Echocardiographic Findings in the Anomalous Origin of the Left Coronary Artery from the Pulmonary Artery : a Single-Center Experience.

Données Echographiques de l'Origine Anormale de l'Artère Coronaire Gauche à partir de l'Artère Pulmonaire : Etude monocentrique

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Summary

Background: Despite its rarity, the Anomalous origin of the left coronary artery from the pulmonary artery (ALCAPA) is life-threatening congenital heart disease. It represents a curable heart disease and a preventable cause of sudden death. Our study aimed to focus on the value of the transthoracic echocardiography (TTE) findings in the diagnosis of this coronaropathy in children.

Methods and Results: Our retrospective study includedsix children diagnosed with ALCAPAfrom 2004 to2021.Left ventricular(LV) systolic dysfunction and wall motion abnormalities were described in all patients in the infant group. Mitral regurgitation (MR) was more severe in this group of patients. Right coronary artery was more importantly dilated in the older group, andcollateral circulation was more expanded in older children. LCA origin from the pulmonary artery was visualized in three patients. Five patients underwent surgical repair, without intervention on the mitral valve, with significant improvement in the LV ejection fraction and a decrease in the severity of MR.

Conclusions: Our study showed the importance of TTE in making the diagnosis of ALCAPA in infants but also inpaucisymptomatic children,as well as the good results of the surgical treatment even in the absence of intervention on the mitral valve.

Keywords

ALCAPA; echocardiography; congenital heart disease; children.

Résumé

Résumé : Background: Malgré sa rareté, l'origine anormale de l'artère coronaire gauche à partir de l'artère pulmonaire (ALCAPA) est une cardiopathie congénitale potentiellement mortelle. Elle représente une maladie cardiaque curable et une cause évitable de mort subite. Notre étude visait à mettre l'accent sur la valeur des résultats de l'échocardiographie transthoracique (ETT) dans le diagnostic de cette coronaropathie chez l'enfant.

Méthodes et résultats : Notre étude rétrospective a inclus six enfants diagnostiqués avec ALCAPA entre 2004 et 2021. Une dysfonction systolique du ventricule gauche (VG) et des troubles de la cinétique segmentaire ont été décrits chez les nourrissons. L'insuffisance mitrale (IM) était plus sévère dans ce groupe de patients. L'artère coronaire droite était dilatée de manière plus importante dans le groupe des enfants plus âgés, et la circulation collatérale était plus étendue également dans ce groupe d'enfants plus âgés. L'origine de l'artère coronaire gauche à partir de l'artère pulmonaire a été visualisée chez trois patients. Cinq patients ont subi une réparation chirurgicale, sans intervention sur la valve mitrale, avec une amélioration significative de la fraction d'éjection du VG et une amélioration de l'IM.

Conclusions : Notre étude a montré l'importance de l'ETT dans lediagnostic d'ALCAPA chez les nourrissons mais aussi chez les enfants paucisymptomatiques, ainsi que les bons résultats du traitement chirurgical même en l'absence d'intervention sur la valve mitrale.

Mots-clés

ALCAPA ; Echocardiographie; Cardiopathie Congénitale ; Enfants

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BACKGROUND

Despite its rarity, Anomalous origin of the left coronary artery from the pulmonary artery (ALCAPA) is a life-threatening congenital heart disease. It affects about 1 in 300 000 newborn infants (1).This coronary abnormality was described for the first time in 1885 by Brooks(2) and it was called Bland-White-Garland syndrome in 1933(3). ALCAPA leads to retrograde flow from the coronary arteries to the pulmonary artery. This "coronary steal" phenomenon is responsible for different clinical presentations. Cardiac catheterization with angiography were the standard means of diagnosis. Recently, significant improvement in echocardiographic techniques allowed diagnostic imaging without the need for more invasive tools.

The purpose of this study was to assess echocardiographic features of ALCAPA in the different clinical presentations.

METHODS

This was a retrospective study conducted at the pediatric cardiology department of the Rabta Hospital in Tunisia. Six patients were diagnosed with ALCAPA from January 2004 to July 2021.There were no exclusion criteria.The collected data included gender, presenting symptoms, age at the onset of the symptoms, age at diagnosis, heart failure signs, body surface area, diagnostic studies, date of surgery, as well as data on short and long-term follow-up. The diagnostic techniques employed were electrocardiogram (ECG), chest X-ray, echocardiography, computed tomography and cardiac catheterization.The electrocardiogram was studied for both Johnsrude electrical signs(4)(Q wave deeper than 3mm and wider than 30 ms with a QR pattern in at least 1 of the following leads: I, aVL, V 5 to V7,and the complete absence of Q waves from leads II, III, and aVF) and theECG criterion of the Chang and Allada score(5) (QT pattern in aVL: Q wave with an inverted T wave).Echocardiographic findings were indexed to z-score.LV measurements including end-diastolic and end-systolic diameter, fractional shortening (FS) and ejection fraction (LVEF) were obtained. Echocardiographic studies were examined to evaluate global and regional wall motion abnormalities, mitral valve apparatus, origins and dimensions of the coronary arteries. The left coronary artery (LCA) diameter was measured on parasternal short axis view and the right coronary artery (RCA) diameter was measured on the same view or on the parasternal long axis view. Color Doppler echocardiography was reviewed to look forthe presence of intraseptal collateral circulation corresponding to continuous color flow regions of low velocity in the ventricular septum, and to evaluate the severity of mitral regurgitation (MR) from 0 to 4 (0: no regurgitation, 1: mild, 2: moderate, 3: significant and 4: severe).

Chang and Allada score(5), a scoring system developed on one electrocardiographic criterion (above-cited) and four echocardiographic features in order to distinguish ALCAPA from dilated cardiomyopathy, was calculated in all our patients. Echocardiographic features are RCA diameter to aortic annulus ratio ≥ 0.14, increased papillary muscle echogenicity, and Doppler color flow mapping of LCA from pulmonary artery or from aorta. A positive score was in support of the ALCAPA diagnosis. It was calculated by deducting 1 to direction of doppler color flow from aorta to LCA and adding 1 for each other item.

Cardiac CT was performed in all our patients to define the anatomic position of the anomalous LCA. Cardiac catheterization was carried out only when echocardiographic and cardiac CT results were not sufficient.

RESULTS

Six patients were included in this study from January 2004 to July 2021, all of female gender. The mean age of diagnosis was 5,4 years (4 months to 14 years). Three patients developed symptoms of heart failure in the first year (infant group) with a cardiogenic shock in one of them. Symptoms were less common in older children.

Table 1 resume the clinical characteristics of patients with ALCAPA in our study.

The ECG study identified Johnsrude electrical signs(4) in all our patients, while the "QT pattern" in aVL(5) was present in three patients.

Chest X-ray films showed cardiomegaly in five patients, with an average cardiothoracic ratio of 0,68. Signs of congestion were present in two patients with the infant type of ALCAPA.

Echocardiographic findings at presentation are summarized in Table 2. Left ventricular (LV) was dilated in 5 patients, with an average end diastolic diameter (EDD) of 47 mm and an average end diastolic diameter indexed to Z score of +3,5 (+1,5 to +6). LV was markedly dilated with significant LV systolic dysfunction in the three youngest patients at the onset of symptoms (infant group), with global wall motion abnormalities in two of these patients and apical wall motion abnormalities in the other one. LV function was more than 50% in the olderchildren with normal LV wall motion.The echocardiogram revealed the presence of mitral regurgitation (MR) in all our patients.It was more significant, graded 2 or 3 in the infant group. RCA was dilated (figure 1) in all our patients, more importantly in the older children, with an average diameter of 4,2 mm (3 mm to 6 mm), the

diameter indexed to Z score ranged from +3,3 to +5,8. The oldest patient (patient n°4) had the most dilated RCA. Intraseptal collateral circulation (figure 2) was visualized in all our patients, particularly in the older group. The Chang and Allada score(5) was positive in all six patients: RCA diameter to aortic annulus ratio was more than 0,14 in three patients; increased papillary muscle echogenicity was described in five patients and retrograde flow within the LCA was visualized in three patients(figure 3).

The LCA origin from the pulmonary artery was clearly seen in three patients (figure 4). Two of them were included in the infant group.

ALCAPA was isolated in five patients, and associated with a patent foramen ovale in one patient.

Echocardiographic findings confirmed the ALCAPA diagnosis by visualizing directly the LCA origin from the PA or by gathering different markers of ALCAPA in each age group. All six patients underwent additional imaging using CT coronary angiogram to precise the exact anatomy of the origin of the LCA from the pulmonary artery, with the need to complete by cardiac catheterization in two patients in whom the CT angiography was not conclusive. The results confirmed the location described on the doppler echocardiography exam in the patients n°1,2 and 4.

Five patients underwent surgical repair: Left coronary artery reimplantation. Average age at operation was three years and a half (6 months to 7 years). No one underwent an additional mitral valve procedure, not even patient number 1 with MR grade III. Regular follow-up, with a mean duration of four years (1 to 9 years),revealed significant clinical improvement. Echocardiographic examinationsshowed a recovery of good LV function in four months for patient n° 3 who was operated at the age of six months while it required more time for the other four patients. LV remained mildly dilated (+2 Z score) in only one patient (number1). Apical wall motion abnormalities didn't disappear after surgical repair in the same patient. The RCA had regained its normal size in all five patients. MR had disappeared in patients n° 2 and 6, decreased in patients n° 1 and 3, and remained grade II in patient n°5. Cardiac catherization was performed in patient n° 1, seven years post-operative, and it showed no coronary stenosis.

Patient n°4, who was initially asymptomatic at the age of 14-year-old, had not yet undergone surgery. At last check-up, 18 months after the diagnosis, shewas complaining of precordialgia on exertion. The ECG remained unchanged. Echocardiographic checks showed the same data. The patient is scheduled for a surgical repair.

DISCUSSION

Coronary arteries connect to the aorta(6) around 60 days of intrauterine life.A left coronary artery connecting to the pulmonary artery is a rare abnormality. Six patients, all of female gender, was included in our study during 17 years. The female predominance was noted in most studies: 55% of patients in Duan et al study(7), 86% in Matoq and Tsuda study(8), 86% in Ramirez et al study(9) and 90% in Menahem et al study(10).The mean age at diagnosis in our study (5,4 years)was comparable to that of the Ramirez et al(9) study (6,2 years), but more advanced compared to the other studies.

ALCAPA was first described by Brooks(2) in 1885 and in 1933, it was called Bland-White-Garland syndrome(3). In 1968, Wesselhoeft et al(11)identified two ALCAPA groups: infant group (82%) and adultgroup(18%).

The pulmonary arterial pressure is high during fetal and early neonatal life leading to an anterograde flow from the pulmonary artery to the anomalous LCA, thus ALCAPA is well tolerated at this stage(12). Soon after birth, as the pulmonary arterial pressure decreases gradually, flow in the LCA decreases and then reverses resulting in a left to right shunt: the "coronary steal" phenomenon(13). During this after birth period, an acquired collateral circulation between LCA and RCA develops. Patients with little or no coronary collateral development have the infant type: Severe myocardial infarction and congestive heart failure are the result of poor LV perfusion when the flow reverses in the LCA(11). This form was reported in only 50% of patients in our series(patients 1, 2 and 3). When collateral circulation is well-expanded or in case of a restrictive LCA ostium, patients have the adult type of the coronaropathy(12): this group of patients may be asymptomatic, they may present with mitral regurgitation or ischemic cardiomyopathy, but most notably, sudden cardiac death may be the first clinical expression of these disease(14). Our series highlighted the presence of the adult type of ALCAPA in older children.This age group was rarely reported in the literature.Therefore, studying coronary arteries abnormalities is essential regardless of the age of the patients and the clinical presentation. In fact,a recent study(15), enrolled patients with late presentation of ALCAPA, showed that before the diagnosis was made, 44% of patients who wereadmitted to the hospital were misdiagnosed. Among themtwo patients diagnosed with mitral regurgitation underwent surgical procedure without the ALCAPA diagnosis.

The ECG criteria are often the first elements suggesting the diagnosis of ALCAPA. Invasive cardiac catheterization

was mandatory to confirm this diagnosis. Nowadays, 2D doppler-coupled echocardiography can visualize the origin of the LCA from the pulmonary artery. Even when it's not possible to identify the anomalous origin of the LCA, many indirect signs canguide the diagnosis of ALCAPA. In Matoq and Tsuda study(8), the ALCAPA diagnosis was made based only on echocardiographic exam in 71% of patients. In our series, the diagnosis was made in all our patients with TTE, but further examinations were made to precise the exact anatomy of the ostium of the LCA.

Regional wall motion abnormalities are more common in the ALCAPA than in dilated cardiomyopathy(5). In our study, apical wall motion abnormality was found in one patient. Markers of myocardial ischemia such as increased echogenicity of the mitral papillary muscle and the endocardium are frequently noted. Thesemarkers, when they are prominent, may mislead the diagnosis with the idiopathic endocardial fibroelastosis.An increased echogenicity of the mitral papillary muscle was described in five patients in our series and all the patients (a total of 9 patients) in the Duan et al study(7).

In 1985, King et al(16)showed that the presence of bi-directional flow at the proximal part of the main pulmonary artery was in favor of the diagnosis of ALCAPA.

In 1989, Koike et al(17) demonstrated that patients with ALCAPA diagnosis had a dilated RCA while patients with dilated cardiomyopathy had normal RCA diameters. They found a ratio of right coronary to aortic annulus diameter of 0,21 to 0,29 in the ALCAPA group and 0,10 to 0,13 in the other group. In our study, the RCA was dilated in all our patients, this ratio was more than 0,2 in two patients.

Chang and Allada(5) regrouped in 2001 a scoring system based on one electrical criterion and four echocardiographic findings (above cited) to discriminate between ALCAPA and dilated cardiomyopathy. The sensitivity of this score was 100% and the specificity was 92%. In our study, Chang and Allada score was positive in all our patients.

In 2002, Frommelt et al (18), pointed out that the identification of a continuous septal flow of low velocity, which represents the septal collateral coronary circulation was an important echocardiographic finding in favor of ALCAPA. The collateral circulation can easily be distinguished from ventricular septal defect flow which is a systolic flow, usually of high velocity. Besides, in case of collateral circulation, there is no ventricular septal defect seen and no color flow visualizedpenetrating the right ventricular(19).As in previous studies, Frommelt et al(18) concluded that the RCA dilation and the retrograde flow within the LCA were frequently documented in ALCAPA. They considered that the combination of these two findings with the septal collateral circulation can make the diagnosis of ALCAPA. The collateral circulation was visualized in all patients in our study and in 44% of patients in the Duan et al study(7). Retrograde flow in the LCA was seen in three (50%) patients in our series, in six (67%) patients in the Duan et al study (7) and in fourteen patients (100%) in the Matoq and Tsuda study(8).

Mitral regurgitation is frequently documented in patients with ALCAPA. Ischemic lesions of the mitral subvalvular apparatus and annular dilation in case of dilated left ventricular are the most common mechanisms. Therefore, in case of significant MR with dilated LV, a careful examination of the coronary arteries is warranted before making the diagnosis of MR causing LV dilatation, especially in children without a history of rheumatic heart disease or congenital valvular disease(20). MR was present in all patients in our study with different degrees of severity, in 89% in the Duan study et al(7) and in 60% in the Ramirez et al study(9).

With the development of 2D doppler echocardiography in recent decades, the study of coronary arteries became more feasible.In order not to make wrong conclusions, the examination of coronary arteries constructed on still images should be avoided. Color flow mapping and lowering the Nyquist limit allow a better sensitivity, with a color scale decreased to 18-50 centimeters per second, the analyze of the flow direction in the coronary arteries is more accurate(19).The parasternal pulmonary artery short axis-view is useful to precise the exact location of the LCA from the PA(21). It should be noted thatcareful examination of the pulmonary artery branches, especially the proximal right pulmonary artery, is mandatory to identify the origin of LCA when it is not seen in the main PA(22).It has been demonstrated that the diagnosis of ALCAPA with exact determination of the origin of the LCA from the PA can be made with 2D echocardiography in 54% of cases(23).The origin of the LCA from the main pulmonary artery was visualized in six patients (67%) in the Duan et al study(7) and in three patients (50%) in our series. All patients in our study underwent additional imaging in order to locate the ostium of the LCA, and final results were in agreement with echocardiographic findings.

Like the clinical presentation, the echocardiographic findings in ALCAPA depend on the development of the collateral circulation(12). In infant group, when this circulation is poor, myocardial ischemia dominate the echocardiographic data with manifest LV dilation and

dysfunction, usually with significant MR. In the other hand, in patients with older presentation, the septal collateral circulation is well visualized on echocardiographic examination with a noticeable dilated RCA which can be easily remarkedin the parasternal short axis view. This dilated RCA can even be noted in the apical four-chamber view(19). There is generally no notable LV dilation nor dysfunction in this group of patients(15). In our study, this form was described in three patients at an age ranging from 6 years to 14 years. The adult form of ALCAPA has been seldom reported in children and adolescents(24). The development of echocardiographic modalities allowed an earlier diagnosis of this form. Because of the important risk of sudden cardiac death, we emphasize the importance of seeking ALCAPA in children even in the absence of signs of heart failure and with normal LV dimension and function. Our cases demonstrate that despite heterogenous age at presentation and varied clinical presentations, the TTE, by gathering different markers in each condition, is the fundamental imaging tool in making the ALCAPA diagnosis.

The diagnosis of ALCAPA is crucial because surgical repair in view of a two-coronary system improves spectacularly the outcome of these patients. The direct reimplantation into the aorta is actually the procedure chosen in most patients with ALCAPA when it is feasible(25). This procedure was performed in all five patients who underwent surgery in our series, in 70% and 71% of patients in Richard et al study(23)and in Matoq and Tsuda study(8) respectively. A recent study(26), that included 907 patients withALCAPA repair registered in the European Congenital Heart Surgeons Association database from 1999 to 2019, showed good post operative survival. In hospital mortality in this study was 6%.

The role of doppler echocardiography remains fundamental during follow-up. When the surgical repair is performed early in life, generally before the age of 10 months(27), full recovery of the LV is expected in a short time after the procedure, as it is the case of our patient operated at the age of six months. Otherwise, it takes more time to obtain normal LV function and the LV may persist dilated in long term follow-up(1), as in the case of patient n°1 in our series. Despite LVEF normalization, long term follow-up after surgical repair showed an impaired longitudinal strain in all cardiac chambers, especially in the LCA regions(28). Therefore, lifelong follow-up is required in these patients.

After surgical repair, even without associated gesture on the mitral valve, mitral regurgitation generally decreases or even disappears(27), as it is the case of four patients (80%) in our series and 75% of patients in the Matoq and Tsuda study(8). It was admitted that mild to moderate MR is a reasonable result in the immediate post-operative period (25,29).

During post-operative follow-up, myocardial ischemia should be investigated in the presence of recent aggravation of MR or at the onset of new regional wall motion abnormalities(30)

CONCLUSION

Because this is a curable abnormality, the diagnosis of ALCAPA should be suspected and investigated in all infants presenting with a dilated cardiomyopathybut also in asymptomatic children. Electrical criteria are important for orienting the diagnosis. The doppler echocardiography is crucial in the assessment of this disorder. Direct visualization of the origin of the LCA from the pulmonary artery confirms the ALCAPA diagnosis.In the infant form, echocardiographic findings are dominated by LV dilation and dysfunction, usually with significant MR. Our study highlights that the adult type of ALCAPA can be diagnosed earlier in children beyond infancy when a meticulous echographic examination is performed. In this group of patients, presenting symptoms are miscellaneous. LV dilation and dysfunction may be absent in the echocardiographic exam which is marked by a well-developed septal collateral circulation and a very dilated RCA.

Performed by experienced examinators, TTE is the preferred examination method for the diagnosis and the follow-up of ALCAPA in children at early age and beyond infancy. Other explorations such as CT coronary angiogram or cardiac catherization are of great importance when echocardiographic data are not conclusive.

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