Special Article

Pediatric Cardiac Tumors: Echocardiographic Imaging Features

Tumores Cardíacos Pediátricos: Características de Imagens Ecocardiográficas

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Abstract

Cardiac tumors (CTs) in children are very rare, but their diagnosis is crucial for patient management. Echocardiography is the most commonly used cardiovascular imaging modality in clinical practice for the initial diagnosis of CTs in pediatric patients. Knowing the echocardiographic characteristics of CTs can enable an increasingly early diagnosis and the identification of its most likely etiology. Primary and benign CTs are the most frequent types in the pediatric population. Among benign CTs, the most frequent in fetuses and neonates are rhabdomyomas and teratomas. In children and adolescents, rhabdomyomas and fibromas are more common. Here we describe the echocardiographic characteristics of the most common CTs in pediatric patients.

Introduction

Cardiac tumors (CTs), rarely encountered in clinical practice, are classified into primary and secondary types according to their site of origin. In the pediatric age group, CTs occur in 0.001–0.03% of autopsy findings, with primary CTs (PCTs) being the most prevalent and usually benign[1,2]. The most frequent benign PCTs in fetuses and newborns are rhabdomyomas, followed by teratomas and fibromas; in older children, these are rhabdomyomas and fibromas. In adults, myxomas are the most common benign PCTs[3-5]. As for malignant PCTs, sarcomas are the most frequent in both children and adults. In adults, secondary malignant CTs (metastatic) are more frequent than primary ones, unlike in the pediatric population[5-8]. Characteristics such as CT density, number, and location aid the identification of CT type (Figure 1, Table 1). Echocardiography is an accessible non-invasive test and the most commonly used imaging method for the initial evaluation of cardiac masses in routine clinical practice. In this scenario, the analysis of CT aspects by echocardiography and its association with patient age groups and other epidemiological aspects can significantly impact the therapeutic approach and clinical evolution of these patients. Although rare, CTs should be considered a differential diagnosis with other types of cardiac masses such as thrombi and vegetations. This pictorial review aimed to describe the characteristics of echocardiographic images of the main PCT types found in the pediatric population, providing tools for its diagnosis.

Keywords

Cardiac Tumors; Echocardiography; Screening; Imaging; Pediatrics.

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Benign CTs

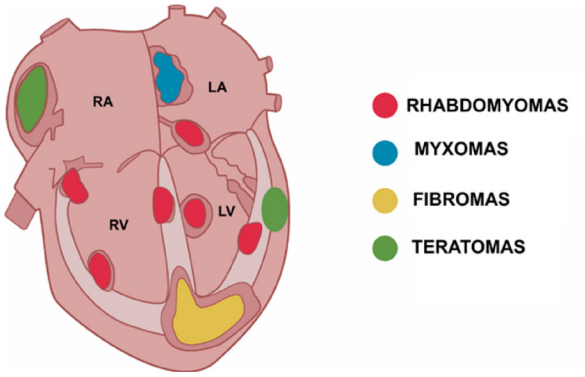
Most (90%) pediatric primary CTs (primary site: heart) are benign[3]. In the pediatric population, rhabdomyomas, teratomas, and fibromas are the most prevalent PCTs[2,3,7]. Other rarer benign pediatric PCTs are hemangiomas, myxomas, and hamartomas[2,6]. Next we will describe the main echocardiographic characteristics of the most frequent benign PCTs.

Rhabdomyomas

Rhabdomyomas are the most common benign PCTs in children, constituting 45–60% of tumors in this age group[2,3,7-9]. In a review including 27,640 patients with PCTs, Beghetti *et al.* described that rhabdomyomas were diagnosed as multiple or single CTs when associated with a family history of tuberous sclerosis or the involvement of other organs (central nervous system, kidneys, and skin)[7,8]. Rhabdomyomas are homogeneous masses that vary in size. They generally present as multiple well-delimited masses (in >60% of these patients) or, less commonly, as a pedunculated mass in the cardiac cavity (Figures 2A and B; Video clip 1). They typically occur at an equal distribution in the right and left ventricular (intracavitary) cardiac chambers[9,10]. Rhabdomyomas can also occur in the interventricular septum, and they can occasionally be intramural.

Most patients are asymptomatic; however, depending on their location, rhabdomyomas can cause arrhythmias (when located in the atrioventricular region), heart failure (HF), and signs of low cardiac output (ventricular) outflow obstruction[10]. In cases of hemodynamic repercussions, pharmacological treatment (rapamycin inhibitor [Everolimus]) or surgical treatment may be indicated[7,11-13].

These tumors usually occur in the fetal period or during the first year of life, as they are hormone-dependent and can grow in the fetal period until the 32nd week of pregnancy[14]. The presence of multiple cardiac masses on obstetric ultrasonography and/or fetal echocardiography should draw



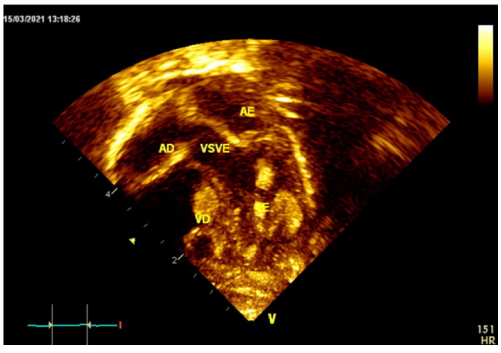
LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Figure 1 – *Pediatric primary cardiac tumor locations. Schematic image of the heart with the most typical locations of where the more common different types of pediatric primary cardiac tumors are located.*

Table 1 - Typical characteristics of the most common pediatric primary CTs.

Cardiac Tumor Type	Location/Association	Echo Features
Rhabdomyoma	Ventricular cardiac chambers, interventricular septum Associated with tuberous sclerosis	Homogeneous and well-delimited masses, variable in size, multiple or less commonly as a pedunculated mass
Fibroma	Interventricular septum and the ventricular free wall Associated with Gorlin syndrome	Heterogeneous and well-delimited large solid mass (single tumor); calcification is an important sign
Myxoma	Atrial septum, left atrium Associated with Carney complex	Single mobile, heterogeneous (pedunculated) mass; papillary myxomas are smaller with an elongated appearance
Teratoma	Pericardium, base of Ao/PA and SVC Associated with pericardial effusion	Non-homogeneous density, (cystic and multilobulated aspect); large mass

Ao, aorta; CTs, cardiac tumors; PA, pulmonary artery; SVC, superior vena cava.



Ao, aorta; IVS, interventricular septum; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle

Figure 2 – *Imaging of rhabdomyomas. Pediatric echocardiogram demonstrating multiple ventricular masses (red arrows) appearing as rhabdomyomas: (A) in the 4-chamber subcostal view (Video clip 1) and (B) in the parasternal left ventricle (LV) view by scanning the LV more apically. Note that the (increased) echogenicity of masses differs from that of the myocardium of the adjacent ventricular cavities.*

attention to the diagnosis of rhabdomyomas. In some cases, the masses can be large and obstruct the ventricular outflow and/or inlet tracts. In such cases, blood flow obstruction may occur, carrying the risk of HF and fetal death. In the postnatal period, the tumor masses may shrink or even completely regress, especially in early childhood.

There is a strong association between rhabdomyoma and tuberous sclerosis, especially in cases of multiple cardiac masses. About 60–80% of patients with rhabdomyomas have tuberous sclerosis[6,7,15], a genetic syndrome with variable clinical presentation, including cognitive deficit, seizures, multiple facial angiofibromas, skin patches (hypochromic "coffee au lait" spots), multiple retinal hamartomas, and cardiac rhabdomyomas, among other features. Rhabdomyoma-type CT is most common fetal and neonatal clinical presentation of tuberous sclerosis. Therefore, the presence of multiple

CTs in fetuses and children should draw attention to the diagnosis of rhabdomyoma and its association with tuberous sclerosis (Figure 3). The identification of mutations in the *TSC1* or *TSC2* genes is sufficient for the diagnosis of tuberous sclerosis, and genetic research should be requested in cases of rhabdomyomas[16,17].

Fibromas

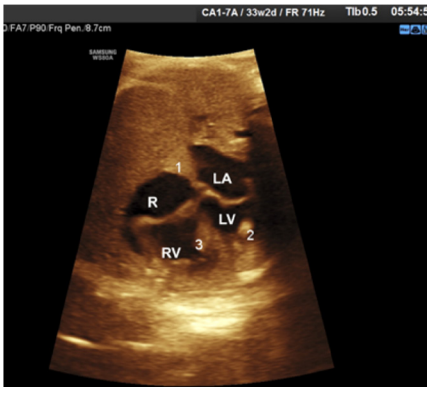
Although rare, fibromas are the second most common benign PCTs in pediatric patients except fetuses and neonates[2,7]. On echocardiography, these CTs usually present as a large solid myocardial mass (single tumor mass) that is well-delimited, non-contractile, echogenic, and heterogeneous within the myocardium (Figure 4, Video clip 2). Their central portion may have calcifications that are pathognomonic, reflecting a poor blood supply to the tumor. Calcification is an important tool that enables the differentiation of fibroma from rhabdomyoma within a single tumor mass. The most common fibroma locations are the interventricular septum and the ventricular free wall, and its extension into the ventricular cavity can lead to obstruction and HF symptoms. Alternatively, myocardial location can lead to arrhythmias[3,19].

These tumors do not regress spontaneously and often require resection. Surgical excision of CTs is recommended and can be subtotal to minimize loss of the myocardial mass. In cases of the evolution to myocardial failure or the involvement of a large cardiac area with the impossibility of complete tumor resection, a heart transplant may be considered.

Patients with multiple basal cell carcinomas should be screened for Gorlin syndrome[20], an autosomal dominant disease caused by a mutation in the *PTCH1* gene. Gorlin syndrome is characterized by skeletal and developmental abnormalities with a tendency for neoplasms such as medulloblastomas, basal cell carcinomas, and cardiac fibromas. In such cases, genetic counseling is crucial and the diagnosis is made through DNA analysis, even from the prenatal period[21].

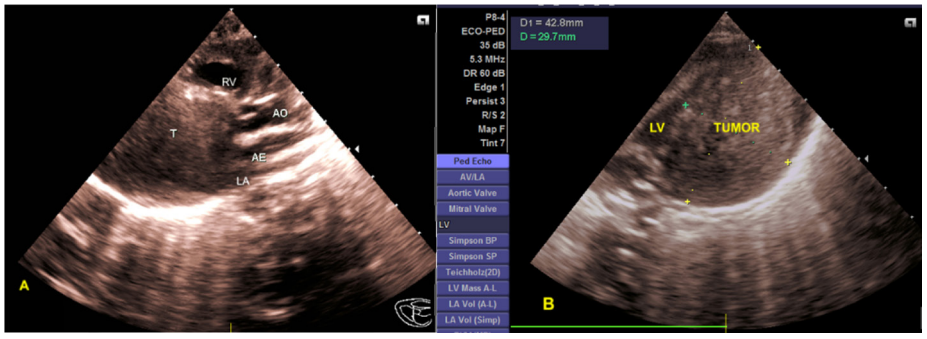
Myxomas

Cardiac myxomas, the most common PCTs in adults, usually present at age 30–60 years, most frequently in women. However, they are rare in children. Most of these PCTs (60%)



Ao, aorta; IVS, interventricular septum; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Figure 3 – *Fetal rhabdomyoma in a case of tuberous sclerosis. Fetal echocardiogram showing multiple masses (1, 2, 3) in ventricular cavities and interventricular septum in a case of rhabdomyoma and tuberous sclerosis.*



Ao, aorta; LA, left atrium; LV, left ventricle; T, tumor (fibroma).

Figure 4 – *Fibroma. Transthoracic echocardiogram showing the presence of a large (single) homogeneous mass corresponding to a fibroma. The large single mass is visible in the LV free wall from the parasternal view by scanning of the LV long (A/ Video clip 2) and short axes (B). The cardiac tumor was removed by cardiac surgery and a histopathological examination confirmed the echocardiographic diagnostic hypothesis.*

are located within the left atrium, characteristically originating from the middle portion of the atrial septum by a narrow pedicle, while 28% originate in the right atrium[22].

On echocardiography, myxomas usually present as a single mobile and heterogeneous (pedunculated) atrial mass (Figures 5A, 5B). Polypoid myxomas are larger with a smooth surface and a rough core and include cystic areas due to hemorrhage and necrosis. Papillary myxomas tend to be smaller and have an elongated appearance with multiple villi. Papillary myxomas are associated with embolic phenomena, while polypoid myxomas tend to obstruct the blood flow, with HF symptoms being the most frequent (Video clip 3). Patients with myxomas may present with systemic symptoms such as fever, weight loss, night sweats, and arthralgia and exhibit laboratory abnormalities such as anemia and elevated inflammatory markers.

Cardiac myxomas may be associated with Carney complex, a syndrome inherited in an autosomal dominant pattern[23]. Carney complex results in several neuroendocrine tumors and cardiac and cutaneous myxomas associated with changes in skin pigmentation resulting from mutations in the *PRKAR1A* gene. Myxomas in this syndrome occur at an earlier age and tend to recur more frequently[24-27].

An atrial myxoma warrants resection due to the risk of cardiovascular embolization, complications, and sudden death. Surgical resection is associated with low operative mortality rates and good outcomes. A small percentage of patients (up to 5%), typically those with a family history, show smaller tumors or ventricular locations and are at risk of recurrence or new myxomas, highlighting the importance of periodic follow-up.

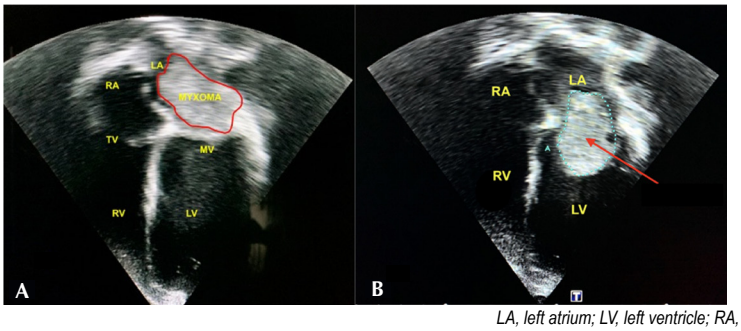
Teratomas

Teratomas are PCTs of which 70% of cases occur in childhood, more frequently in fetuses and neonates[3]. The main echocardiographic characteristics of teratomas include large masses with a non-homogeneous density and a cystic and multilobulated aspect, as they contain all germinative layers[3,28]. Their most common location is the pericardium, close to the base of the great arteries (adherent to the aorta and pulmonary arteries), and the superior vena cava. In some cases, extrinsic compression of these vessels can occur[3,28]. These patients may have dyspnea and HF signs. Pericardial effusion is generally present and may progress to cardiac tamponade, especially in fetuses[6,28].

Teratomas are frequently detected on prenatal ultrasound or fetal echocardiography with a risk of fetal death of extrinsic compression or cardiac tamponade (Figure 6). These fetuses may benefit from prenatal intervention[3,28,29]. Teratomas have a good postnatal prognosis after curative surgical resection and generally show no recurrence in long-term follow-up[7,30].

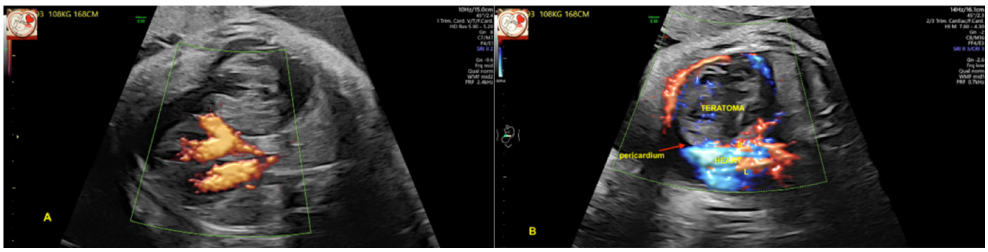
Hemangiomas

Hemangiomas are rare CTs usually located in the right



LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Figura 5 – *Left atrial myxoma. Transthoracic echocardiogram (apical 4-chamber view) demonstrating a large mobile mass (red arrow) in the left atrium with irregular contours (A) obstructing the LV inlet tract flow (B; Video clip 3).*



LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Figure 6 – *Fetal teratoma. Three-dimensional fetal echocardiogram with power and color Doppler imaging demonstrating a teratoma in a fetus at 32 weeks' gestation. Note the large pericardial mass (A) and pericardial effusion (B).*

atrium and right ventricle. Depending on their location and size, they can cause systemic venous congestion, right ventricular outflow tract obstruction, elevated right ventricular end-diastolic pressure, and irreversible right ventricular dysfunction. Electrocardiography can reveal ST-segment abnormalities, signs of right ventricular hypertrophy, signs of pre-excitation, and arrhythmias. The presence of pericardial effusion is prevalent in hemangioma cases[31]. Remarkably, this type of CT has the best prognosis due to the possibility of its spontaneous regression[32].

Malignant CTs

Malignant tumors account for about 15% of CTs and are rather rare in childhood[30]. They typically show rapid growth, local invasion, hemorrhagic pericardial effusion, and precordial pain. Among them, the most prevalent are sarcomas and rhabdomyosarcomas.

a. Sarcomas

Sarcomas are the most common among malignant CTs and typically diagnosed in the mid-4th decade of life. Undifferentiated sarcomas appear as broad masses on echocardiography, typically in the left atrium (which allows differential diagnosis with myxomas), heterogeneous echogenicity, and hypoechoic areas, indicating tumor necrosis. The most common sarcoma in the heart is angiosarcoma. It is often located to the right, particularly the right atrium. Echocardiograms show a clearly heterogeneous lobulated mass with areas of necrosis and hemorrhage but without a pedicle, differentiating it from other tumors. Sarcomas tend to show direct involvement with the pericardium, resulting in hemorrhagic effusion that may or may not cause tamponade.

Angiosarcomas tend to replace the cardiac wall of the right atrium and fill the chamber. Depending on their location and hemodynamic repercussions, they can show signs and symptoms of pericardial precordial pain, obstruction, congestion, dyspnea, and fatigue. Unfortunately, metastasis to the lung is common at diagnosis and the prognosis is restricted, even after surgery, due to recurrence and metastasis[3,31].

b. Rhabdomyosarcomas

Rhabdomyosarcomas, the second most common malignant tumor type, can appear in any cardiac structure without location preference. They tend to occupy multiple areas and can cause obstructions. They grow quickly, involve the pericardium early, and carry a poor prognosis[4,31].

Leiomyosarcomas, osteosarcomas, fibrosarcomas, and undifferentiated sarcomas are other rare types that have a very poor prognosis[3,21].

c. Lymphomas

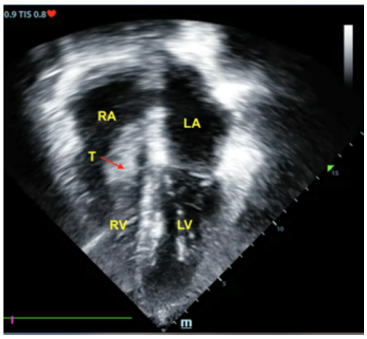
In general, due to cardiac involvement in patients with Hodgkin's and non-Hodgkin's lymphoma, however. Primary cardiac lymphomas show an increased incidence in immunocompromised patients, those after transplantation, and those infected with HIV. These tumors are most commonly diffuse large B cell lymphoma. On echocardiography, they are homogeneous and infiltrative, leading to wall thickening and hemodynamic restriction, with nodular masses occupying the cardiac chambers, mainly the right atrium (Figure 7, Video clip 4). The atrioventricular region can be affected, involving the right coronary artery and pericardial effusion.

Transesophageal echocardiography is the best imaging technique and should be performed to identify tumor type. Depending on its location, it can generate symptoms of inlet obstruction, leading to vena cava syndrome, HF, and arrhythmias such as complete atrioventricular block and embolism.

The diagnosis can be made by pericardial effusion cytology or echo-guided biopsy. Cytology is the key to lymphoma prognosis, which is usually much better than that of other primary CTs, especially if patients are candidates for adequate chemotherapy. Radiotherapy is less favorable, while surgical resection of the entire tumor is very difficult[4,31].

d. Mesothelioma

Mesotheliomas represent half of primary pericardial tumors, the other half being benign (teratomas, fibromas, and lipomas). Their symptoms include chest pain, cough, and palpitations. These tumors form bulky nodules within the pericardial cavity, circumventing the heart, mimicking



LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle; T, tumor (lymphoma).

Figure 7 – *Lymphoma. Two-dimensional echocardiogram showing a large nodular mass (lymphoma) in the RA cavity (red arrow). The features of this mass in an adolescent patient infected with the human immunodeficiency virus raised the suspicion of this diagnosis.*

pericarditis, and cardiac tamponade[30]. Echocardiography typically reveals pericardial effusion and a tumor involving the heart, but a mild mass may not be seen. The patient prognosis is restricted, although surgery and radiotherapy can provide palliative benefits.

e. Metastasis

Cardiac metastasis is not uncommon, with an incidence of around 0.7–3.5% in the general population that reaches 7.1% in people with known malignancies[3]. They can invade the heart by hematogenous dissemination, contiguity, or via the venous/lymphatic route. Heart metastasis is most common in primary breast and lung tumors, esophageal carcinoma, malignant lymphoma, leukemia, and malignant melanoma (Figure 8). Melanoma is more prone to cardiac metastasis due to its hematogenous spread. The pericardium is more seriously affected, with an effusion that can even be asymptomatic. However, metastasis should be considered in any patient with a known malignant disease and new cardiovascular symptoms.

Echocardiography should be performed as an initial diagnostic test for the presence of metastatic implants, and it can be complemented with other imaging tests. Unfortunately, metastatic cardiac disease occurs in patients with already disseminated disease, making its prognosis quite poor when identified[3,33].

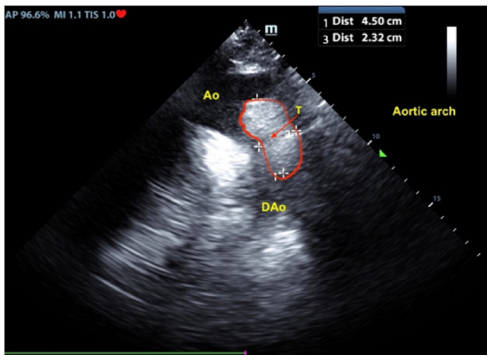
We can currently detect CT, make the diagnosis, and treat and follow patients, but in this chain, the missing link is very first one: What causes CTs, and why? To answer this question, international cooperation is needed, as is the establishment of national databases. Is it possible that air pollution plays a role? The first such suggestion came from Poland[34].

Differential diagnosis

The main differential diagnosis of CTs is thrombi, which occur more frequently on the right side of the heart and are related to a clinical history of central venous catheter use (Figure 9A) or structural heart diseases with dilated cardiomyopathy (Figure 9B). Cardiac thrombi generally appear as mural masses or pedunculated and mobile intraluminal masses. Unlike CTs, they are avascular and do not show increased echogenicity on contrast-enhanced echocardiography[3,30,35,36].

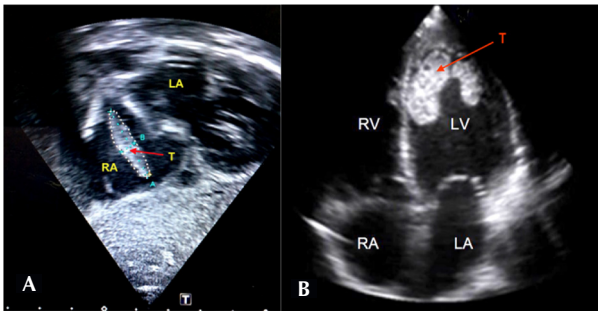
Left ventricular diverticulum is another differential diagnosis characterized by the image of a structure connected to the ventricular cavity by a narrow pedicle presenting asynchronous contractility with the left ventricular myocardium (Figure 10)[3,37].

Other differential diagnoses are pericardial cysts and vegetations, the latter being associated with a clinical history of fever and, in general, the presence of structural heart disease (valvular disease or shunt heart disease with communication



Ao, aorta; DAo, descending aorta; T, secondary cardiac tumor (red arrow).

Figure 8 – *Transthoracic echocardiogram showing a secondary cardiac tumor (metastasis) in the aorta in an adult patient. Secondary cardiac tumors are encountered more frequently in the adult population than in the pediatric population.*



LA, left atrium; LV, left ventricle; RA, right atrium; T, thrombus (red arrow).

Figure 9 – *Cardiac thrombus. Transthoracic echocardiogram showing a thrombus (red arrow): (A) in the right atrium adherent to a catheter and (B) in the LV apical wall. The first was identified in a child with a central venous catheter and the latter was identified in an adolescent with myocardial disease.*

between the left and right sides of the heart) (Figure 11, Video clip 5)[3,30,38]. Vegetations generally appear as echogenic masses attached to the atrial side of the atrioventricular valves or the ventricular side of the semilunar valves. Indeed, important features of vegetations on echocardiography are isoechoic to the tissue, move independently, and are associated with valvular regurgitation[38-40].

Conclusions

Although CTs are rarely encountered in the pediatric age group, their early diagnosis can impact the conduct and prognosis of these patients. Primary CTs are most frequently seen in children, with a high prevalence of a benign nature. Echocardiography, the most commonly used cardiovascular diagnostic test, provides important tools for an initial diagnosis. Knowledge of the echocardiographic characteristics of pediatric CTs can enable the identification of different CT types and their differential diagnosis with other images of masses such as thrombi, contributing to treatment optimization (Table 1, Figure 12).

Authors' contributions

Conception and study design: Bravo-Valenzuela NJM, Lucas E; Data collection, data analysis and interpretation, manuscript writing: Bravo-Valenzuela NJM, Lucas E, Velloso Netto N, Conceicao LV, Estrada NPD and Respondek-Liberska M; Critical revision of the manuscript for important intellectual content: Araújo Júnior E and Bravo-Valenzuela NJM.

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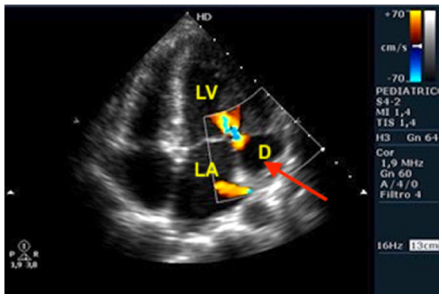
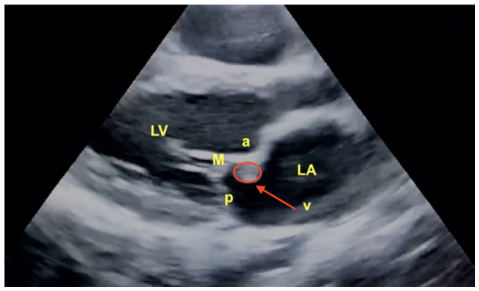
Conflict of interest

The authors have declared that they have no conflict of interest.



D, diverticulum (red arrow); LA, left atrium; LV, left ventricle

Figure 10 – *Ventricular diverticulum. Transthoracic echocardiogram (4-chamber view) of a child with left ventricular diverticulum. Observe the color Doppler on the narrow pedicle demonstrating that this structure is communicating with the ventricular cavity.*



a, anterior cusp; LA, left atrium; LV, left ventricle; M, mitral valve; MR, mitral regurgitation; p, posterior cusp; V, vegetation.

Figure 11 – *Infective endocarditis in a pediatric patient affecting the anterior cusp of the mitral valve on the atrial side of the valve (Video clip 5).*

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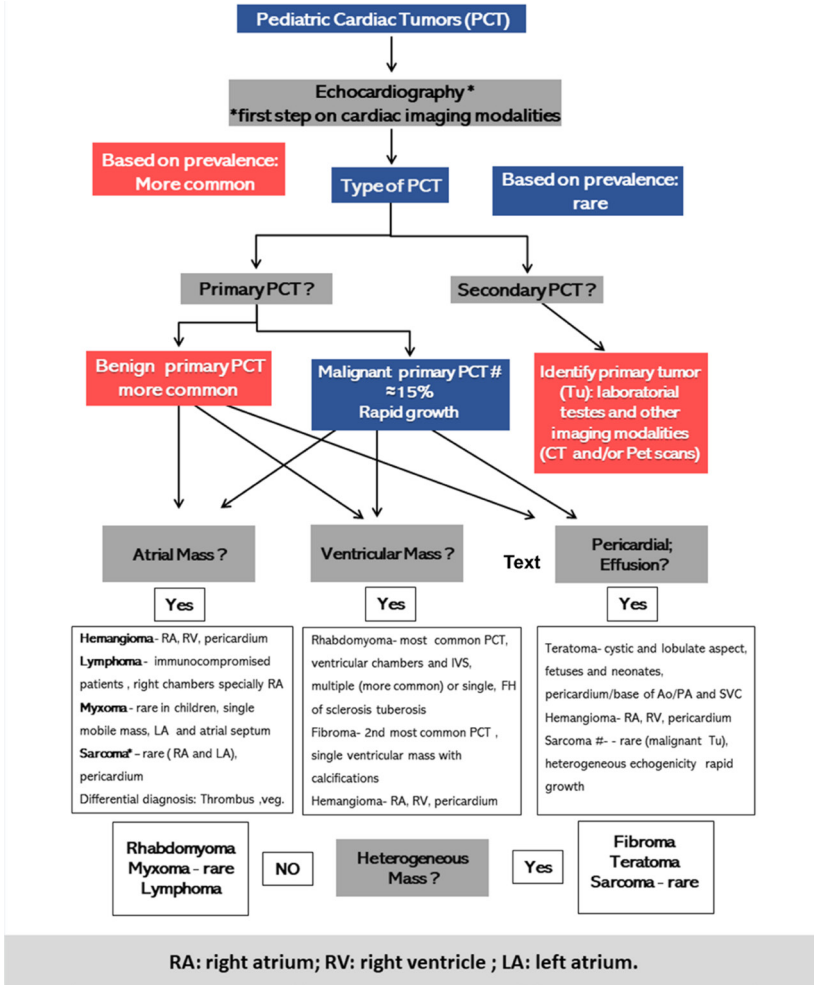

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Figure 12 – *Echocardiographic approach to pediatric cardiac tumors (PCT).*

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