risk for rupture or aortic dissection. Current criteria for aortic replacement includes: a dimension between 5-5.5 cm depending on associated risks factors, like family history of dissection, growth rate >0.5 cm /year, or aortic coarctation[22]. Special consideration should be given to pregnant women who may be at increased risk of rupture, therefore not recommended to undergo vaginal delivery[23].Similarly, patients with dilated aorta should be restricted from isometric exercises.

SINGLE VENTRICLE

Patients with single ventricle lesions encompass a broad anatomic spectrum from hypoplastic right heart to hypoplastic left heart, unbalanced AV canal and complex forms of congenital heart disease which cannot be septated into a biventricular circulation due to a combination of issues including the location of a ventricular septal defect, straddling of AV valves, and or complex variations of systemic and or pulmonary venous return. Palliation of single ventricle is based on the premise that systemic venous return can flow passively across the pulmonary vascular bed without the help of a pump, leaving the heart to do the work of pumping oxygenated blood to the systemic circulation (Fontan circulation). Experience has demonstrated that to achieve this it is preferable to do it in stages with the goal of achieving a Fontan circulation after infancy. The single ventricle physiology requires several conditions to be met, irrespective of cardiac morphology: 1) unrestrictive egress of the pulmonary venous return to reach the systemic ventricle via an atrial septal communication, in cases of mitral atresia or stenosis. Alternatively, unrestrictive flow of systemic venous return across an atrial septal communication in cases of tricuspid atresia or stenosis; 2) unobstructed systemic outflow from the ventricle to the aorta; 3) Control of pulmonary blood flow to allow growth and maturation of the pulmonary vascular bed prior to the creation of a cavopulmonary connection. In hypoplastic left heart syndrome (HLHS) even with a diminutive aorta, the pulmonary valve and artery are used to recreate and unobstructed systemic outflow towards the thoracic aorta. Subsequently, the Fontan circulation is achieved in two-stages, including the creation of a superior cavopulmonary anastomosis (Glenn/Hemi-Fontan) at age 4-6 months, followed by the Fontan completion later in life. This

physiology has several particular characteristics, 1) a single pumping chamber is the only source of energy for the systemic and pulmonary circulation, 2) pulmonary vascular resistance is generally low to allow passive flow across the pulmonary bed, 3) systemic veins and splanchnic territory are exposed to a higher venous pressure, 4) increased production of lymphatic effluent, 5) limited ability to increase cardiac output during exercise, 6) augmented contribution of the respiratory mechanics and skeletal muscle to facilitate systemic venous return, 7) polycythemia, etc. These issues should be recognized and managed by experts, as this population exhibits the most complex physiology, and require specialized lifelong care. In addition, many patients require rhythm management and/or heart failure management, which are very common conditions. Lastly, patients can develop protein losing enteropathy and/or plastic bronchitis, which are very difficult to manage and are associated with increased morbidity and mortality[24].

Pregnancy in a Fontan patient has a very high risk of fetal demise and intrauterine growth restriction requiring very close monitoring by a team of experts.

SUMMARY

Adults with congenital heart disease (ACHD) present along a wide anatomical and pathophysiological spectrum. Moreover, the presence of important residual lesions and /or the natural evolution of unrepaired lesions make this a very complex group of patients to manage. As the prevalence of ACHD continues to grow, there is an increasing need for a clear transition process, specialized providers, and coordination among members of a multidisciplinary team to manage these complex patients. Specific lesions, require focused surveillance to address specific issues and optimize functional capacity.

Declaration of conflict of interest
The authors have no conflicts of interest to declare that are relevant to the content of this article.

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